NOAA Technical Memorandum NMFS-AFSC-188

Fur Seal Investigations, 2006-2007

by
J. W. Testa (editor)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

November 2008

NOAA Technical Memorandum NMFS

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This document should be cited as follows:

> Testa, J. W. (editor). 2008. Fur seal investigations, 2006-2007. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-188, 76 p.

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November 2008

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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*) annually on the Pribilof Islands, Bogoslof Island in the eastern Bering Sea, and on San Miguel Island off the coast of California. The estimate of the total stock for the Pribilof Islands population in 2006 was ~678,000. The approximate total stock size for the United States was 744,000 northern fur seals.

In 2006 and 2007, population parameters monitored on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals. Counts on St. Paul Island yielded totals of 3,669 and 3,568 territorial male seals with females in 2006 and 2007, respectively. On St. George Island comparable numbers were 720 and 744. On St. Paul Island, 392 and 269 sub-adult male seals were harvested in 2006 and 2007, respectively. On St. George Island, 212 and 208 sub-adult male seals were taken in the two harvest years, respectively.

In 2006, the number of pups born and the mortality rates of fur seals were assessed on St. Paul and St. George Islands. The estimate for the total number of pups born was 109,961 (SE = 1,520) on St. Paul Island (excluding Sea Lion Rock) and 17,072 (SE = 143) on St. George Island. Pup mortality from birth to late August was 4.5% on St. Paul Island and 4.2% on St. George Island. The number of pups on St. Paul Island was 10.5% less than in 2004 ($P < 0.01$), but on St. George Island there was a 1.1% increase in the same period. The annual rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 5.75% (SE = 0.34%, $P < 0.01$) from 1998 to 2006.

The mass and length of fur seal pups on the Pribilof Islands are used as indicators of population health and have been monitored semi-annually since 1989. In 2006, both male and female pups on St. George Island were significantly longer ($P < 0.01$), but not heavier than those on St. Paul Island, though the difference in length may be attributable to measurement biases. The sex ratio in 2002 was significantly skewed toward males on St. Paul Island (46.2% female, $P = 0.002$), but not St. George Island (47.5%, $P = 0.22$).

Pup production on San Miguel Island, California, was estimated at 2,390 and 2,465 in 2006 and 2007, respectively. There was no evidence of a trend in recent production estimates, but pup mortality was 49.0% and 64.6% in the rookery at Adams Cove in 2006 and 2007, continuing the high levels of pup mortality begun in 2004 that were likely caused by the high incidence of hookworm disease. Pup weights suggest that pups were in poor condition in 2006, but weights conformed to the long-term average at San Miguel Island in 2007. Pup production remained below the 1997 production levels by more than 22% in Adams Cove and by more than 24% at Castle Rock in 2007.

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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) constitutes roughly half of the world population. Other breeding colonies are located on the Kuril and Commander Islands in Russia, Bogoslof Island (Fig. 4) in the southeastern Bering Sea, and on 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 (R.R. Ream, NMML-AFSC, pers. comm.), 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 in spite of the cessation of female harvests. Beginning around 1980 until 1998, the population at St. Paul Island fluctuated around 35-45% of its peak numbers, while the smaller

population at nearby St. George declined at a more or less steady rate to less than 30% of the peak. Both populations renewed a downward trend in 1998 at roughly 6% annually (Towell et al. 2006). 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 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 disseminate that information. Research by NMML on northern fur seals in 2006 and 2007 was conducted under Marine Mammal Protection Act Permit No. 782-1708-00.

