



NOAA Technical Memorandum NMFS-AFSC-241

Fur Seal Investigations, 2010-2011

by J. W. Testa (editor)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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ABSTRACT

Researchers from the Alaska Fisheries Science Center's National Marine Mammal Laboratory conduct field investigations on the population status of northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. This report summarizes these monitoring efforts in 2010 and 2011.

Population parameters monitored on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals. On St. Paul Island 3,974 and 3,829 territorial male seals with females were counted in 2010 and 2011, respectively, and both years represented a 3.6% annual decline from the previous year. On St. George Island the respective totals were 805 and 873, representing a 4.9% decrease in 2010 and 1.4% increase in 2011. On St. Paul Island, 357 and 322 subadult male seals were harvested in 2010 and 2011, respectively. On St. George Island the respective totals were 78 and 120. The estimate for the total number of pups born in 2010 was 93,627 (SE = 1,034) on St. Paul Island (not including Sea Lion Rock) and 17,973 (SE = 323) on St. George Island. Pup mortality from birth to late August was 5.3% on St. Paul Island and 5.3% on St. George Island. The number of pups born on St. Paul Island in 2010 was 8.8% less than in 2008 ($P < 0.01$), while at St. George the number of pups was not significantly different from the 2008 estimate. The overall rate of decline on the Pribilof Islands since 1998 was 4.9%. Both male and female pups on St. George Island were significantly longer and heavier than those on St. Paul Island ($P < 0.01$) in 2010.

Index counts of territorial bulls on San Miguel Island, California, in 2010 and 2011 were 65 and 148, respectively. In 2010 and 2011, total numbers of pups born at Adams Cove on San Miguel Island were 1,537 (SE = 12) and 1,398 (SE = 4); at nearby Castle Rock the numbers were 1,144 (SE = 27) and 1150 (SE = 8). Pup production in 2010 was near the peak recorded in 1997, just prior to a strong El Niño event, though the recovery since that time has been sporadic. Pup mortality in recent years has been high, and remained so in 2010 (47%) and 2011 (37%). Pup weights at San Miguel Island in both 2010 and 2011 were near the long-term average.

The estimated stock size for all fur seals breeding in the United States in 2010 was ~671,000, with the Pribilof Islands population accounting for ~566,000.

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INTRODUCTION

by

J. Ward Testa

The northern fur seal (*Callorhinus ursinus*) population in the Pribilof Islands Archipelago (on St. Paul and St. George Islands, Figs. 1-3) makes up approximately 50% of the world population. Smaller breeding colonies are located on the Kuril and Commander Islands in Russia, Bogoslof Island (Figs. 1 and 4) in the southeastern Bering Sea, and San Miguel Island (Fig. 5) off California. The rookeries at San Miguel and Bogoslof Islands probably originated in the late 1950s (DeLong 1982) and 1980 (Lloyd et al. 1981), respectively.

Northern fur seals were placed under international management in 1911 under the Treaty for the Preservation and Protection of Fur Seals and Sea Otters between the United States, Russia, Japan, and Great Britain after over a century of commercial exploitation (Gentry 1998). The major population concentration on the Pribilof Islands has been monitored since that time, primarily by counting of territorial adult males and newborn pups on the rookeries. The population grew rapidly from 1911 (possibly 5-8%/year) until the late 1930s, and remained at high levels throughout the 1940s and 1950s. Japan abrogated the convention in 1941, and a new convention was signed in 1957 that called for commercial harvest of adult female fur seals to reduce population size and, according to theory, maximize productivity of the population for commercial harvest. The population declined under that harvest from 1958 to 1968, but productivity did not increase. After a brief rebound in the early 1970s, the population declined further. At St. Paul Island the population fluctuated for two decades at 35-45% of its peak numbers, while the smaller population at nearby St. George has declined at a more or less steady

rate to less than 30% of the peak. Commercial harvesting of fur seals was discontinued on St. George Island in 1973 and on St. Paul Island in 1984, but a small subsistence harvest of juvenile males continues on both islands. There is no subsistence or commercial harvest on the remaining U.S. rookeries.

Northern fur seals were designated as depleted in 1988 under the Marine Mammal Protection Act. This report is part of an ongoing effort by the Alaska Fisheries Science Center's National Marine Mammal Laboratory (NMML) to monitor the status of northern fur seals on U.S. rookeries and to disseminate that information. Research by the NMML on northern fur seals in 2010 and 2011 was conducted under Marine Mammal Protection Act Permit No. 782-1708-00.

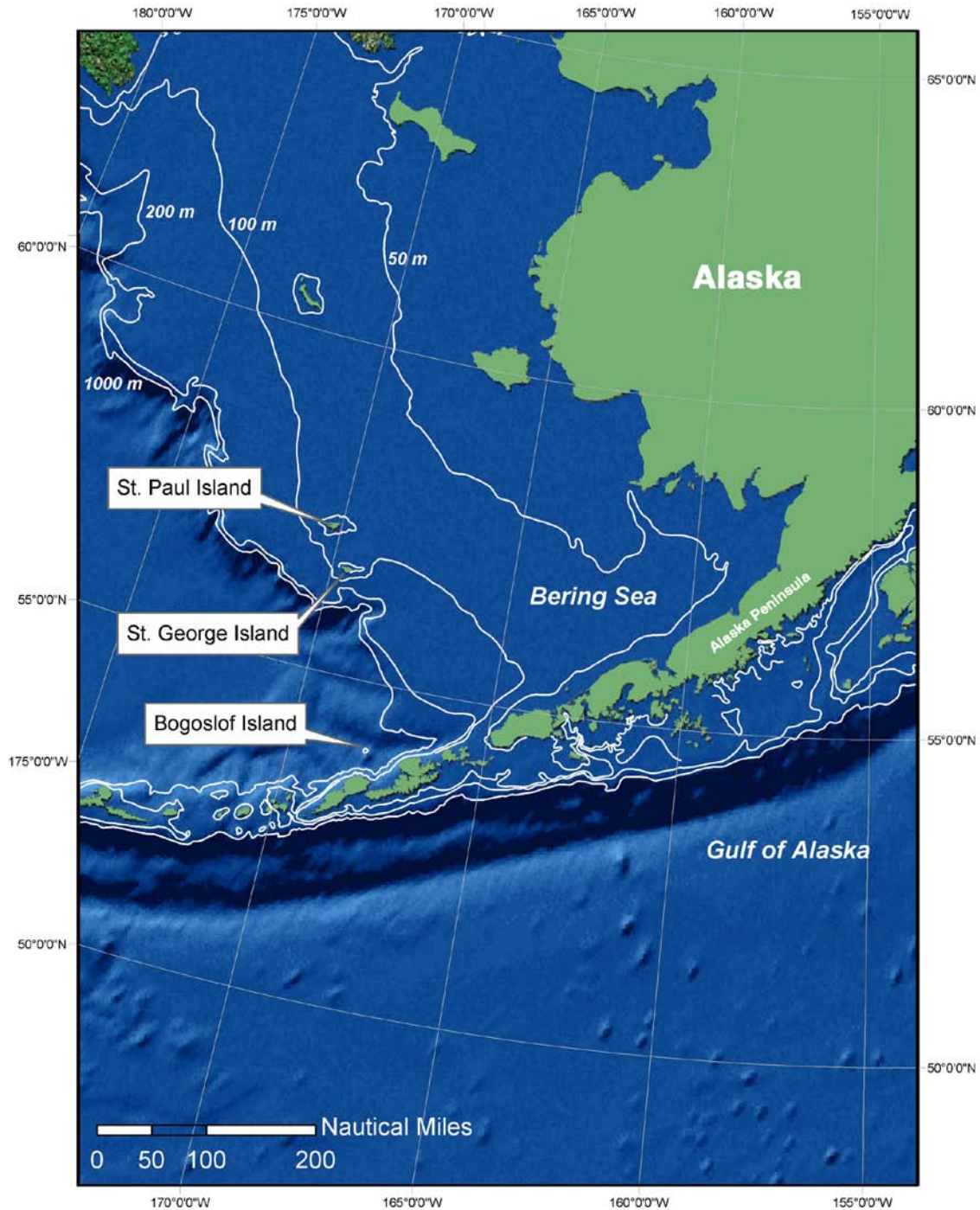


Figure 1.-- Location of the three northern fur seal breeding areas within U.S. Alaskan waters.



Figure 2.-- Location of northern fur seal rookeries on St. Paul Island, Alaska.



Figure 3.-- Location of northern fur seal rookeries on St. George Island, Alaska.

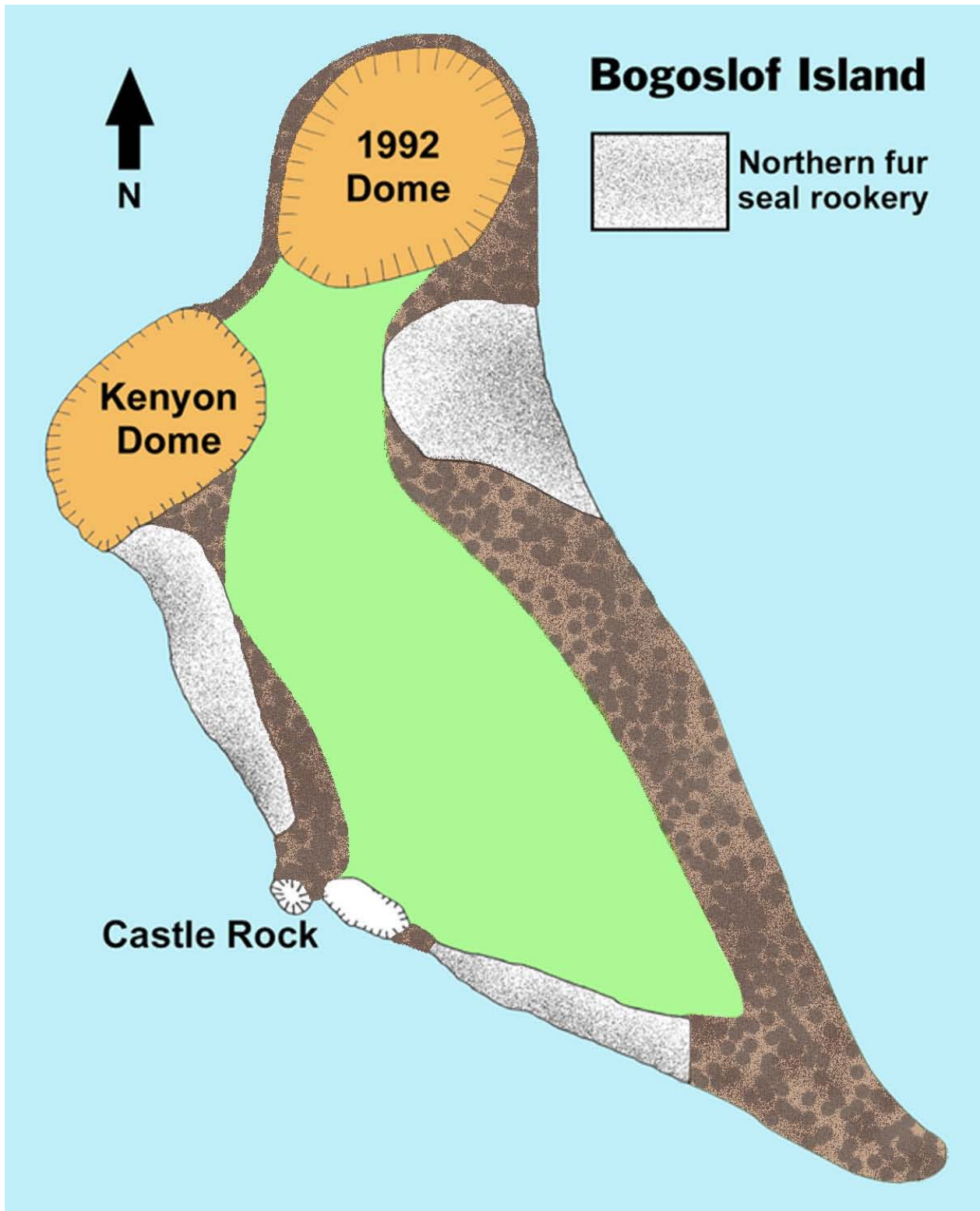


Figure 4.-- Location of northern fur seal rookeries on Bogoslof Island, Alaska.



Figure 5.-- Location of northern fur seal rookeries on San Miguel Island, California.

POPULATION ASSESSMENT OF NORTHERN FUR SEALS

ON THE PRIBILOF ISLANDS, ALASKA, 2010 - 2011

by

Rodney G. Towell, Rolf R. Ream, Jeremy T. Sterling,

Michael Williams, and John L. Bengtson

In accordance with provisions originally established by the Interim Convention on Conservation of North Pacific Fur Seals and to inform management decisions of the National Marine Fisheries Service, the National Marine Mammal Laboratory (NMML) continues to monitor the status of fur seal populations on the Pribilof Islands. To meet these objectives, data on population size, age and sex composition, and natural mortality are collected annually following the methods described by Antonelis (1992).

METHODS




Population characteristics monitored in 2010 on St. Paul and St. George Islands included the size of the subsistence harvest, numbers of adult males and pups, and mortality rates of fur seal pups. Only the subsistence harvest and counts of adult males were monitored in 2011. The subsistence harvest was monitored for the number of juveniles killed for consumption, any other fur seals inadvertently killed, injured or compromised (e.g., hyperthermia) by harvest activities, harvest waste, entanglement, and any unusual conditions among animals on targeted haulouts. Monitoring on St. Paul Island was conducted and reported by staff from the St. Paul Island Tribal Governments Ecosystem Conservation Office and a board-certified veterinarian, both under contract with the National Marine Fisheries Service (NMFS). The St. George Island Kayumixtax

Eco-Office, also under contract with NMFS, monitors and reports the subsistence harvest of northern fur seals on St. George Island.