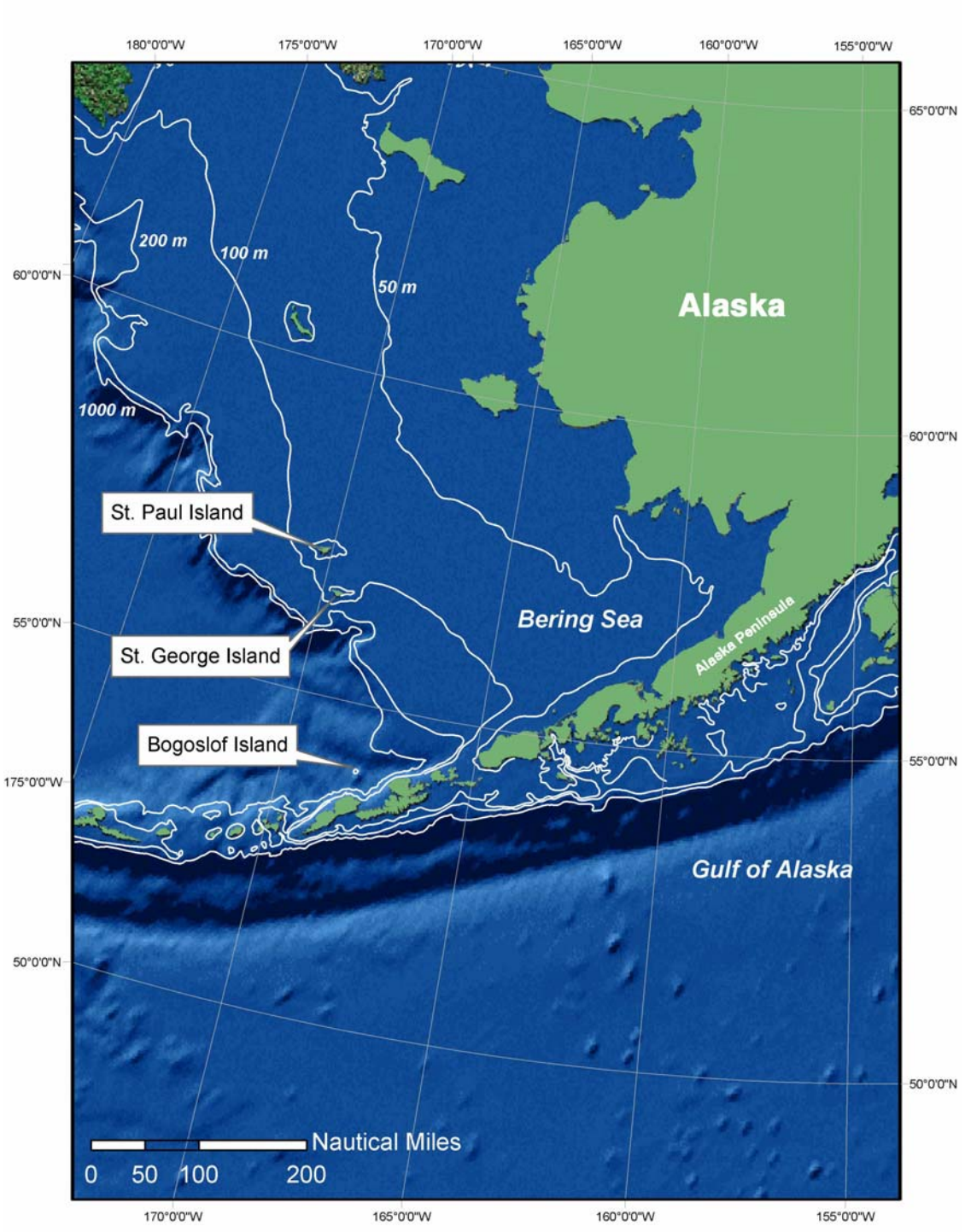


Figure 1.-- Location of the three northern fur seal breeding areas within Alaska waters.

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.

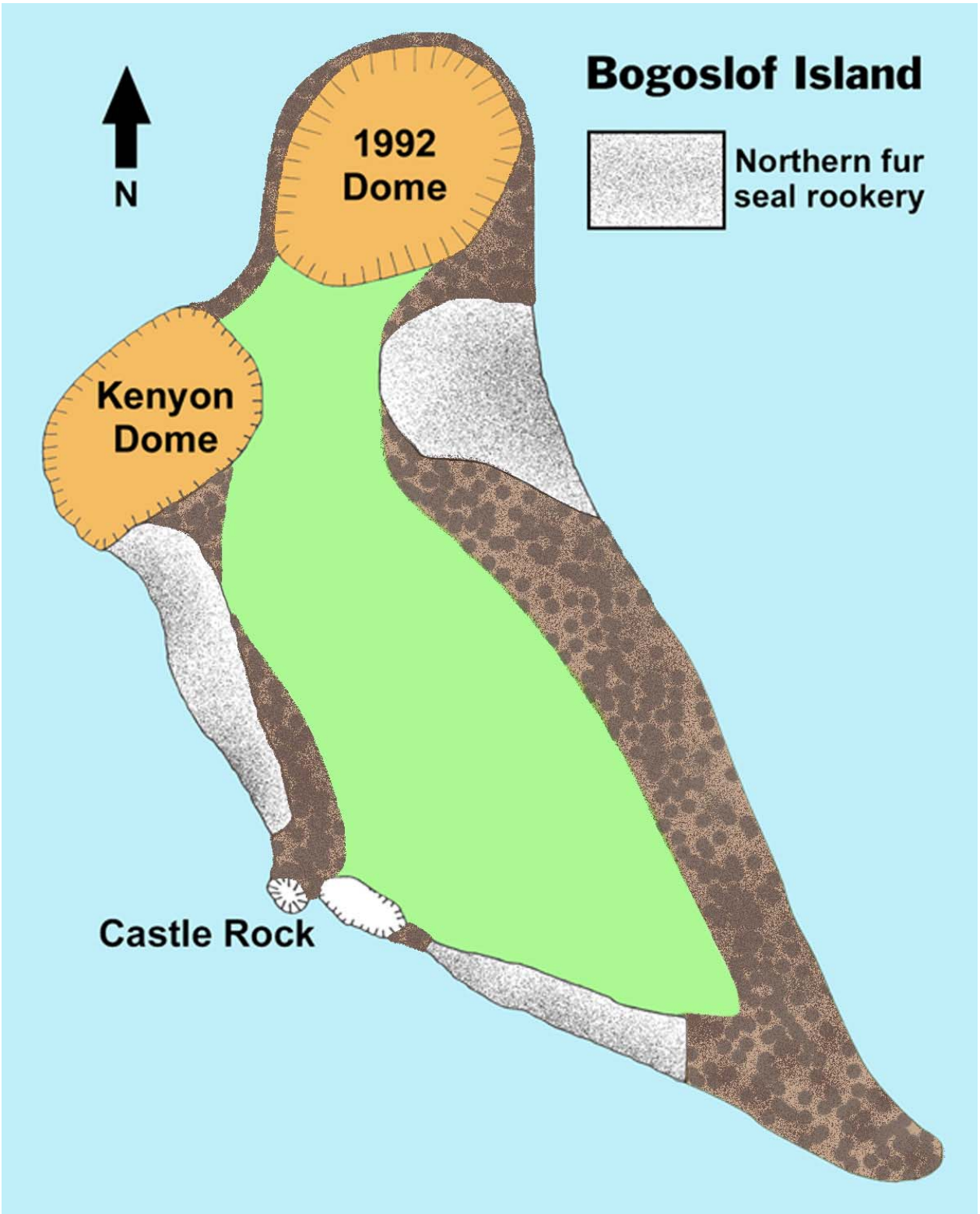


Figure 4.-- Location of northern fur seal rookeries on Bogoslof Island, Alaska.

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

POPULATION ASSESSMENT OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2006 - 2007

by

Rodney G. Towell, Rolf R. Ream, Charles W. Fowler, Jeremy T. Sterling, Lowell W. Fritz, and John L. Bengtson

In accordance with provisions originally established by the Interim Convention on Conservation of North Pacific Fur Seals, the National Marine Mammal Laboratory (NMML) continues to monitor the status of fur seal populations on the Pribilof Islands. To meet this objective, 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 2006 included the size of the subsistence harvest, numbers of adult males and pups, and mortality rates of fur seal pups on St. Paul and St. George Islands. The subsistence harvest and counts of adult males were the only population characteristics monitored in 2007.

The subsistence harvest was monitored for the number of juveniles killed, waste, adult animals killed or injured, entanglement, hyperthermic seals and other unusual conditions. 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 monitors and reports the subsistence harvest of northern fur seals on St. George Island, also under contract with NMFS.

Adult male fur seals were counted by section for each rookery (see Appendix A glossary for definitions of terms and Fig. 6 for illustration of a typical fur seal rookery) on St. Paul Island from 10-18 July 2006 and 9-15 July 2007 (Appendix Tables B-1 and B-2, respectively**)** and on St. George Island from 9-11 July 2006 and 8-10 July 2007.

On St. Paul Island, dead fur seal pups were counted on four sample rookeries and the numbers of live pups were estimated on 13 rookeries in August 2006 using the shearing-sampling method (York and Kozloff 1987, Antonelis 1992). The total number of pups born was estimated using ratio estimation (Cochran 1977). From 7 to 13 August, pups were marked by shearing. The number of pups sheared on each rookery was approximately 10% of the last estimate of pup production for the sample rookeries in 2004. 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 11 to 25 August. Each observer counted 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