We report territorial males with (Class 3) and without (Class 2) females on the rookeries, and males on hauling grounds (Class 5, see Appendix A for a glossary of definitions of terms and Figure 6 for illustration of a typical fur seal rookery). Adult male fur seals were visually counted by section for each rookery on St. Paul Island from 10 to 17 July 2010 and 9 to 14 July 2011 (Appendix Tables B-1 and B-2, respectively) and on St. George Island from 9 to 12 July 2010 and 10 to 12 July 2011.

On St. Paul Island, dead fur seal pups were counted on 4 sample rookeries and the numbers of live pups were estimated on 13 rookeries in August 2010 using the shearing-sampling method (York and Kozloff 1987, Antonelis 1992). Tooth samples (usually canines) were collected from dead fur seals older than pups whenever possible. Additionally, sample rookeries and adjacent beaches of St. Paul and St. George Islands were surveyed for dead fur seals older than pups during dead pup counts in August 2010. The total number of pups born was estimated using ratio estimation (Cochran 1977). From 7 to 12 August, pups were marked by shearing the guard hairs on top of the head to make the light underfur conspicuous to observers later. The number of pups sheared on each rookery was approximately 10% of the last estimate of pup production for the sample rookeries in 2008. Shear marks were allocated proportionally on each rookery by section (Appendix Table B-3) according to the fraction of the rookery total for breeding males counted in each section of the sampled rookery. The ratio of marked to unmarked pups was determined by two observers scanning (with the aid of binoculars when necessary) on two occasions for each rookery from 13 to 24 August. Each observer counted

CLASSES OF ADULT MALES

1. TERRITORIAL WITHOUT FEMALES 
2. TERRITORIAL WITH FEMALES 
3. HAULING GROUND 

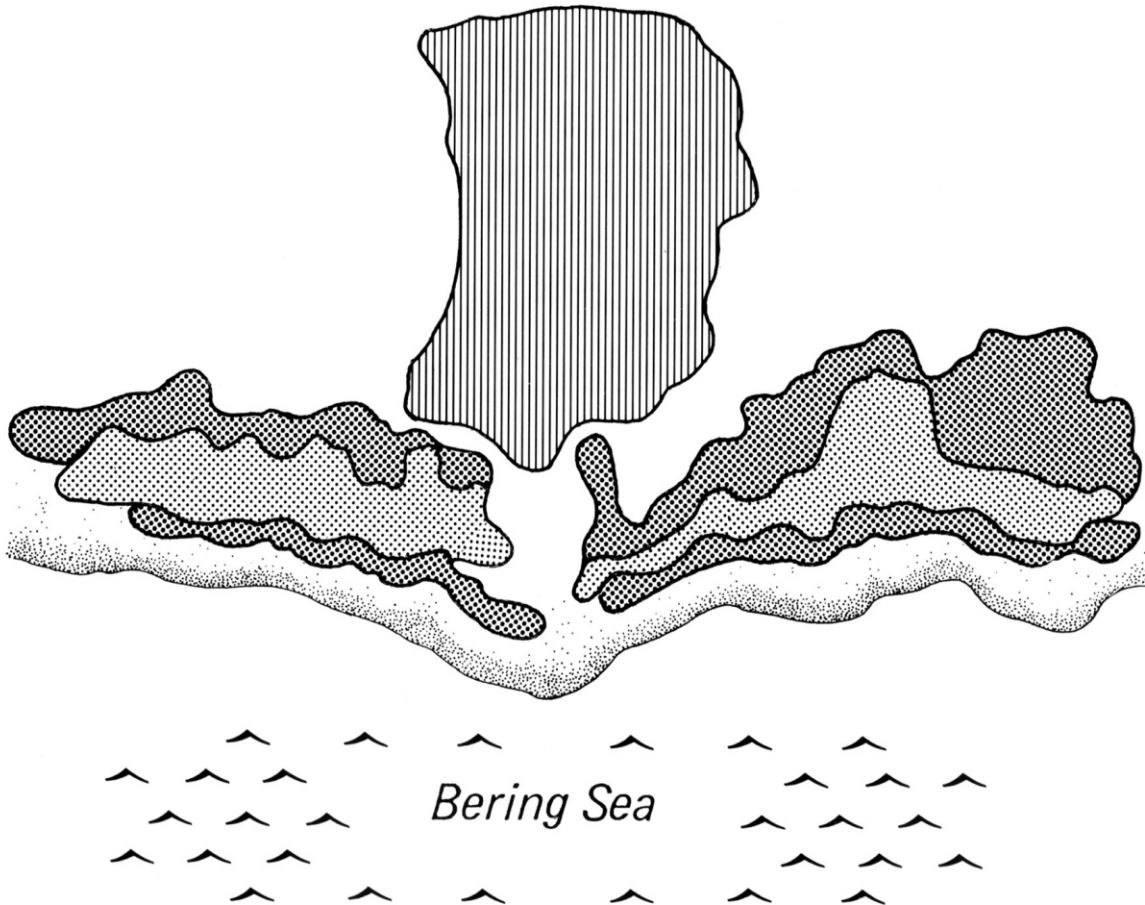


Figure 6.-- The relative location of the different classes of adult males for a typical fur seal rookery/haul-out complex.

marked and unmarked pups independently to ensure that the entire rookery was well sampled. Each sampling day was considered an independent replicate; the variance was computed for each rookery based on these replicates (York and Kozloff 1987). Little Polovina rookery was not sampled due to the concern that this small rookery might be more sensitive to disturbance. We estimated the number of pups born on Little Polovina rookery from a regression of total pups born versus numbers of breeding adult males. By assuming that the pup mortality on Little Polovina rookery was equal to the observed rate on the other rookeries, we estimated the number of dead pups as the product of that mortality rate and the estimate of total pups born. Dead pups were counted from 17 to 21 August on four rookeries. The estimated variance for total pups born was calculated using ratio estimation techniques (Cochran 1977).

The number of pups born on St. George Island was estimated from a shearing-sampling study conducted on all rookeries from 15 to 25 August 2010 in the same manner as applied on St. Paul Island. The ratio of marked to unmarked pups on each rookery was determined by two observers from 18 to 20 August and again from 21 to 23 August with a third sample of South rookery on 24 August. Dead pups were counted on three rookeries from 21 to 23 August 2010.

RESULTS AND DISCUSSION

Harvest

A total of 357 and 322 sub-adult male seals were harvested for subsistence on St. Paul Island in 2010 and 2011, respectively (Table 1). On St. George Island, 78 sub-adult male seals were taken in the subsistence harvest in 2010 and 120 were killed in 2011 (Table 2). One female

Table 1.-- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvests on St. Paul Island, Alaska, in 2010 and 2011.

2010			2011		
Date	Rookery	Number	Date	Rookery	Number killed
July 2	Polovina	25	June 30	Polovina	22
July 9	Zapadni	21	July 8	Zapadni	38
July 16	Moriovi	52	July 15	Lukanin	37
July 23	Zapadni	40	July 22	Polovina	58
July 30	Reef	42	July 29	Moriovi	47
August 4	Polovina	32	August 3	Lukanin	26
August 5	Little	51	August 4*	Polovina	33
August 6	Gorbatch	94	August 5	Gorbatch	62
Total		357			323

* Includes 1 female.

Table 2.-- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvest drives on St. George Island, Alaska, in 2010 and 2011.

2010			2011		
Date	Rookery	Number killed	Date	Rookery	Number killed
July 9	Zapadni	12	July 8	North	11
July 16	North	4	July 14	Zapadni	17
July 16	Zapadni	9	July 21	North	14
July 23	North	13	July 28	Zapadni	16
July 27	Zapadni	10	August 2	Zapadni	18
July 30	North	18	August 4	North	22
August 6	Zapadni	12	August 5	Zapadni	22
Total		78			120

on St. Paul Island was killed in 2011 and was included as part of the subsistence harvest (Table 2).

Adult Males Counted

The count of territorial males with females (Class 3 or harem males) on St. Paul Island decreased 3.6% between 2009 and 2010 and declined another 3.6% between 2010 and 2011 (Tables 3 and 4; Appendix Table B-4). The count of harem males on St. George Island decreased 4.9% between 2009 and 2010, and increased 1.4% between 2010 and 2011 (Tables 3 and 4; Appendix Table B-4). Owing to the larger size of the population on St. Paul Island, the Pribilof Islands total for harem males decreased by 3.8% between 2009 and 2010 and 2.8% between 2010 and 2011.

Number of Pups Born on St. Paul Island in 2010

The estimated total number of pups alive on St. Paul Island at the time of marking in 2010 was 89,218 (SE = 538) (Table 5). The number of dead pups as counted by section on four sample rookeries of St. Paul Island is given in Appendix Table B-5: the total estimated dead on all rookeries on St. Paul was 5,284. The estimated mortality rate for late August was 5.6% (Table 6). The total number of pups born on St. Paul Island in 2010 was estimated at 94,502 (SE = 1,120; 95% CI = (91,798 – 97,286)). The standard error accounts for variance in the estimation of both live and dead pups. The approximate 95% CI of pups born was computed as a log-normal CI due to the ratio estimation of the total pups born. The above total does not include the pups born on Sea Lion Rock which was not sampled in 2010.

Table 3.-- Number of adult male northern fur seals counted by rookery and behavior class (2 = territorial without females, 3 = territorial with females, 5 = non-territorial on hauling grounds), Pribilof Islands, Alaska, July 2010 (Appendix A for descriptions).

Rookery	Date (July)	Class of adult male			Total
		2	3	5	
<u>St. Paul Island</u>					
Lukanin	16	33	149	95	277
Kitovi	16	56	208	145	409
Reef	15	169	507	262	938
Gorbatch	15/17	107	326	332	765
Ardiguen	15	7	60	16	83
Moriovi	13	152	376	361	889
Vostochni	12/13	217	701	442	1.360
Polovina	14	29	92	187	308
Little Polovina	14	5	1	99	105
Polovina Cliffs	14	70	395	93	558
Tolstoi	10	141	329	351	821
Zapadni Reef	11/17	76	175	238	489
Little Zapadni	11	159	255	229	643
Zapadni	11/17	257	400	512	1.169
Island total		1.478	3.974	3.362	8.814
<u>St. George</u>					
South	12	51	188	74	313
North	9	142	254	233	629
East Reef	10	33	78	83	194
East Cliffs	10	57	183	194	434
Starava Artil	12	20	34	46	100
Zapadni	12	26	93	71	190
Island total		329	830	701	1.860

Table 4.-- Number of adult male northern fur seals counted by rookery and behavior class (2 = territorial without females, 3 = territorial with females, 5 = non-territorial on hauling grounds), Pribilof Islands, Alaska, July 2011.

Rookery	Date (July)	Class of adult male			Total
		2	3	5	
<u>St. Paul Island</u>					
Lukanin	9	49	107	167	323
Kitovi	9	63	158	168	389
Reef	13	209	526	389	1,124
Gorbatch	13	103	338	329	770
Ardiguen	13	6	48	7	61
Moriovi	12	134	334	320	788
Vostochni	12	151	696	488	1,335
Polovina	14	32	105	224	361
Little Polovina	14	0	0	168	168
Polovina Cliffs	14	100	363	101	564
Tolstoi	10	175	348	317	840
Zapadni Reef	11	61	174	181	416
Little Zapadni	11	127	256	257	640
Zapadni	11	216	376	597	1,189
Island total		1,426	3,829	3,713	8,968
<u>St. George</u>					
South	12	49	175	76	300
North	12	109	277	298	684
East Reef	11	33	83	50	166
East Cliffs	11	93	191	156	440
Starava Artil	10	19	35	74	128
Zapadni	12	22	81	133	236
Island total		325	842	787	1,954

Table 5.-- Total number of northern fur seal pups sheared, number of pups estimated to be alive at the time of marking (E1 and E2), mean number alive (Mean) and standard error (SE), on sampled rookeries of St. Paul Island, Alaska, 2010.

Rookery	Sheared	E1	E2	Mean	SE
Lukanin	341	2,685	2,896	2,791	105.5
Kitovi	407	3,735	4,033	3,884	149.0
Reef	1,298	11,104	11,146	11,125	21.0
Gorbatch	967	8,377	8,187	8,282	95.0
Ardiguen	119	992	1,027	1,010	17.5
Morjovi	799	7,088	6,920	7,004	84.0
Vostochni	1,473	14,317	13,912	14,115	202.5
Polovina	281	2,723	2,457	2,590	133.0
Little Polovina*				22	1.3
Polovina Cliffs	912	7,514	7,509	7,512	2.5
Tolstoi	1,149	9,485	10,209	9,847	362.0
Zapadni Reef	498	4,356	3,953	4,155	201.5
Little Zapadni	798	6,658	6,845	6,752	93.5
Zapadni	1,204	10,137	10,120	10,129	8.5

* Little Polovina estimated from the regression of live pups on number of harem males.

Table 6.-- Number of pups alive at the time of marking, estimated total pups born, harem males and the ratio of pups alive at marking to harem males, on sampled rookeries of St. Paul Island, Alaska, 2010.

Rookery	Pups alive at marking	Total pups born	Harem males	Ratio pups/males
Lukanin	2,791	2,956	149	19.84
Kitovi	3,884	4,114	208	19.78
Reef	11,125	11,784	507	23.24
Gorbatch	8,282	8,773	326	26.91
Ardiguen	1,010	1,070	60	17.83
Morjovi	7,004	7,419	376	19.73
Vostochni	14,115	14,951	701	21.33
Polovina	2,590	2,743	92	29.82
Little Polovina	22	23	1	23.00
Polovina	7,512	7,957	395	20.14
Tolstoi	9,847	10,430	329	31.70
Zapadni Reef	4,155	4,401	175	25.15
Little Zapadni	6,752	7,152	255	28.05
Zapadni	10,129	10,729	398	26.96
St. Paul Total	89,218	94,502	3,972*	23.79

* Does not match Table 3 since 2 territorial males with females were counted on a haulout during the adult male census.

The number of pups born and the number of harem bulls at different rookeries on St. Paul Island were significantly correlated ($r^2 = 0.98$, Fig. 7). The slope of the regression line without an estimated intercept ($P = 0.44$) was 23.34 (SE = 1.00, $P < 0.01$), representing an estimate of the ratio of pups to breeding males.

Number of Pups Born on St. George Island in 2010

Estimated total number of pups alive on St. George Island at the time of marking was 17,014 (SE = 282.5, Tables 7 and 8). The total number of dead pups was estimated to be 959 (Appendix Table B-7) and the estimated mortality rate was 5.34% (Table 8). The total number of pups born on St. George Island was 17,973 (SE = 323, 95% CI = (17,201 – 18,780)).

The 2010 estimate of pups born on St. George Island was not significantly different than the estimate of pups born in 2008 ($P = 0.66$) but was significantly different than the estimate of pups born in 2006 ($P = 0.01$). The number of pups born and the number of harem males on St. George Island rookeries were highly correlated ($r^2 = 0.99$; Fig. 7). The intercept of the regression line was not significantly different from zero ($P = 0.27$) and was not included in the regression equation. The slope of the regression line was 21.36 (SE = 0.45) representing an estimate of the ratio of pups born to breeding males.

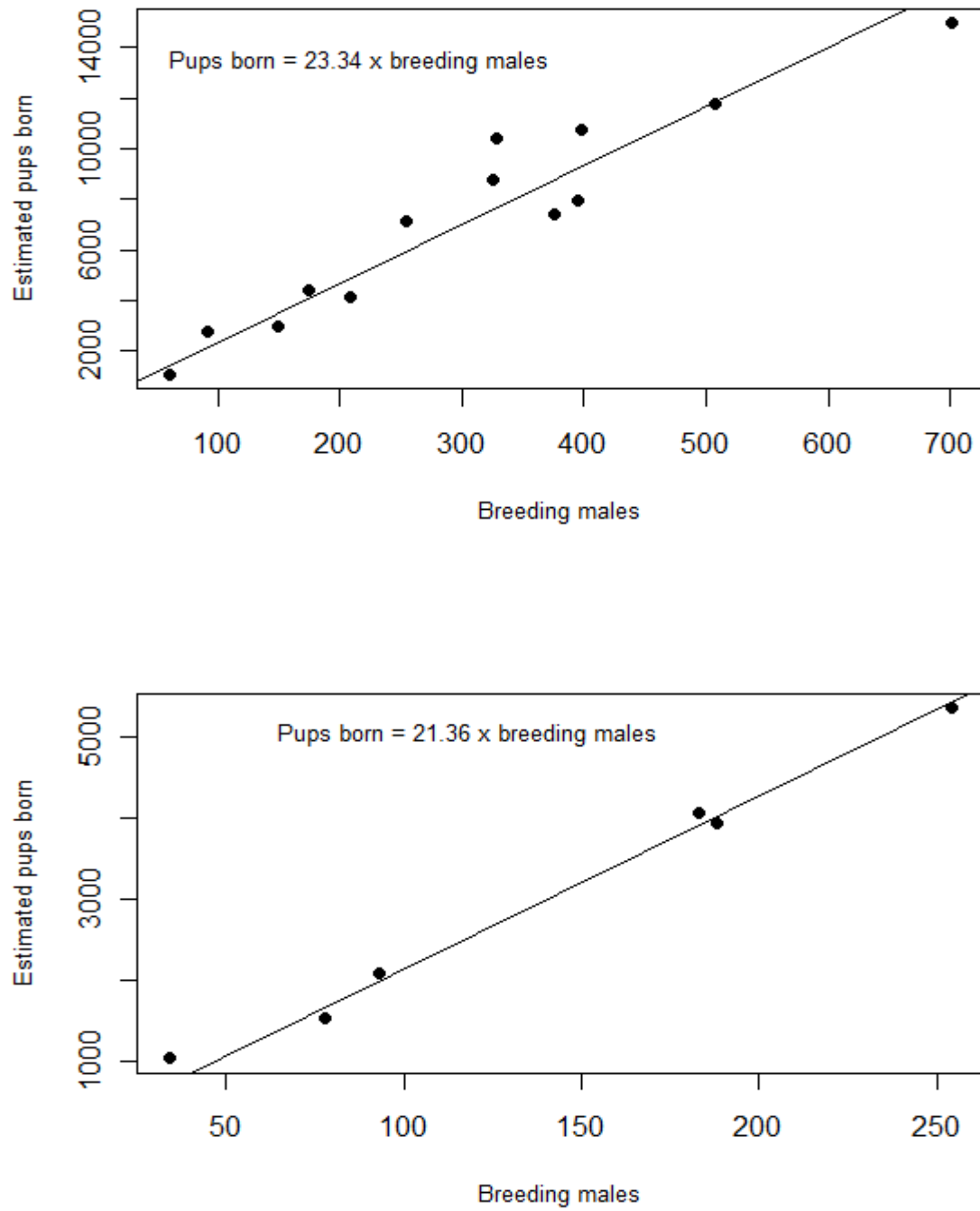


Figure 7.-- Pups born versus number of breeding males on St. Paul Island (top) and St. George Island (bottom), Alaska, 2010. Solid regression lines are shown for both locations.

Table 7.-- Number of pups sheared, number of pups estimated to be alive at the time of marking (E1 and E2), mean number alive (Mean) and the standard error of the mean (SE), for St. George Island, Alaska, 2010.

Rookery	Sheared	E1	E2	Mean	SE
South	428	3,378	4,017	3,713*	261.2
North	596	5,083	5,058	5,071	12.5
East Reef	151	1,516	1,388	1,452	64.0
East Cliffs	446	3,814	3,853	3,834	19.5
Staraya Artil	88	892	1,059	976	83.5
Zapadni	210	1,969	1,966	1,968	1.5

* A third sample was done due to the large discrepancy in the first to samples resulting in a third estimate of 3,745 which is not displayed in the table.

Table 8.-- Number of pups alive at the time of marking, total pups born, harem males, and the ratio of pups alive at marking to harem males for St. George Island, Alaska, 2010.

Rookery	Pups alive at marking	Total pups	Harem males	Ratio pups/males
South	3,713	3,922	188	20.86
North	5,071	5,357	254	21.09
East Reef	1,452	1,534	78	19.67
East Cliffs	3,834	4,050	183	22.13
Staraya	976	1,031	34	30.32
Zapadni	1,968	2,079	93	22.35
Total	17,014	17,973	830	21.65

Trends in Numbers of Pups

The total estimated number of pups born on St. Paul Island in 2010 (not including Sea Lion Rock) was 8.0% less than in 2008 (Fig. 8; $P < 0.01$). On St. Paul Island, estimated numbers of fur seal pups born in 2008 were 6.6% less than in 2006 (Appendix Table B-4). On St. George Island there was a 6.4% increase between 2006 and 2008, and a 1.0% decrease between 2008 and 2010. Since 2002, pup production has been below estimated pup production of 1919 on St. Paul Island and below the estimated pup production of 1916 on St. George Island, when the population was recovering at 8% annually from a pelagic harvest that ended in the early 20th century.

Pup production on the Pribilof Islands has been declining since 1998 at an annual rate of 5.42% (SE = 0.34%, $P < 0.01$) on St. Paul Island and 2.09% (SE = 0.69%, $P = 0.03$) on St. George Island. The overall rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 4.87% (SE = 0.37%, $P < 0.01$) from 1998 to 2010.

Estimate of Total Stock Size

Rough estimates of the total fur seal abundance have been presented in the past (Loughlin et al. 1994). These were calculated by multiplying the average number of pups born over the past three censuses by a correction factor of 4.47 (See Table 9 for the calculation method). That correction factor was derived from estimates of survival and fecundity (Loughlin et al. 1994) using data collected at sea during 1958-74. Its application here rests on the assumption that these vital rates were still valid. Since we cannot verify this assumption, the estimate must be viewed as a rough approximation. The estimate of the total stock for the Pribilof Islands population in 2010 (Table 9) was about 568,000 fur seals. The total stock

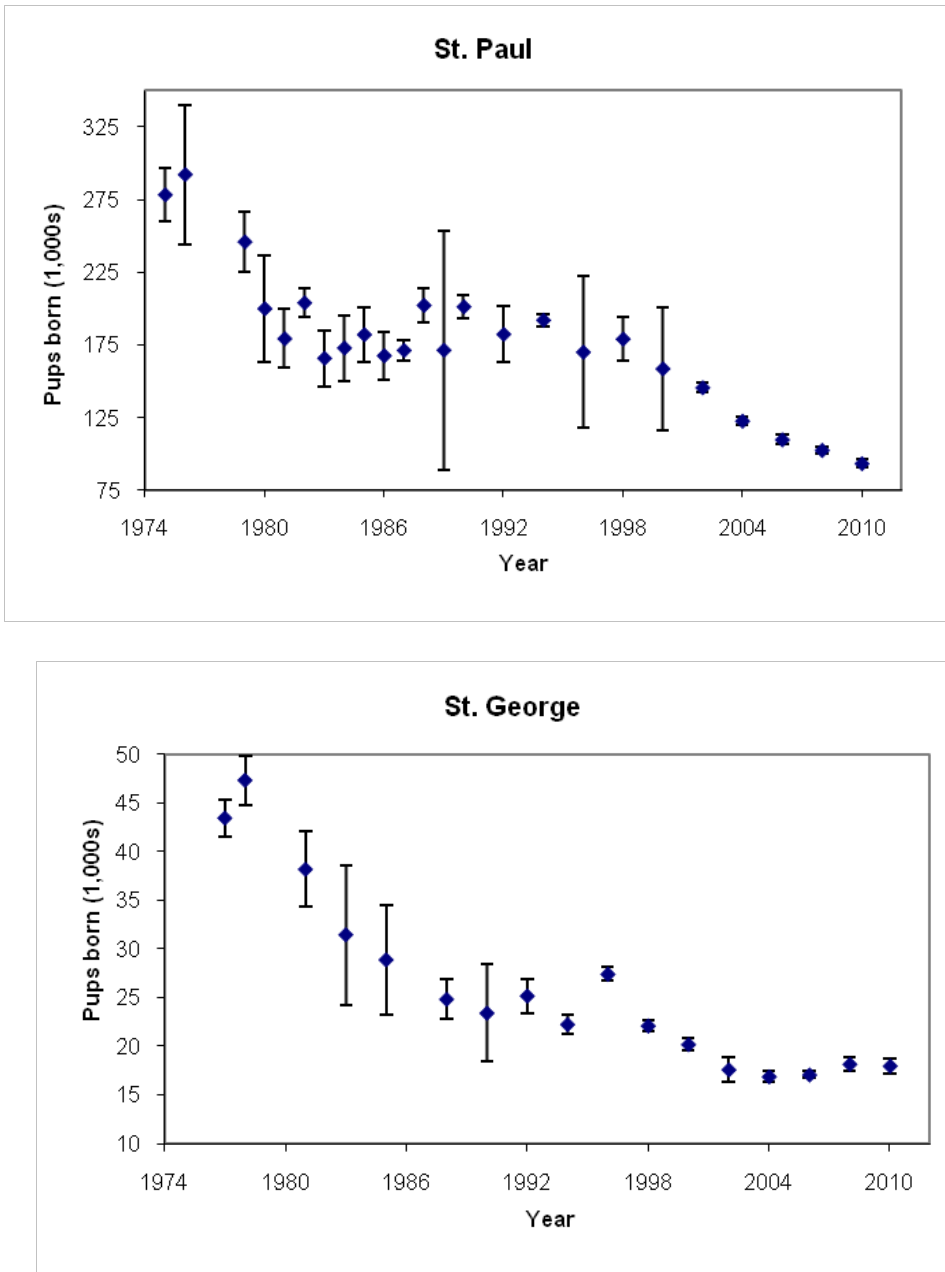


Figure 8.-- Estimated number of pups born (\pm 95% confidence intervals) on St. Paul and St. George Islands, Alaska, 1975 to 2010.

Table 9.-- Details of the computation of stock size estimates of fur seals in U.S. rookeries in 2010. Separate columns are given for the Pribilof (St. George and St. Paul Islands, including Sea Lion Rock) and non-Pribilof populations (San Miguel and Bogoslof Islands).

Formula	San Miguel and		Component
	Pribilof Islands	Bogoslof Islands ²	
Average for 2006, 2008 ¹ , 2010	126,855	23,353	Pups
(Pups) × 0.5	63,428	11,677	Yearlings
(Yearlings) × 0.8	50,742	9,341	Age 2 year
(2-year old females) × 0.86 / 2	21,819	4,017	Females age 3 year
(2-year old males) × 0.8 / 2	20,296	3,736	Males age 3 year
(Pups) / 0.6	211,425	38,922	Females 3+ years
(3-year old males) × 3.6	73,066	13,450	Males 4+ years
Total	567,631	104,496	

¹ The 2008 estimate for Sea Lion Rock was added to the St. Paul estimates of pup production for all years because it is the most current.

² The 2009, 2010, and 2011 estimates for San Miguel Island and the 2007 and 2011 estimates for Bogoslof Island were used.

size for the United States, which includes the Pribilof, Bogoslof, and San Miguel Islands, was approximately 672,000 fur seals.

Counts of Dead Fur Seals Older Than Pups and Collection of Teeth

A total of 77 dead adults were counted on rookeries sampled for dead pups and tooth samples were collected from a total of 69 fur seals: 55 on St. Paul Island and 14 on St. George Island (Table 10). Appendix Table B-8 summarizes the number of dead male and female fur seals from which teeth were collected from 1976 to 2010.

Table 10.-- Number of animals older than pups found dead and from which teeth were collected during August 2010 on the Pribilof Islands.

Rookery	Male	Female	Unknown	Total
<u>St. Paul</u>				
Reef ¹	10	22	0	32
Vostochni ²	0	13	0	13
Polovina Cliffs ²	0	5	0	5
Zapadni Reef ²	0	12	0	12
Total St. Paul	10	52	0	62
<u>St. George</u>				
North	0	2	0	2
East Cliffs ²	5	7	0	12
Zapadni	0	0	1	1
Total St. George	5	9	1	15
Total Both Islands	15	61	1	77

¹ No teeth collected from 4 females and 4 males.

² No teeth collected from 1 female.