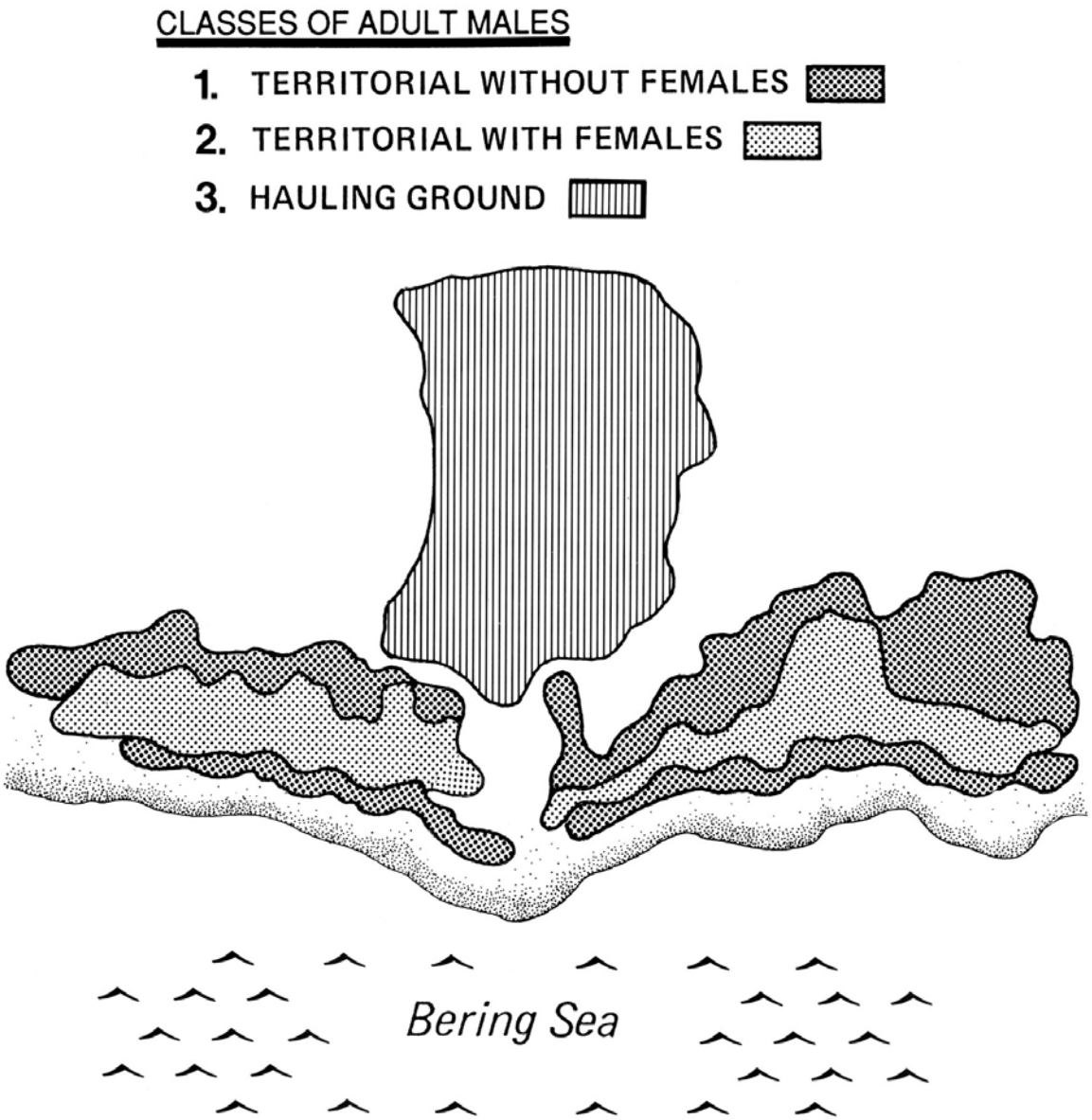


Figure 6.-- The relative location of the different classes of adult males for a typical fur seal rookery/haul-out complex.

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 19 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 17 to 25 August 2006 in the same manner as applied on St. Paul Island. The ratio of marked to unmarked pups on each rookery was determined by three observers from 20 to 22 August and again from 23 to 25 August. Dead pups were counted on three rookeries from 21 to 23 August 2006.

RESULTS AND DISCUSSION

Harvest

A total of 396 and 272 sub-adult male seals were harvested for subsistence on St. Paul Island in 2006 and 2007, respectively (Table 1). On St. George Island, 212 sub-adult male seals were taken in the subsistence harvest in 2006 and 208 were killed in 2007 (Table 2). Four females on St. Paul Island were killed in 2006. Three females on St. Paul Island and two on St. George Island were accidentally killed in the 2007 harvest. All were included as part of the subsistence harvest (Table 2).

Table 1.-- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvest drives on St. Paul Island, Alaska, in 2006 and 2007.

2006			2007		
Date	Rookery	Number killed	Date	Rookery	Number killed
July 22	Reef/Gorbatch	80	July 21	Zapadni	36
July 26	Polovina	83	August 7	Polovina	120
July 28[1]	Zapadni	90	August 8[3]	Gorbatch	116
August 8[2]	Gorbatch	143			

[1] Includes 1 female.
[2] Includes 3 females.
[3] Includes 3 females.

Table 2.-- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvest drives on St. George Island, Alaska, in 2006 and 2007.

2006			2007		
Date	Rookery	Number killed	Date	Rookery	Number killed
July 11	Zapadni	17	July 10	North	11
July 13	North	11	July 13	Zapadni	14
July 18	Zapadni	23	July 14	North	10
July 22	North	16	July 16	Zapadni	10
July 24	Zapadni	11	July 18	Zapadni	16
July 26	North	23	July 20	North	15
July 28	Zapadni	21	July 23	Zapadni	14
July 31	North	14	July 25	North	17
August 3	Zapadni	24	July 27	Zapadni	16
August 7	Zapadni	30	July 30[*]	North	16
August 8	North	22	August 1	Zapadni	18
			August 3	North	11
			August 6	Zapadni	17
			August 8	Zapadni	25

[*] Includes 2 females.