MASS, LENGTH, AND SEX RATIOS OF NORTHERN FUR SEAL PUPS
ON THE PRIBILOF ISLANDS, 2010

by

Rodney G. Towell, Rolf R. Ream, James R. Thomason, Katherine A. Call,
and Robert Caruso

Mass and length measurements of northern fur seal pups on St. Paul and St. George Islands have historically been recorded in late August and serve as an indicator of population health. Here we report average mass, average length, and sex ratios for male and female pups from Tolstoi, Vostochni, Polovina Cliffs, and Reef rookeries on St. Paul Island and all rookeries on St. George Island in 2010. We also report on comparisons of mass, length, and sex ratios between islands.

METHODS

Pups were sampled in mid- to late August using the techniques described by Antonelis (1992) and Robson et al. (1994). A Pesola spring scale was used to weigh pups to the nearest 0.2 kg; lengths were measured to the nearest centimeter. We limited statistical comparisons to an analysis of variance of pup mass and length by island, sex, and rookery variables. Differences in mass and length by sex between islands were analyzed using a two sample t-test for samples with variances not significantly different from one another, or a Welch-modified two-sample t-test (Snedecor and Cochran 1980) for samples with significantly different variances. We used an exact binomial test to determine if the proportion of female pups at different islands and rookeries was significantly different from 50%.

RESULTS

Pup Mass and Length

Pup mass (Fig. 9, Table 11) varied significantly by sex ($P < 0.01$) on St. Paul Island in 2010. Mass of male and female pups was analyzed separately because the variance for males was greater than that for females ($P < 0.01$). Rookery effects on mass were significant for males ($P < 0.01$, Table 12) and females ($P < 0.01$, Table 12). The variance in pup lengths was not significantly different between males and females ($P = 0.51$); therefore, the sexes were analyzed together. Pup lengths (Fig. 10, Table 13) were significantly different by sex and rookery on St. Paul Island ($P < 0.01$, Table 14).

On St. George Island, pup mass (Fig. 9, Table 15) was also significantly different by sex ($P < 0.01$). Again, male and female pup masses were analyzed separately due to the difference in the variances for each sex. Rookery was not a significant factor in the analyses of female mass ($P = 0.17$, Table 16) or male mass ($P = 0.15$). The variance in pup lengths was not significantly different between males and females ($P = 0.26$). The analysis of variance for lengths (Fig. 10, Tables 17 and 18) indicated significant differences by sex ($P < 0.01$) and rookery ($P < 0.01$).

Mass and length were compared between islands by sex after testing for unequal variances with an F-statistic assuming normal distributions. There was significant difference between islands for male (St. Paul 8.72 kg, St. George 9.22 kg, $P < 0.01$) and for female (St. Paul 7.48 kg, St. George 8.01 kg, $P < 0.01$) mass. Males (St. Paul 73.5 cm, St. George 76.1 cm, $P < 0.01$) and females (St. Paul 70.3 cm, St. George 72.8 cm, $P < 0.01$) were significantly longer on St. George.

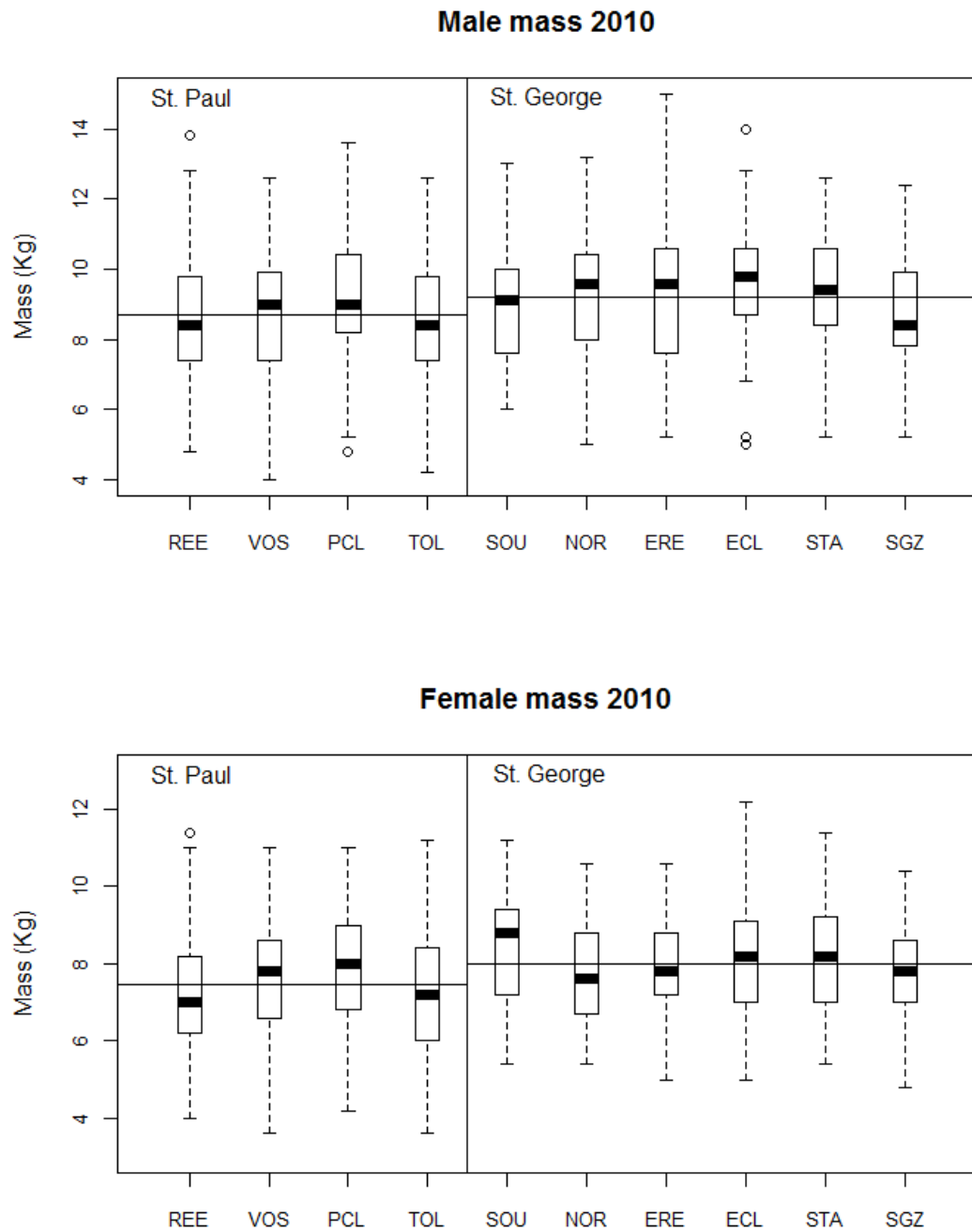


Figure 9.-- Boxplots of the mass of northern fur seal pups on St. Paul and St. George Islands, Alaska, August 2010: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL), Tolstoi (TOL), South (SOU), North (NOR), East Reef (ERE), East Cliffs (ECL), Staraya Artil (STA), and St. George Zapadni (SGZ). Whiskers represent 1.5 times the interquartile range; open circles are outliers.

Table 11.-- Mean mass (kg), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups weighed on St. Paul Island, Alaska, 22-24 August 2010.

Rookery		Females	Males	Combined
Reef	kg	7.22	8.46	7.86
23 August	SD	1.48	1.78	1.75
	n	111	118	229
Vostochni	kg	7.60	8.73	8.21
24 August	SD	1.43	1.77	1.72
	n	120	143	263
Pol. Cliffs	kg	7.85	9.15	8.52
22 August	SD	1.48	1.82	1.79
	n	126	134	260
Tolstoi	kg	7.21	8.54	7.96
23 August	SD	1.52	1.78	1.80
	n	115	149	264
Combined	kg	7.48	8.72	8.15
	SD	1.50	1.80	1.78
	n	472	544	1,016

Table 12.-- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. Paul Island, Alaska, August 2010.

Factor	df	SS due to factor	MSS*	Residual	df	<i>F</i>	<i>P</i>
Females							
Rookery	3	34.78	11.6	1,022	468	5.31	<0.01
Males							
Rookery	3	38.12	12.7	1,730	540	3.97	<0.01

*MSS = SS divided by df

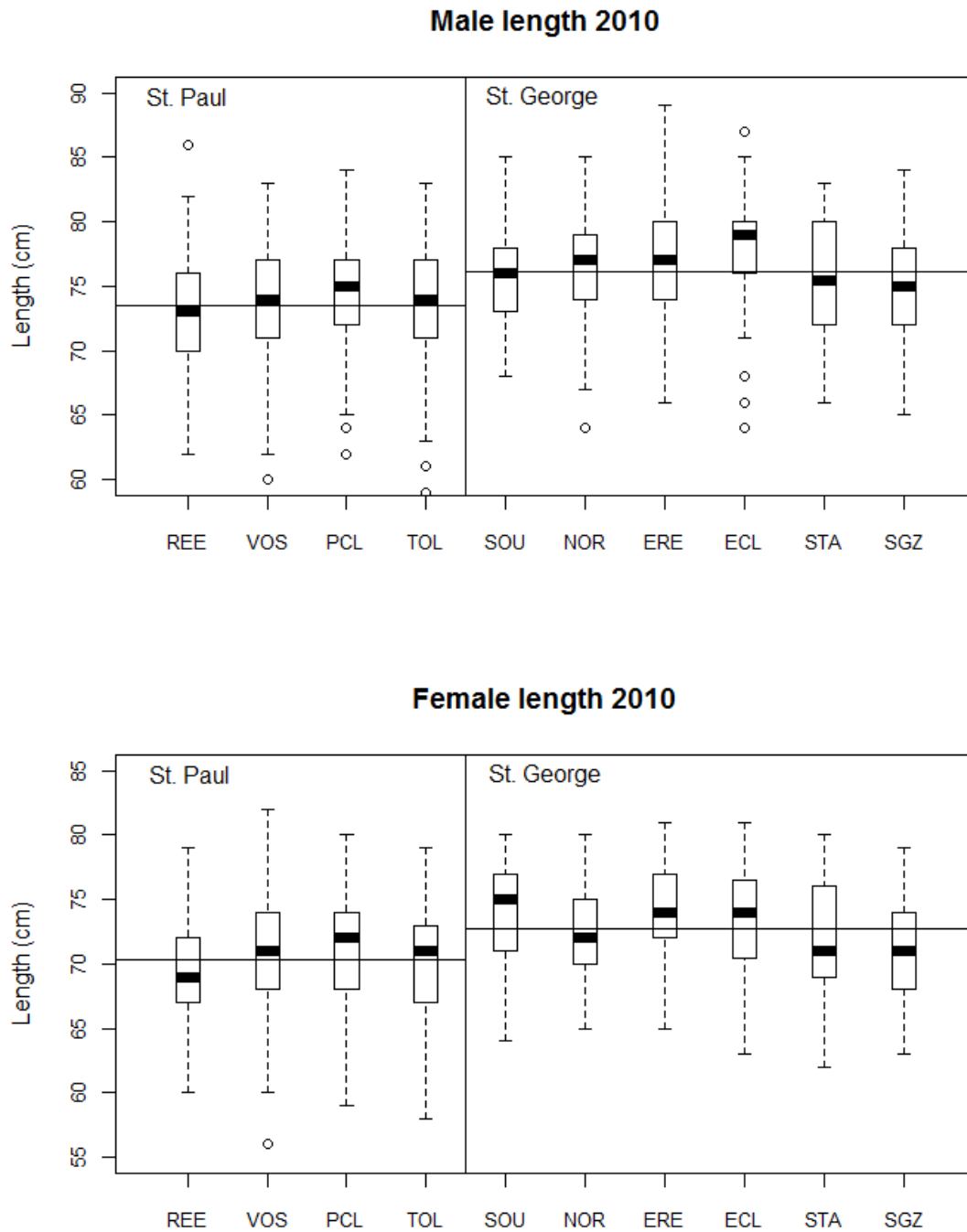


Figure 10.-- Boxplots of the length of northern fur seals on St. Paul and St. George Islands, Alaska, August 2010: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL), Tolstoi (TOL), South (SOU), North (NOR), East Reef (ERE), East Cliffs (ECL), Staraya Artil (STA), and St. George Zapadni (SGZ). Whiskers represent 1.5 times the interquartile range; open circles are outliers.

Table 13.-- Mean length (cm), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups measured on St. Paul Island, Alaska, 22-24 August 2010.

Rookery		Females	Males	Combined
Reef	cm	69.3	72.5	70.9
23 August	SD	4.87	4.47	4.93
	n	111	118	229
Vostochni	cm	70.9	73.7	72.4
24 August	SD	4.55	4.92	4.95
	n	120	143	263
Pol. Cliffs	cm	71.1	74.3	72.8
22 August	SD	4.19	4.32	4.54
	N	126	134	260
Tolstoi	cm	69.7	73.3	71.7
23 August	SD	4.28	4.73	4.88
	n	115	149	264
Combined	cm	70.3	73.5	72.0
	SD	4.52	4.66	4.87
	n	472	544	1,016

Table 14.-- Analyses of variance of length of male and female northern fur seal pups on St. Paul Island, Alaska, August 2010.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Sex	1	2,593	2,593	21,436	1,014	125.21	< 0.01
Rookery	3	497	165	20,939	1,011	8.00	< 0.01

*MSS = Sum of squares (SS) divided by df.

Table 15.-- Mean mass (kg), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups weighed on St. George Island, Alaska, 22-25 August 2010.

Rookery		Females	Males	Combined
South	kg	8.39	8.95	8.70
25 August	SD	1.39	1.70	1.59
	n	50	62	112
North	kg	7.70	9.27	8.56
23 August	SD	1.28	1.83	1.78
	n	47	57	104
East Reef	kg	8.00	9.29	8.75
24 August	SD	1.30	1.91	1.79
	n	45	62	107
East Cliffs	kg	8.09	9.66	8.93
24 August	SD	1.59	1.79	1.87
	n	51	59	110
Staraya Artil	kg	8.16	9.31	8.81
25 August	SD	1.60	1.86	1.84
	n	45	58	103
Zapadni	kg	7.79	8.78	8.23
22 August	SD	1.44	1.76	1.66
	n	65	51	116
Combined	kg	8.01	9.22	8.66
	SD	1.45	1.82	1.76
	n	303	349	652

Table 16.-- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2010.