Adult Males Counted

The count of territorial males with females (Class 3 or harem males) on St. Paul Island increased 4.4% between 2005 and 2006, but decreased 2.75% between 2006 and 2007 (Tables 3 and 4; Appendix Table B-4). The count of harem males on St. George Island decreased 20.4% between 2005 and 2006, and increased 3.3% between 2006 and 2007 (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 0.7% between 2005 and 2006 and decreased 1.75% between 2006 and 2007.

Number of Pups Born on St. Paul Island in 2006

The estimated total number of pups alive on St. Paul Island at the time of marking in 2006 was 104,967 (SE = 1,403) (Table 5). The number of dead pups were counted by section on four sample rookeries of St. Paul Island and the total estimated dead on all rookeries was 4,994 (Appendix Table B-5). The estimated mortality rate for late August was 4.5% (Table 6). The total number of pups born on St. Paul Island in 2006 was estimated at 109,961 (SE = 1,520; 95% CI = (106,757 – 113,265)). 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 on Sea Lion Rock. Sea Lion Rock was not sampled in 2006 due to logistical difficulties. The last estimate of pup production on Sea Lion Rock was 8,262 in 2002.

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 2006.

Rookery	Date (July)	Class of adult male * 2	3	5	Total
St. Paul Island					
Lukanin	11	34	100	133	267
Kitovi	11	85	167	234	486
Reef	12	187	511	460	1,158
Gorbatch	12/18	109	284	551	944
Ardiguen	12	22	54	14	90
Morjovi	14	81	314	632	1,027
Vostochni	16	142	737	788	1,667
Polovina	11	26	69	248	343
Little Polovina	11	0	2	269	271
Polovina Cliffs	11	109	278	87	474
Tolstoi	10	187	333	318	838
Zapadni Reef	15	47	159	255	461
Little Zapadni	15	124	253	298	675
Zapadni	13	151	408	692	1,251
Island total		1,304	3,669	4,979	9,952
St. George Island					
South	10	51	155	30	236
North	9	93	260	150	503
East Reef	11	23	56	37	116
East Cliffs	11	58	143	71	272
Staraya Artil	9	22	38	60	120
Zapadni	10	32	68	23	123
Island total		279	720	371	1,370

* See Appendix A for a description of the classes of adult male seals.

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 2007.

Rookery	Date (July)	Class of adult male * 2	3	5	Total
St. Paul Island					
Lukanin	9	45	91	168	304
Kitovi	9	84	150	247	481
Reef	10	211	428	349	988
Gorbatch	10	128	232	312	672
Ardiguen	10	17	48	6	71
Morjovi	12	138	305	463	906
Vostochni	12/13	199	686	530	1,415
Polovina	15	27	95	200	322
Little Polovina	15	0	2	157	159
Polovina Cliffs	15	86	350	151	587
Tolstoi	14	146	403	325	874
Zapadni Reef	11/13	55	152	189	396
Little Zapadni	11	117	260	200	577
Zapadni	11/13	183	366	537	1,086
Island total		1,436	3,568	3,834	8,838
St. George Island					
South	9	44	165	62	271
North	8	110	248	97	455
East Reef	8	13	53	9	75
East Cliffs	8	63	159	63	285
Staraya Artil	9	16	41	23	80
Zapadni	9/10	19	78	40	137
Island total		265	744	294	1,303

* See Appendix A for a description of the classes of adult male seals.

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 and standard error (SE), on sampled rookeries of St. Paul Island, Alaska, 2006. Sea Lion Rock was not sampled due to logistical difficulties.

Rookery	Sheared	E1	E2	Mean	SE
Lukanin	311	2,738	2,619	2,678	59.5
Kitovi	474	4,670	4,492	4,581	89.0
Reef	1568	13,650	12,838	13,244	406.0
Gorbatch	993	8,968	8,439	8,704	264.5
Ardiguen	173	1,094	1,224	1,159	65.0
Morjovi	983	9,211	8,110	8,660	550.5
Vostochni	1,975	16,432	17,037	16,690	347.5
Polovina	260	2,669	2,241	2,455	214.0
Little Polovina*				54	2.65
Polovina Cliffs	1,118	9,581	9,376	9,478	102.5
Tolstoi	1,380	10,006	11,837	10,922	915.5
Zapadni Reef	525	4,876	4,473	4,674	201.5
Little Zapadni	1,230	8,954	8,031	8,492	461.5
Zapadni	1,602	13,559	12,792	13,176	383.5
Total	12,592	106,408	103,509	104,967	1403.3

* 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, standard error (SE), numbers of dead pups, estimated total pups born, mortality rate, idle males, harem males and the ratio of pups alive at marking to harem males, on sampled rookeries of St. Paul Island, Alaska, 2006. Sea Lion Rock was not sampled due to logistical difficulties.