Factor	df	SS due to factor	MSS*	Residual	df	<i>F</i>	<i>P</i>
Females							
Rookery	5	16.3	3.3	617	297	1.57	0.17
Males							
Rookery	5	26.7	5.3	1,126	343	1.63	0.15

*MSS = Sum of squares (SS) divided by df.

Table 17.-- Mean length (cm), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups measured on St. George Island, Alaska, 22-25 August 2010.

Rookery		Females	Males	Combined
South	cm	73.8	75.4	74.7
25 August	SD	4.06	4.07	4.13
	n	50	62	112
North	cm	72.5	76.5	74.7
23 August	SD	3.84	4.40	4.60
	n	47	57	104
East Reef	cm	74.0	77.0	75.8
24 August	SD	3.26	4.71	4.40
	n	45	62	107
East Cliffs	cm	73.4	77.5	75.6
24 August	SD	4.65	4.14	4.84
	n	51	59	110
Staraya Artil	cm	71.9	75.4	73.9
25 August	SD	4.85	4.51	4.95
	n	45	58	103
Zapadni	cm	71.4	74.5	72.8
22 August	SD	3.79	4.31	4.29
	n	65	51	116
Combined	cm	72.8	76.1	74.5
	SD	4.18	4.45	4.63
	n	303	349	652

Table 18.-- Analyses of variance of length of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2010.

Factor	df	SS due to factor	MSS*	Residual	df	<i>F</i>	<i>P</i>
Sex	1	1,794	1,794	12,186	650	99.49	<0.01
Rookery	5	557	111	11,629	645	6.18	<0.01

*MSS = Sum of square (SS) divided by df.

Sex Ratios

The fraction of female pups was significantly different from 50% only on Tolstoi ($P = 0.04$) rookery on St. Paul in 2010 (Table 19). Also, the fraction of total females was not significantly different than 50% (46.5%, $P = 0.08$) on St. George Island but was significantly different than 50% on St. Paul Island (46.5%, $P = 0.03$) and for both islands combined (46.5%, $P < 0.01$). Comparison of the sex ratios between islands showed no significant difference ($P = 0.99$).

DISCUSSION

Consistent with earlier evaluations of pup mass data (York and Antonelis 1990, York and Towell 1993, Towell et al. 1996, and Towell et al. 1997), the strongest pattern was that the size of pups varied by sex; male pups were heavier and longer than female pups. After controlling for sex, both male and female pups were significantly heavier and longer on St. George Island than on St. Paul Island. The fraction of females was not significantly different than 50% on St. George Island (46.5%, Table 20), but was for St. Paul Island (46.5%) and both islands combined (46.5%) in 2010; across the past two decades the only significant differences from a 50:50 sex ratio have favored males (Table 20). These differences in mass and length may reflect the influence of environmental variability on the condition of pups and their mothers. Undetected biases in sampling techniques may also be responsible for the differences detected in this study.

Table 19.-- Numbers of female pups, total number of pups, and fraction (that are female) of northern fur seal pups sampled during pup weighing on St. Paul and St. George Islands, Alaska, August 2010. The fraction of females is significantly less than 50% ($P \leq 0.05$) for bold items.

Rookery	Females	Total	Fraction
<u>St. Paul</u>			
Reef	111	229	0.485
Vostochni	120	263	0.456
Polovina Cliffs	126	260	0.485
Tolstoi	115	264	0.436
Total	472	1,016	0.465
<u>St. George</u>			
South	50	112	0.446
North	47	104	0.452
East Reef	45	107	0.421
East Cliffs	51	110	0.464
Staraya Artil	45	103	0.437
Zapadni	51	116	0.439
Total	303	652	0.465

Table 20.-- Numbers of female pups, total number of pups, and fraction (that are female) of northern fur seals pups weighed on St. Paul and St. George Islands, Alaska, for the years 1992-2010. Bold numbers indicate the fraction of females significantly different than 50% ($P \leq 0.05$).

Year	St. Paul			St. George		
	Females	Total	Fraction	Females	Total	Fraction
1992	494	1,118	0.442	291	634	0.459
1994	926	1,926	0.481	430	886	0.485
1995	939	2,040	0.460	294	653	0.450
1996	520	1,149	0.453	331	749	0.442
1997	495	1,020	0.485	311	639	0.487
1998	506	1,100	0.460	344	745	0.462
1999	462	1,081	0.427	--	--	--
2000	543	1,079	0.503	292	640	0.456
2001	510	1,095	0.466	--	--	--
2002	424	1,016	0.417	300	627	0.478
2004	489	1,067	0.458	279	619	0.451
2006	446	983	0.454	304	640	0.475
2008	500	1,029	0.486	298	627	0.475
2010	472	1,016	0.465	303	652	0.465

STATUS OF THE NORTHERN FUR SEAL POPULATION
AT SAN MIGUEL ISLAND, CALIFORNIA, DURING 2010 AND 2011

by

Anthony J. Orr, Sharon R. Melin, and Robert L. DeLong

Demographic studies of the northern fur seal population at San Miguel Island (SMI), California, have been conducted since discovery of the colony in 1968. The population was established by individuals from the Pribilof (Alaska) and Russian Islands during the late 1950s or early 1960s (DeLong 1982). During the breeding season, the majority of northern fur seals in the United States are found on the Pribilof (St. George and St. Paul) Islands, which are located in the cool, subarctic waters of the Bering Sea. Northern fur seals are able to inhabit SMI because the marine environment around the island is influenced by the California Current and coastal upwelling, which produces cold surface waters, fog, and wind conditions that keep the island cool during summer months when northern fur seals return to pup and breed (DeLong 1982).

The northern fur seal population has thrived at SMI with the exception of two severe declines during 1983 and 1998 that were associated with El Niño (EN) events (DeLong and Antonelis 1991, Melin and DeLong 2000). EN events cause changes in marine communities by altering the sea-level height, sea-surface temperature, thermocline and nutricline depths, current-flow patterns, and upwelling strength of marine ecosystems (Norton et al. 1985, Arntz et al. 1991). These environmental changes result in lower productivity at lower trophic levels that adversely affects abundance and availability of species at higher trophic levels. Prey of fur seals generally move to more productive areas farther north and deeper in the water column (Arntz et al. 1991) and thereby become less accessible for fur seals. Consequently, fur seals at SMI are in poor physical condition during EN events and the population experiences reduced reproductive

success and high mortality of pups, and occasionally adults (DeLong and Antonelis 1991, Melin and DeLong 1994, Melin et al. 1996, Melin and DeLong 2000). Because EN events occur periodically along the California coast and impact the population growth of fur seals at SMI, they greatly influence the dynamics of this population (DeLong and Antonelis 1991, Melin and DeLong 1994, Melin et al. 1996).

EN events are short-term events that can affect a population for one to two years. But long-term oceanographic processes, such as the Pacific Decadal Oscillation (PDO), also occur and result in large-scale and basin-wide changes in ecosystems (Hayward et al. 1999). The PDO is primarily based upon patterns of variation in sea-surface temperatures in the Pacific Ocean and is often referred to being in one of two phases, “warm” or “cool”, depending on the sign of sea-surface temperature anomalies. Each phase can persist for decades, affecting several generations of fur seals. The California Current System shifted into a “warm” phase in 1977, and in 1998 it transitioned into a “cool” phase, following a strong EN event (Hayward et al. 1999). Recently, the decadal cycles have broken down and the PDO has switched from a “cool” phase (1998-2002), followed by a “warm” phase (2002-2005), followed by a relatively neutral phase (2005-August 2007), then to a “cool” phase (September 2007-July 2009; McClatchie et al. 2008, <http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm>). From August 2009 to May 2010 there was an EN event (Bjorkstedt et al. 2010). Since June 2010, the PDO has remained in a “cool” phase due to the subsequent La Niña (see <http://jisao.washington.edu/pdo/PDO.latest> for PDO Index data: accessed March 2012).

Theoretically, productivity near SMI should increase and cooler environmental conditions should prevail during a “cool” phase of the PDO. During the last 13 years following the 1998 EN, 9 years have been dominated by “cool” or relatively “neutral” PDO conditions that should

have resulted in higher productivity, survival, and good condition of northern fur seal pups at SMI. However, hookworm disease, which has decreased pup survival for the past 15 years, and a mild EN event in 2002 mitigated the positive effects of the “neutral to cool” PDOs. Here, we present the results of the 2010 and 2011 northern fur seal population monitoring studies at SMI and discuss the importance of environmental influences and disease on the population trends during the past 15 years (1997-2011).

METHODS

Census

Fur seal censuses were conducted at two rookeries of SMI (34°01' N, 120°26' W): Adams Cove (ACV) on the main island, and Castle Rock, located ~1 km northwest of SMI. The Castle Rock rookery was visited only once each July, to conduct a census of pups. Daily censuses were conducted at ACV between 26 May and 14 July 2010, and 24 May and 17 July 2011. For the long-term comparisons, territorial bull counts were used as an index of the maximum number of breeding bulls, and the cumulative live pup count was used to determine the date of the first birth and median pupping date for each year. In 2001 and 2007, daily censuses were terminated too early in the season to determine a median pupping date.

Counts of live and dead pups were used as an index of the number of pups born (i.e., production) at the Castle Rock and ACV rookeries. Total births each year was the sum of the number of live pups counted at the census and the cumulative number of dead pups counted up to the time of the live pup census. Dates of the censuses were determined by the frequency of births observed during daily surveys in ACV. When no births were documented over three consecutive days, pupping was considered complete and the live pup census was conducted. In ACV, the live

pup census was conducted on 2 August 2010 and 30 July 2011. The live pup census was conducted on 1 August 2010 and 23 July 2011 at Castle Rock. In ACV, the live pup counts were conducted from a mobile blind by two observers using binoculars. At Castle Rock, pups were counted by two observers moving through the colony. The observers defined section boundaries while counting in each area to ensure that they were counting the same groups of animals. Counts were not compared until the end of the census to ensure independence between observer counts. At ACV, the substrate is sandy and there are no markers to delineate counting areas. However, observers arbitrarily demarcated sections and independently counted the number of pups within each section. The number of pups for the colony was estimated from the mean of both observers' total counts.

In ACV, fur seal pup mortality surveys were conducted between July and September 2010 and 2011. Each dead pup was counted, removed from the territory, and then stacked away from the survey area to minimize the possibility of recounting the same pup during subsequent surveys. Because pups died and disappeared between surveys, the observed count was an underestimate of the total mortality. In a departure from the methods in previous reports, we estimated total mortality by calculating a correction factor for the observed mortality in ACV based on a daily disappearance rate of dead California sea lion (CSL; *Zalophus californianus*) pups in the same area that were tagged and resighted during subsequent mortality surveys (1.33 for early season mortality (before 3 August) and 1.25 for late season mortality (4 August – 30 September)). Thus, the total births and pup mortality in Table 2 will not agree with those in previous reports (Melin and DeLong 2001, Melin et al. 2002, Melin et al. 2005). We have not estimated a species-specific mortality correction factor for northern fur seal pups at SMI because we do not have access to the territories early in the season (before 4 July) due to breeding CSLs.

The processes contributing to disappearance of dead pups (e.g. surf, sand, flooding) for the two species are similar except that a greater proportion of dead northern fur seal pups are more likely to be washed out to sea relative to CSLs because fur seal territories are located along or below the beachcrest. However, we believe the correction factor is a suitable (although minimal) approximation of the disappearance rate of dead northern fur seal pups.

At Castle Rock, pup mortality was estimated from one survey conducted at the time of the live pup count during 2010 (1 August) and 2011 (23 July). Pup mortality at Castle Rock was a minimum estimate because only one survey was performed each year and the number of carcasses that decomposed or disappeared was not determined. A correction factor was not applied to counts at Castle Rock; using the CSL mortality correction factor would not be appropriate because it was based on a single survey and because different disappearance rates are likely to occur at Castle Rock due to the different substrate.

Tagging and Pup Condition

We sexed, tagged, measured (length), and weighed pups in October 2010 ($n = 166$) and September 2011 ($n = 201$) in ACV to continue survival and condition studies that began in 1975. We used pup mass at the time of tagging as an index of pup condition. To account for differences in mean pup mass due to different weighing dates among years, we developed a predictive linear mixed-effects model with normal errors to adjust the observed mean mass to 1 October for each year between 1975 and 2011. The model used an estimated sex-specific daily growth rate and a random cohort effect for the daily growth rate to incorporate annual variation in growth rate for estimating mass. We compared the long-term (adjusted) mean mass of pups between 1975 and 2009 with 2010, and then between 1975 and 2010 with 2011 using T-tests. We excluded EN years (1983, 1992, 1993, 1997, 1998, and 2002) from the calculation of the

long-term mean because pups born in 2009 and 2010 were assumed to be unaffected by EN conditions (the 2010 EN subsided before pups were born).

Sightings of Marked Individuals

Surveys of tagged northern fur seals were conducted from a mobile blind in ACV during 2010 (2 July – 30 September; $n = 12$) and 2011 (1 June – 29 September; $n = 13$). The blind was moved through sections of the rookery and hauling grounds at least once a week, and tag numbers and reproductive status were recorded for each tagged individual observed.

Farallon Islands

Surveys of northern fur seals were conducted at the West End Island of the Farallon National Wildlife Refuge by biologists from Point Reyes Bird Observatory (PRBO, Petaluma, California) during fall 2010 and 2011. During each survey, researchers followed the same route and stopped at the same vantage points to count animals and search for tagged individuals.

RESULTS

Census

The maximum number of territorial bulls counted in ACV was 65 during 2010 and 148 during 2011, representing a 128% increase between the 2 years (Fig. 11), though bull counts were 74% and 42% lower, respectively, than that observed in 1997, the highest recorded (Fig. 11).

The first live pup at ACV was observed on 9 June in 2010 and 7 June in 2011. The median pupping date was 29 June during 2010 and 4 July during 2011. The mean median pupping date between 1998 and 2009 was 7 July ($SD = 2.7$ days; not including 2001 and 2007). The mean number of live pups at ACV was 1537 ($SE = 11.5$) during 2010 and 1398 ($SE = 4.1$)

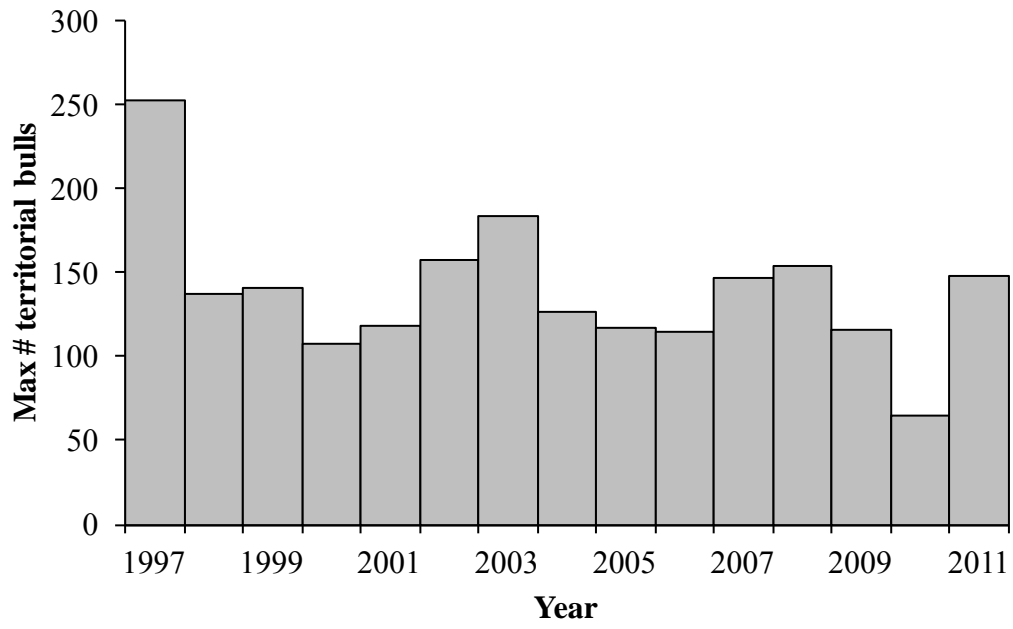


Figure 11.--Maximum number of territorial northern fur seal bulls at Adams Cove on San Miguel

Island, California, 1997-2011.

during 2011. The mean number of live pups counted at Castle Rock was 1,144 (SE = 26.8) in 2010 and 1,150 (SE = 8.2) in 2011 (Table 21).

At ACV, total births in 2010 and 2011 were 4% and 14%, respectively, below the record high estimated in 1997 (Table 21; Fig. 12). At Castle Rock, total births in both 2010 and 2011 were 17% higher than the peak in 1997. Over the past 15 years, only in 2010 have total births surpassed those in 1997 (Table 21; Fig. 12). However, the annual growth rates have increased at ACV (10.7%), Castle Rock (12.2), and SMI total (11.2) since the 1998 EN (Fig. 12). At ACV, early season pup mortality (birth to ~1 month old) rates since 1997 have ranged from 6% (in 2001) to 43% (in 2007; Table 21). Total pup mortality (birth to ~3 months old) rates ranged between 6% (in 2001) and 82% (in 2009; Table 21). At ACV, total pup mortality rate was 47% during 2010 and 37% during 2011 (Table 21).

Tagging and Pup Condition

During 2010, adjusted estimated mean mass (\pm SE) of female (11.3 kg \pm 0.2) and male (12.6 kg \pm 0.2) pups was higher (although not significantly) than the long-term average for both sexes (female₁₉₇₅₋₂₀₀₉ = 10.5 \pm 0.2, male₁₉₇₅₋₂₀₀₉ = 11.8 \pm 0.2; ($|t_{\text{obs } \text{♀}\&\text{♂}}| = 0.62) < (t_{0.05(28)} = 2.06)$; Fig. 13). In 2011, the adjusted estimated mean mass (9.3 kg \pm 0.1 females; 10.6 kg \pm 0.1 males) of northern fur seal pups decreased from 2010 and was lower (although not significantly) than the long-term means for both sexes (female₁₉₇₅₋₂₀₁₀ = 10.5 \pm 0.2, male₁₉₇₅₋₂₀₁₀ = 11.8 \pm 0.2; ($|t_{\text{obs } \text{♀}\&\text{♂}}| = 0.98) < (t_{0.05(29)} = 2.05)$; Fig.13).

Sightings of Marked Individuals

Adults that were tagged as pups were resighted during 2010 (females = 149, males = 48) and 2011 (females = 220, males = 90) in ACV (Figs. 14 and 15). Tagged females ranged in age

Table 21.--Summary of pup counts of northern fur seals at Adams Cove and Castle Rock
(rookeries of San Miguel Island), 1997-2011.

Colony/Year	Mean number of live pups (SE)	Early season pup mortality (%) ¹	Total births	Late season pup mortality (%) ²	Total pup mortality (%) ³
Adams Cove					
1997	1,765 (9)	448 (20)	2,213	717 (32)	1,165 (53)
1998	308 (2)	154 (33)	462	142 (31)	296 (64)
1999	604 (3)	225 (27)	829	32 (4)	257 (31)
2000	962 (6)	145 (13)	1,107	41 (4)	186 (17)
2001	1,226 (2)	76 (6)	1,302	0	76 (6)
2002	1,126 (4)	102 (8)	1,228	109 (9)	211 (17)
2003	1,083 (3)	302 (22)	1,385	82 (6)	384 (28)
2004	810 (4)	606 (43)	1,416	219 (16)	825 (58)
2005	1,133 (14)	504 (31)	1,637	521 (32)	1,025 (63)
2006	1,129 (37)	606 (35)	1,735	244 (1)	850 (49)
2007	972 (4)	735 (43)	1,707	368 (22)	1,103 (65)
2008	1,390 (2)	448 (24)	1,838	243 (13)	692 (38)
2009	1,266 (19)	867 (41)	2,133	871 (41)	1,738 (82)
2010	1,537 (12)	600 (28)	2,137	413 (19)	1,013(47)
2011	1,398 (4)	507 (27)	1,905	198 (10)	705 (37)

Table 21.--Continued.

Colony/Year	Mean number of live pups (SE)	Early season pup mortality (%) ¹	Total births	Late season pup mortality ²	Total pup mortality (%) ³
Castle Rock					
1997	940 (5)	68 (7)	1,008	---	---
1998	194 (1)	39 (17)	233	---	---
1999	300 (2)	15 (5)	315	---	---
2000	562 (4)	17 (3)	579	---	---
2001	708 (5)	57 (8)	765	---	---
2002	724 (2)	28 (4)	752	---	---
2003	---	---	---	---	---
2004	804 (4)	28 (3)	832	---	---
2005	782 (4)	24 (3)	806	---	---
2006	634 (37)	21 (3)	655	---	---
2007	758 (9)	---	758	---	---
2008	1,076 (58)	---	---	---	---
2009	800 (5)	138 (15)	938	---	---
2010	1,144 (27)	23 (2)	1167	---	---
2011	1,150 (8)	19 (2)	1169	---	---

¹Estimated number of dead pups at the time of the live pup census based on a correction factor of 1.33 to account for pups that are missed during surveys or disappear between surveys. Note: A correction factor was not applied to counts at Castle Rock.

²Estimated number of dead pups after the live pup census based on a correction factor of 1.25 to account for pups that are missed during surveys or disappear between surveys after the live pup census.

³Rate calculated based on estimated total number of dead pups in early and late season surveys as percentage of live births.

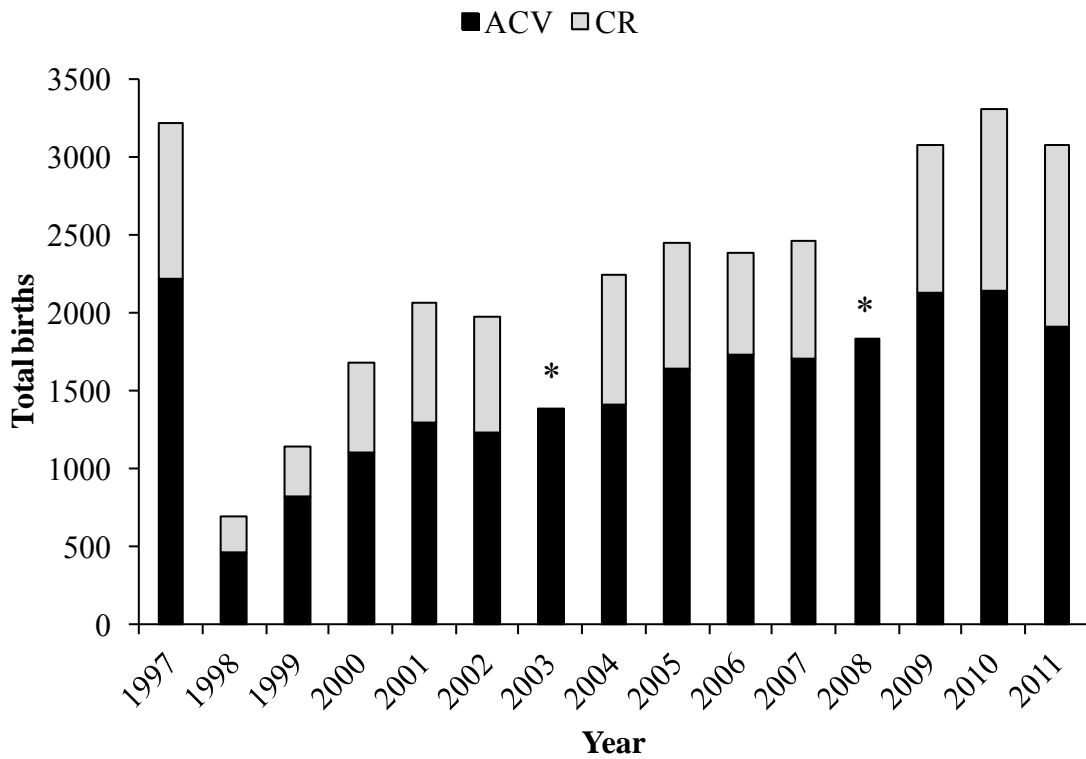


Figure 12.--Total number of births (i.e. number of live pups + number of early season dead pups) of northern fur seal pups at Adam's Cove (ACV) and Castle Rock (CR) rookeries during 1997 – 2011. Asterisk (*) indicates no counts at Castle Rock.

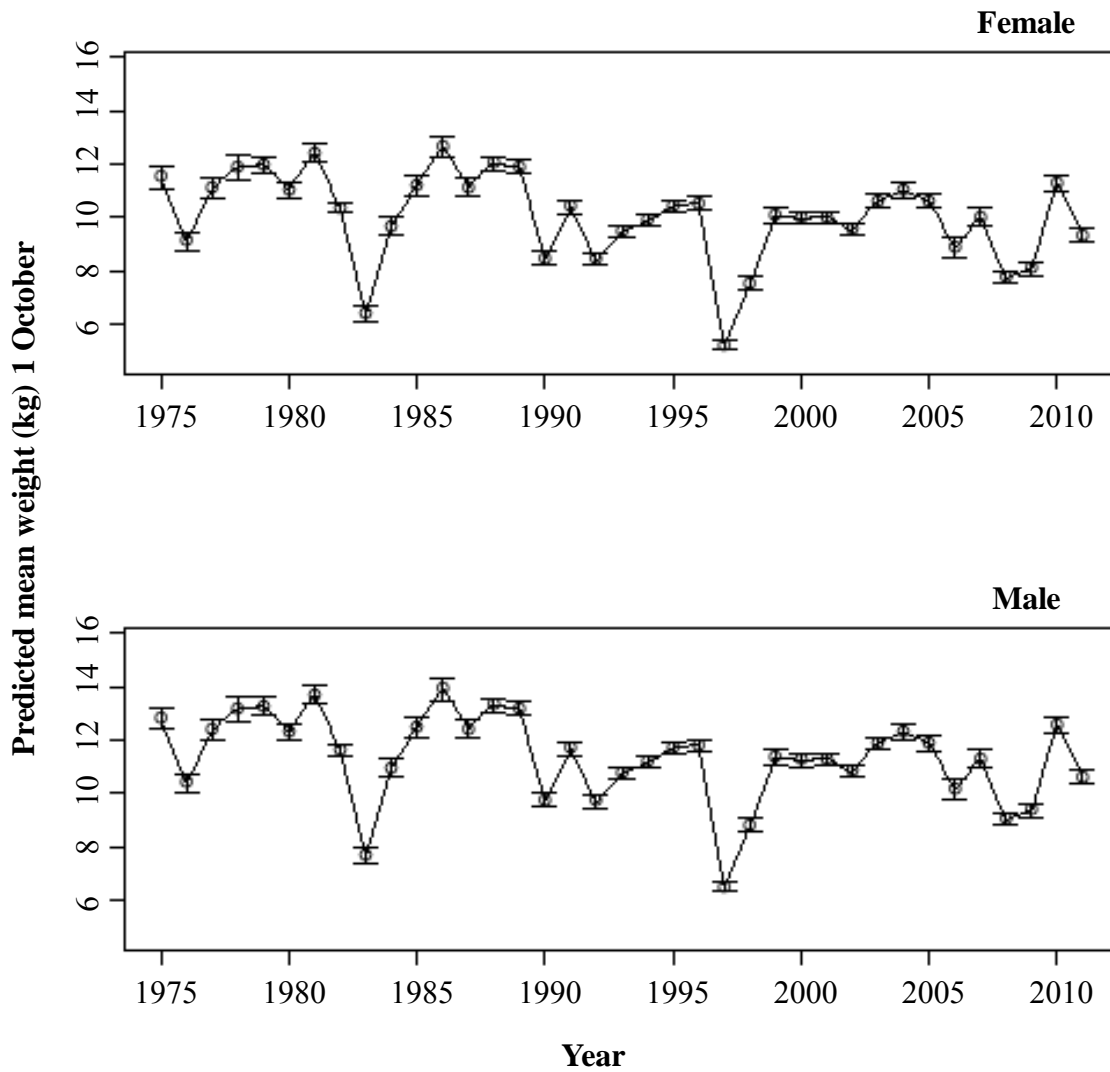


Figure 13.--Mean mass (kg) of northern fur seal pups at San Miguel Island, California, adjusted for a weighing date of 1 October each year. The masses are adjusted because pups were weighed on different dates throughout the time series.