Sample Rookery	Pups alive at marking	SE	Dead pups*	Total pups born	Mortality rate (%)	Harem males	Ratio pups/males
Lukanin	2,678		150	2,805		100	28.05
Kitovi	4,581			4,799		167	28.74
Reef	13,244			13,874		511	27.15
Gorbatch	8,704			9,118		284	32.10
Ardiguen	1,159		51	1,214		54	22.48
Morjovi	8,660			9,072		314	28.89
Vostochni	16,690		700	17,484		737	23.72
Polovina	2,455			2,572		69	37.27
Little Polovina	54			57		2	28.50
Polovina Cliffs	9,478			9,929		278	35.71
Tolstoi	10,922			11,442		333	34.36
Zapadni Reef	4,674			4,896		159	30.79
Little Zapadni	8,492			8,896		253	35.16
Zapadni	13,176		703	13,803		408	33.83
Total	104,967	1,519.6	4,994	109,961	4.5	3,669	29.97

* Includes dead pups taken for necropsies from Vostochni (37) and Zapadni (1).

The number of pups born and the number of harem bulls at different rookeries on St. Paul Island were significantly correlated (r^2 = 0.976, Fig. 7). The slope of the regression line with a zero intercept is 28.49 (SE = 1.30), representing an estimate of the ratio of pups to breeding males.

Number of Pups Born on St. George Island in 2006

Estimated total number of pups alive on St. George Island at the time of marking was 16,360 (SE = 123.6, Table 8). The total number of dead pups was estimated to be 712 (Appendix Table B-7) and the estimated mortality rate was 4.2% (Table 8). The total number of pups born on St. George Island was 17,072 (SE = 143, 95% CI = (16,737 – 17,413)).

The 2006 estimate of pups born on St. George Island was not significantly different than the estimate of pups born in 2004 (P = 0.27) nor was it significantly different than the estimate of pups born in 2002 (P < 0.18). The number of pups born and the number of harem males on St. George Island rookeries were highly correlated (r^2 = 0.985; Fig. 7). The intercept of the regression line was not significantly different from zero (P = 0.48) and was not included in the regression equation.

Trends in Numbers of Pups

The total estimated number of pups born on St. Paul Island in 2006 (not including Sea Lion Rock) was 10.5% less than in 2004 (Fig. 8; P < 0.01). On St. Paul Island, estimated numbers of fur seal pups born in 2004 were 15.7% less than in 2002 (Appendix Table B-4). On St. George Island there was a 4.1% decrease between 2002 and 2004, and a 1.1% increase between 2004 and 2006.

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, 2006.

Rookery	Sheared	E1	E2	Mean	SE
South	400	3,816	3,772	3,794	22.0
North	551	5,264	5,290	5,277	13.0
East Reef	93	821	845	833	12.0
East Cliffs	389	3,617	3,388	3,502	114.5
Staraya Artil	113	954	956	955	1.0
Zapadni	246	1,962	2,036	1,999	37.0
Total	1,792	16,434	16,287	16,360	123.6

Table 8.-- Number of pups alive at the time of marking, standard error (SE), number of dead pups, total pups born, mortality rate, harem males, and the ratio of pups alive at marking to harem males for St. George Island, Alaska, 2006.

Rookery	Pups alive at marking	SE	Dead pups	Total pups born	Mortality rate (%)	Harem males	Ratio pups/males
South	3,794		188	3,959		155	25.54
North	5,277			5,507		260	21.18
East Reef	833			869		56	15.52
East Cliffs	3,502		128	3,654		143	25.55
Staraya Artil	955		40	997		38	26.24
Zapadni	1,999			2,086		68	30.68
Total	16,360	143.0	712	17,072	4.2	720	23.71