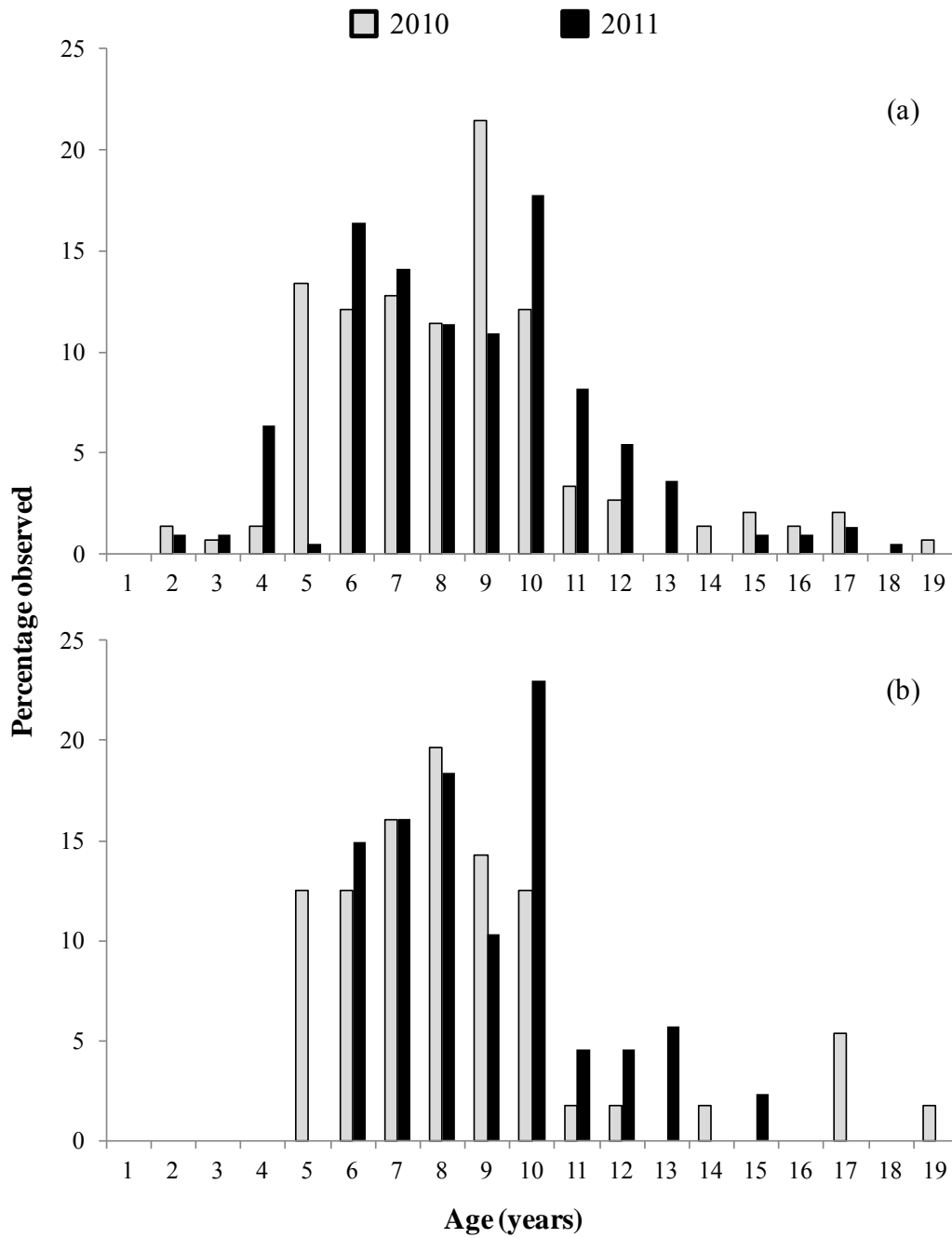


Figure 14.--Age distribution of (a) adult female northern fur seals that were tagged as pups since 1991 and re-sighted at San Miguel Island, California, during 2010 ($n = 149$) and 2011 ($n = 220$), and (b) of marked adult females that were observed with a pup in 2010 ($n = 56$) and 2011 ($n = 87$).

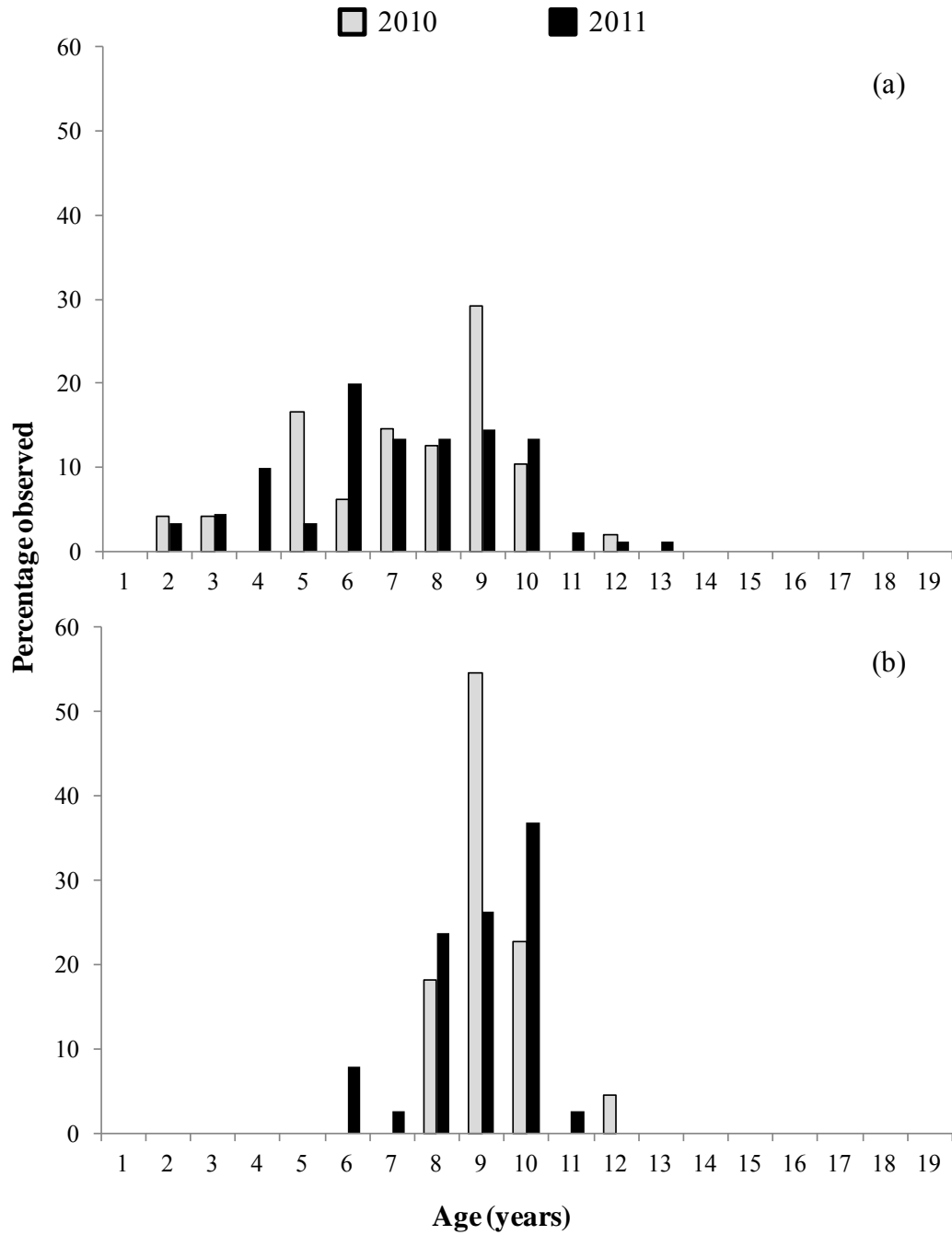


Figure 15.--Age distribution of (a) adult male northern fur seals that were tagged as pups since 1991 and re-sighted at San Miguel Island, California, during 2010 ($n = 48$) and 2011 ($n = 90$), and (b) of marked bulls that were territorial in 2010 ($n = 22$) and 2011 ($n = 38$).

from 2 to 19 years old during 2010, and from 2 to 18 years old during 2011 (Fig. 14). Females sighted with pups were 5-19 years of age in 2010 (n = 56), and 6-15 years of age in 2011 (n = 87; Fig. 14). Eight-year-olds (20%) in 2010 and 10-year-olds in 2011 (23%) were the modal ages of tagged females with pups (Fig. 4). Tagged males ranged in age from 2 to 12 years old during 2010, and from 2 to 13 years of age during 2011 (Fig. 15). Territorial males were between 8 and 12 years old in 2010 (n = 22), and between 6 and 11 years old in 2011 (n = 38; Fig. 15). Nine and 10-year old males had the highest number of territories during 2010 and 2011, respectively (Fig. 15). Only a small proportion of tagged females (10% in 2010, 13% in 2011) and even fewer tagged males (2% in 2010 and 2011) older than 12 years of age were seen. There were no tagged individuals from the 1992 (18 years old in 2010, 19 years old in 2011) or 1997 (13 years old in 2010, 14 years old in 2011) EN cohorts seen during 2010 or 2011 (Figs. 14 and 15), perhaps indicating high mortality of these cohorts due to EN.

Farallon Islands

The maximum count of northern fur seals at the Farallon Islands was 282 in 2010 and 476 in 2011. The number of tagged individuals was 23 (48% female, 39% male) in 2010 and 14 (43% female, 50% male) in 2011. These animals were tagged at SMI. The sex of the remaining proportion of tagged individuals was not determined.

DISCUSSION

The California Current System has experienced two “cold” phases of the PDO during the past decade (1998-2002, September 2007-present, with an EN interruption from August 2009

through May 2010) and a La Niña event (June 2010-present) which were predicted to create advantageous ocean conditions for northern fur seals at SMI during the latter half of 2010 and throughout 2011. We believed that the fur seals would have high productivity and survivorship, as well as be in good condition during a period when the environment was relatively cool and productive. However, the number of territorial bulls in ACV remained lower than the historical record high number in 1997. There was a large decline in the number of territorial bulls in 1998, and their numbers have fluctuated throughout the years, but they have not exceeded 75% of their historic high numbers. The lowest number of territorial bulls counted since 1997 occurred during 2010. There was an EN event from mid-2009 to May 2010, which might have negatively affected potential reproductive males from returning to SMI to establish territories. La Niña conditions existed during 2011, which coincided with a rebound in the number of territorial males counted in 2011 to twice that of 2010.

On the other hand, the favorable environmental conditions experienced during the past decade have resulted in positive trends in pup production. Pup production in ACV during 2010 was only 3.4% below the record high in 1997. This represents the highest pup count since 1997. At Castle Rock, a record-setting number of pups were counted during 2010 and 2011, surpassing the pup production of 1997. The annual mean and total growth rates at ACV and Castle Rock from 1998 to 2011 have exceeded 10%, which is encouraging considering the pup mortality estimates. Additionally, the masses of pups (both females and males) in 2010 and 2011 were not significantly different than the long-term average.

The low percentage of older animals represented in the tagged-animal population may represent high tag loss for older animals. Double-tagging studies of northern fur seals were

conducted in the Pribilof Islands to estimate tag loss. Results from these studies confirmed that tag loss was significant, with 67% of the pups losing one tag and 3% losing both tags by 3 years of age (Scheffer et al. 1984). Although the studies were based on a different tag type and tagging methods than those used in our study, tag loss has been identified (but not quantified) as a problem with the tags that were used at SMI. Thus, the age structure of the tagged animals is likely biased toward younger animals due to accumulated tag loss for older animals. However, the abrupt decline in the number of territorial bulls and the slow recovery of total births (i.e., fewer reproductive females in the population) after the 1997-1998 EN indicates that adult mortality did occur in 1997 and 1998 (Melin and DeLong 2000, Melin et al. 2005) or the breeding population did not return to SMI during that period. The low number of tagged individuals from the 1997 and 1998 cohorts seen subsequently suggests lower survival and thus lower recruitment of these cohorts into the breeding population in 2000 through 2011. The highest number of tagged animals resighted was from the 2001 cohort, indicating that survival for this cohort was high.

Accounting for the biases associated with tag data, females live to a minimum of 19 years of age and continue to have pups until that age. The oldest tagged males were only 13 years old; males as old as 12 years defended territories. The mode age of territorial males was 9 or 10 years old. These findings indicate that males do not live as long as females or that they do not return to the island to defend a territory when they get too old.

Whereas EN events represent an external, periodic, density-independent factor affecting the population, hookworm disease is generally a density-dependent factor (Spraker and Lander 2010). Northern fur seal pup mortality associated with hookworm disease occurs within the first

6 weeks of life. However, residual effects exhibited in survivors include: a weakened immune system, retarded growth, and weight gain once the infection has cleared. Hookworm disease was first described in the SMI northern fur seal population during 1996 (Lyons et al. 1997). In 2000, 95% of the dead pups less than one month old had hookworm infections (Lyons et al. 2001). We believe that high incidence of hookworm disease in the population has contributed to the high mortality of pups during the past 15 years. We speculate that the high pup mortality will continue until the population mounts an immune response to the parasite (or the prevalence of the parasite is reduced), perhaps several generations into the future. Therefore, in addition to environmental perturbations (e.g., EN and PDO events), disease appears to play an influential role in the population dynamics of the northern fur seals at SMI.

The population of northern fur seals at the Farallon Islands has been increasing during the past several years, in large part due to the emigration of individuals from SMI. Count data are available in a report by PRBO (Tietz 2012). From a preliminary analysis of tag-resight data, it appears that over 50% of tagged northern fur seals observed at the Farallon Islands are resighted again on SMI. This indicates considerable interisland movement of individuals.

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Class 4 (non-territorial)	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 grounds)	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.
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.
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.’

APPENDIX B

Tabulations of northern fur seal adults and pups counted by rookery, size class, and rookery section during population assessment.

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Table B-1. – Number of adult male northern fur seals counted (rounded average of two counts), by class^a and rookery section, St. Paul Island, Alaska, 10-17 July 2010. A dash indicates no section.

Rookery and class of male	Section														Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
<u>Lukanin</u>															
2	23	10													33
3	101	48													149
5	87	8													95
<u>Kitovi^b</u>															
2	(6) 4	5	13	11	17										56
3	(11) 20	29	53	43	52										208
5	(18) 4	24	10	13	76										145
<u>Reef</u>															
2	16	20	25	20	21	23	3	18	13	9	1				169
3	41	58	54	43	53	102	0	82	40	30	4				507
5	17	17	24	20	41	15	9	40	17	44	18				262
<u>Gorbatch</u>															
2	19	21	27	9	10	21									107
3	84	38	76	18	61	49									326
5	220	16	37	28	19	12									332
<u>Ardiguin</u>															
2	7														7
3	60														60
5	16														16
<u>Morjovi^c</u>															
2	(11) 14	18	40	15	41	13									152
3	(53) 52	48	47	36	87	53									376
5	(37) 164	29	25	11	32	63									361
<u>Vostochni</u>															
2	14	5	13	16	10	39	17	11	12	6	5	15	32	22	217
3	68	18	33	37	40	90	40	28	34	19	24	45	130	95	701
5	23	12	14	44	49	14	11	29	14	13	7	42	90	80	442
<u>Little Polovina</u>															
2	5														5
3	1														1
5	99														99
<u>Polovina</u>															
2	15	14													29
3	48	44													92
5	168	19													187
<u>Polovina Cliffs</u>															
2	12	6	3	7	9	19	14								70
3	54	33	27	51	59	85	86								395
5	15	8	6	6	14	14	30								93
<u>Tolstoi</u>															
2	5	10	8	10	24	25	26	33							141
3	29	23	34	48	38	54	46	57							329
5	4	9	20	9	37	37	21	214							351
<u>Zapadni Reef</u>															
2	58	18													76
3	134	41													175
5	97	141													238
<u>Little Zapadni</u>															
2	5	23	28	35	35	33									159
3	18	33	48	39	50	67									255
5	24	16	25	19	34	111									229
<u>Zapadni</u>															
2	13	29	40	26	51	40	35	23							257
3	30	34	50	52	66	66	59	43 ^d							400
5	89	19	24	22	23	40	24	271							512

^a Class 2 = territorial adult male without female; class 3 = territorial adult male with female; class 5 = non-territorial adult male.

^b Numbers in parentheses are the adult males counted in Kitovi Amphitheater.

^c Numbers in parenthesis are the adult males counted on the second point south of Sea Lion Neck.

^d Includes 2 territorial males with females on Zapadni Sands haulout.

Table B-2. – Number of adult male northern fur seals counted (rounded average of two counts), by class^a and rookery section, St. Paul Island, Alaska, 9-14 July 2011. A dash indicates no section.

Rookery and class of male	Section														Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
<u>Lukanin</u>															
2	34	15													49
3	69	38													107
5	157	10													167
<u>Kitovi</u>															
2	10	2	18	20	13										63
3	25	30	33	24	46										158
5	36	14	10	8	100										168
<u>Reef</u>															
2	12	43	29	25	22	16	4	28	10	16	4				209
3	50	82	55	51	57	82	0	75	44	27	3				526
5	26	28	37	46	34	12	28	32	23	93	30				389
<u>Gorbatch</u>															
2	17	22	25	11	15	13									103
3	71	51	86	24	56	50									338
5	185	22	30	52	24	16									329
<u>Ardiguin</u>															
2	6														6
3	48														48
5	7														7
<u>Morjovi^b</u>															
2	(22) 13	16	24	11	35	13									134
3	(52) 52	48	50	28	64	40									334
5	(14) 192	31	13	14	27	29									320
<u>Vostochni</u>															
2	16	5	8	9	6	25	11	8	8	3	4	8	26	14	151
3	52	25	28	58	39	64	37	39	32	20	24	63	143	72	696
5	35	17	15	41	48	19	20	5	14	7	11	60	111	85	488
<u>Little Polovina</u>															
2	0														0
3	0														0
5	168														168
<u>Polovina</u>															
2	17	15													32
3	59	46													105
5	200	24													224
<u>Polovina Cliffs</u>															
2	19	5	7	11	17	26	15								100
3	51	31	35	51	41	75	79								363
5	37	2	7	14	27	8	6								101
<u>Tolstoi</u>															
2	5	15	11	9	27	37	30	41							175
3	28	26	30	57	43	59	47	58							348
5	6	8	7	5	16	14	17	244							317
<u>Zapadni Reef</u>															
2	59	2													61
3	131	43													174
5	105	76													181
<u>Little Zapadni</u>															
2	7	11	21	29	28	31									127
3	16	39	54	44	45	58									256
5	39	21	11	17	24	145									257
<u>Zapadni^c</u>															
2	14	20	31	22	31	44	33	21							216
3	21	35	41	55	55	59	64	46							376
5	(37) 115	6	19	18	19	33	26	324							597

^a Class 2 = territorial adult male without female; class 3 = territorial adult male with female; class 5 = non-territorial adult male.

^b Numbers in parenthesis are the adult males counted on the second point south of Sea Lion Neck.

^c Numbers in parenthesis are the adult males counted on Zapadni Point Reef.

Table B-3.-- Number of northern fur seal pups sheared on each sampled rookery of St. Paul Island, Alaska, 2010.

Rookery	Section														Total	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13		14
Lukanin		235	106													341
Kitovi ¹	21	35	68	105	83	95										407
Reef ²		109	161	162	82	135	239		209	105	86	10				1,298
Gorbatch		210	133	237	55	166	166									967
Ardiguen		119														119
Morjovi ¹	114	110	99	100	82	191	103									799
Vostochni		100	54	72	90	77	207	90	65	70	42	53	99	267	187	1,473
Polovina		143	138													281
Little Polovina																
Polovina Cliffs		126	70	67	115	135	200	199								912
Tolstoi		107	85	98	189	125	189	158	198							1,149
Zapadni Reef		384	114													498
Little Zapadni		56	105	146	120	161	210									798
Zapadni		95	104	145	156	201	200	175	128							1,204
Sea Lion Rock																
Total																10,246

¹Section 0 corresponds to 2nd Point South on Morjovi and Kitovi Amphitheater.²Section 7 was combined with Section 6.

Table B-4.--Number of harem and idle males, pups born, number of rookeries sampled, standard deviation (SD) of the number of pups born, and the number of dead pups on the Pribilof Island, Alaska, 1983-2011. A dash indicates no data.

Year	St. Paul						St. George					
	Harem Bulls	Idle Bulls	Pups Born	SD	Rookeries Sampled (n)	Dead Pups	Harem Bulls	Idle Bulls	Pups Born	SD	Rookeries Sampled	Dead Pups
1983	4,827	4,242	165,941	6,034	4	5,997	--	--	31,440	2,930	6	903
1984	4,803	3,977	173,274	8,117	5	6,115	1,473	1,452	--	--	--	--
1985	4,372	3,363	182,258	7,997	7	5,266	1,268	1,601	28,869	2,297	6	806
1986	4,603	1,865	167,656	5,086	4	7,771	1,394	1,342	--	--	--	--
1987	3,636	1,892	171,610	3,218	13	7,757	1,303	1,283	--	--	--	--
1988	3,585	3,201	202,229	3,751	4	7,272	1,259	1,258	24,819	827	6	1,212
1989	4,297	6,400	171,534	25,867	4	9,096	1,241	1,163	--	--	--	--
1990	4,430	7,629	201,305	3,724	13	9,128	909	1,666	23,397	2,054	6	928
1991	4,729	9,453	--	--	--	--	736	1,271	--	--	--	--
1992	5,460	10,940	182,437	8,918	13	8,525	1,028	1,834	25,160	707	6	806
1993	6,405	9,301	--	--	--	--	1,123	1,422	--	--	--	--
1994	5,715	10,014	192,104	2,029	13	8,180	1,179	1,481	22,244	410	6	788
1995	5,154	8,459	--	--	--	--	1,242	1,054	--	--	--	--
1996	5,643	9,239	170,125	21,244	6	6,837 ¹	1,248	790	27,385	294	6	719
1997	5,064	8,560	--	--	--	--	910	1,474	--	--	--	--
1998	4,762	8,396	179,149	6,193	7	5,058 ¹	1,116	1,084	22,090	222	6	452
1999	3,767	7,589	--	--	--	--	1,052	916	--	--	--	--
2000	3,646	6,998	158,736	17,284	6	4,778 ¹	871	1,300	20,176	271	6	756
2001	3,388	7,174	--	--	--	--	843	1,596	--	--	--	--
2002	3,669	7,877	145,716	1,629	13	4,792	899	1,265	17,593	527	6	533
2003	3,652	7,572	--	--	--	--	716	1,158	--	--	--	--
2004	3,286	5,045	122,825	1,290	13	4,041	760	905	16,878	239	6	417
2005	3,515	5,811	--	--	--	--	905	634	--	--	--	--
2006	3,669	6,283	109,961	1,520	13	4,994 ²	720	650	17,072	143	6	712 ²
2007	3,568	5,270	--	--	--	--	744	559	--	--	--	--
2008	4,119 ³	5,050	102,674	1,084	13	5,503 ²	805	638	18,160	288	6	986 ²
2009	4,121	5,226	--	--	--	--	873	824	--	--	--	--
2010	3,974	4,840	94,502	1,120	13	5,284 ²	830	1,030	17,973	323	6	959 ²
2011	3,829	5,139	--	--	--	--	842	1,112	--	--	--	--

¹ Dead pups for the entire Island are estimated from the mortality rate on sampled rookeries.

² Total dead pups are estimated from dead pup counts on sample rookeries, different protocol than ¹.

³ Error in bull counts, see Appendix Table B-1 (FSI 2008-09) for details on Vostochni, section 14.

Table B-6.-- Number of northern fur seal pups sheared on each rookery of St. George Island, Alaska, 2010.

Rookery	Section					Total
	1	2	3	4	5	
South	104	178	146			428
North	108	147	203	76	62	596
East Reef	151					151
East Cliffs	269	177				446
Staraya Artil	36	52				88
Zapadni	60	90	60			210
Total						1,919

Table B-7.-- Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 2010.

Rookery	Date	Section					Total	
		1	2	3	4	5		
North	8/23	74	105	92		32	19	322
East Cliffs	8/21	105	54					159
Zapadni	8/22	46	56	30				132

Table B-8.-- Number of dead northern fur seals counted that were older than pup, Pribilof Islands, Alaska, 1976-2010. Teeth (usually canines) were collected from most of these seals. A dash indicates no data.

Year	St. Paul Island		St. George Island		Total	
	Males	Females	Males	Females	Males	Females
1976	46	64	-	-	46	64
1977	60	69	-	-	60	69
1978	57	87	-	-	57	87
1979	56	66	- ^a	- ^a	56	66
1980	102	117	14	65	116	182
1981	44	83	12	61	56	144
1982	47	117	-	-	47	117
1983	57	66	-	-	57	66
1984	66	72	-	-	66	72
1985	5	34	17	35	22	69
1986	24	67	-	-	24	67
1987	20	90 ^b	-	-	20	99
1988	56	112	21	29	77	141
1989	55	162	-	-	55	162
1990	97	151	13	31	110	182
1992	97	265	7	19	104	284
1994	84	223 ^c	6	19 ^d	90	242
1996	20 ^e	92 ^e	3	20 ^f	23	112 ^f
1998 ^g	-	-	-	-	-	-
2000	20	77	26	98	46	175
2002 ^h	36	107	6	19	42	126
2004 ⁱ	37	85	9	12	46	97
2006 ^j	23	37	2	8	25	45
2008 ^j	4	41	2	10	6	51
2010 ^j	10	52 ^k	5	10 ^l	32	45

^a A total of 70 dead adult fur seals of both sexes were counted on the rookeries of St. George Island.

^b Includes 10 dead adult fur seals of unknown sex.

^c Includes 16 dead adult fur seals of unknown sex.

^d Includes 2 dead adult fur seals of unknown sex.

^e Counts made only on the 6 sample rookeries where dead pups were counted.

^f Includes 16 dead adult fur seals of unknown sex.

^g A total of 108 dead adults were counted on St. Paul and 34 dead adults were counted on St. George.

^h Does not include 8 dead adults that were unidentifiable, had no teeth and both.

ⁱ Does not include 11 dead adults that were not sexually identifiable.

^j Only four rookeries were sampled for dead pups and therefore dead adults also.

^k Teeth not taken from 4 males and 4 females on Reef, nor from 1 female each on VOS, PCL and ZAR.

^l Teeth were not taken from 1 female on East Cliffs, includes 1 dead adult of unknown sex.

APPENDIX C

Scientific staff engaged in northern fur seal
field research in 2010-2011

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Tom Gelatt, Leader, Alaska Ecosystem Program
Rolf R. Ream, Northern Fur Seal Task Leader

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Mark Hoover	ABL
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DVM – Contract Veterinarian

MMC – Marine Mammal Center, California

NMFS – National Marine Fisheries Service

NMFSA – National Marine Fisheries Service Regional Office, Anchorage, AK

NMML – National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA

OAI – Ocean Associates, Inc.

PISP – Pribilof Island Stewardship Program

SGTC – St. George Tribal Council

TGSP – Tribal Government of St. Paul, AK

USN – U.S. Navy

USFWS – U.S. Fish & Wildlife Service, Alaska Maritime Wildlife Refuge, Homer, AK

WPI – Wildlife Pathology International

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