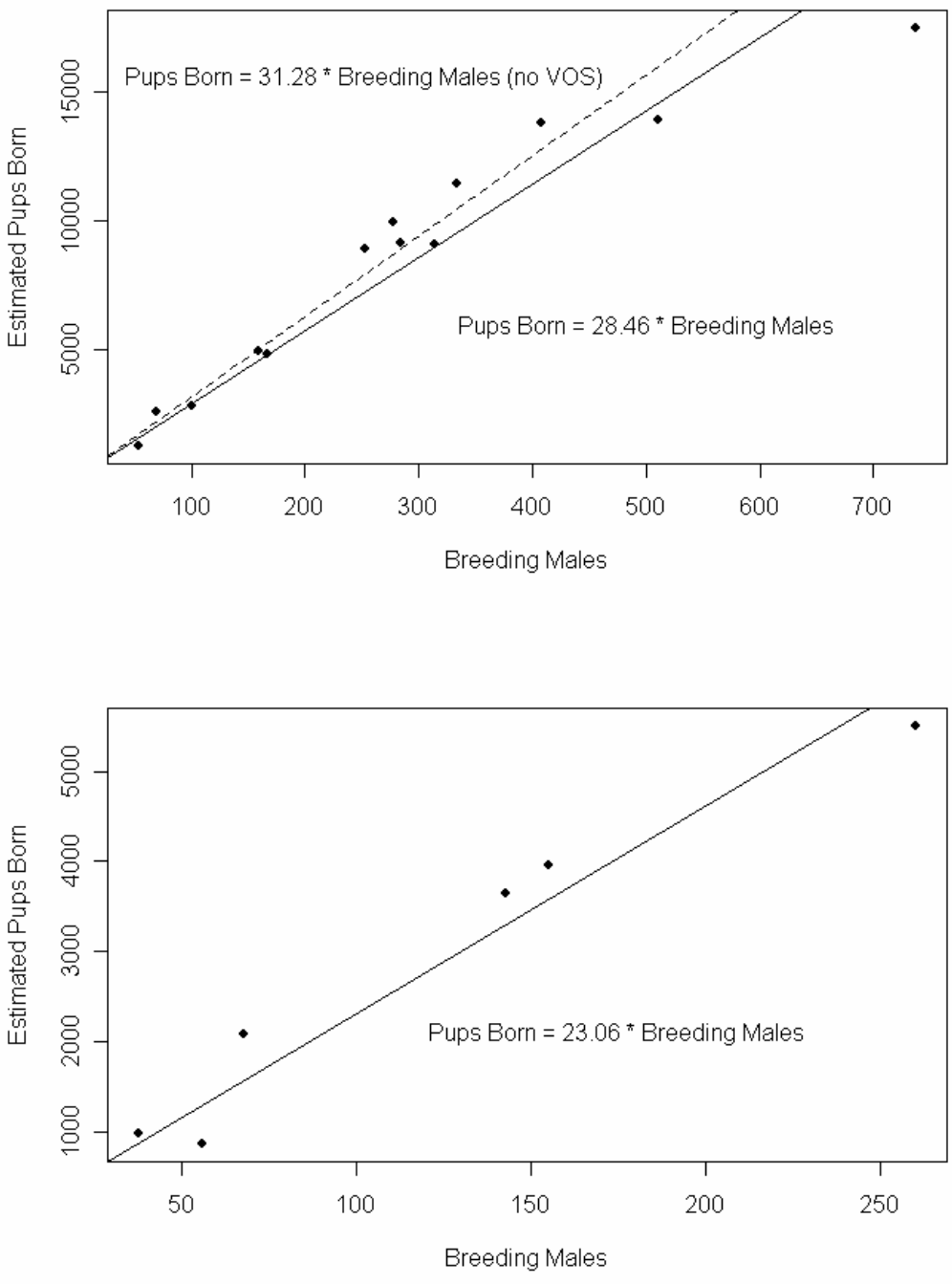
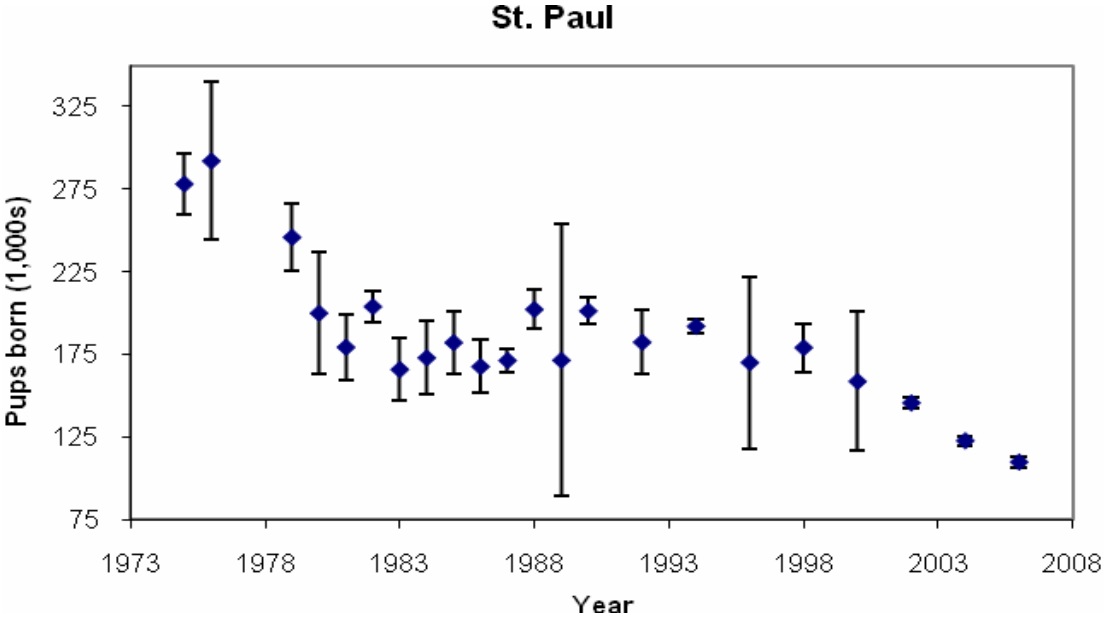


Figure 7.-- Pups born versus number of breeding males on St. Paul Island (top) and St. George Island (bottom), Alaska, 2006. Solid regression lines are shown for both locations; dotted line in top graph is regression excluding Vostochni (VOS) rookery at far right.



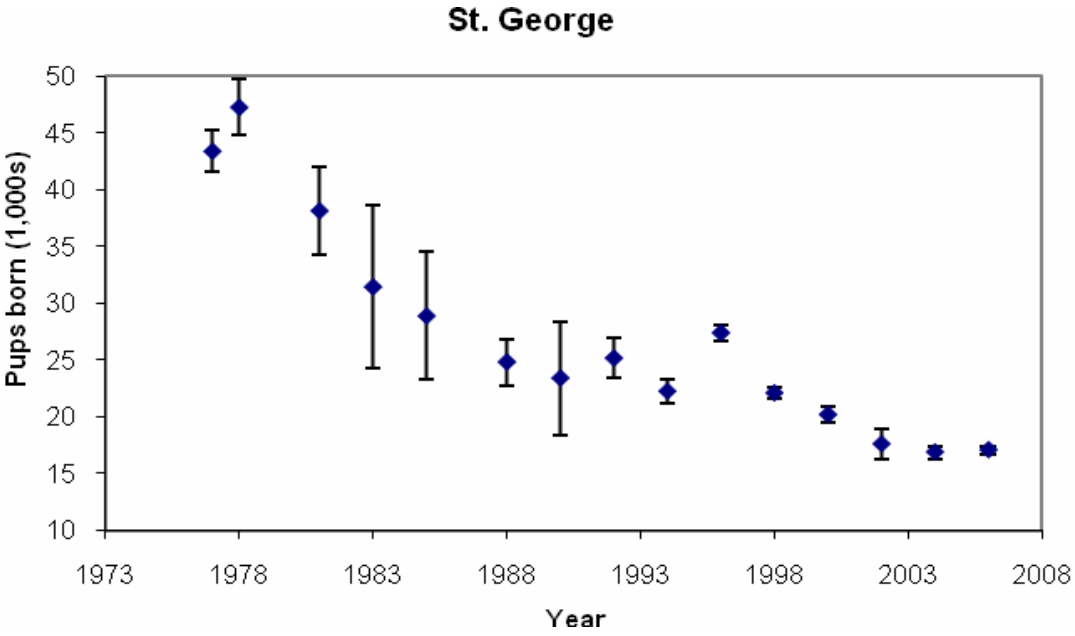


Figure 8.-- Estimated number of pups born (± 95% confidence intervals) on St. Paul and St. George Islands, Alaska, 1975 to 2006 .

Table 9.-- Details of the computation of stock size estimates of fur seals in U.S. rookeries in 2006. 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	Pribilof Islands	San Miguel and Bogoslof Islands[2]	Component
Average for 2002, 2004, 2006[1]	151,610	14,757	Pups
(Pups) × (0.5)	75,805	7,379	Yearlings
(Yearlings) × (0.8)	60,644	5,903	Age 2 year
(2-year old females) × (0.86)/2	26,077	2,538	Females age 3 year
(2-year old males) × (0.8)/2	24,258	2,361	Males age 3 year
(Total pups) / (0.6)	252,683	24,595	Females 3+ years
(3-year old males × (3.6)	87,329	8,500	Males 4+ years
Total	678,406	66,033	

[1] The 2002 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 2004, 2005, and 2006 estimates for San Miguel Island and the 2005 estimate for Bogoslof Island were used.

Since 2002, pup production remains below estimated pup production of 1919 on St. Paul Island and below the estimated pup production of 1916 on St. George Island, when the northern fur seal population was increasing at about 8% per year as it was recovering 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 6.06% (SE = 0.45%, $P < 0.01$) on St. Paul Island and 3.41% (SE = 0.60%, $P = 0.01$) on St. George Island to 2006. The overall rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 5.75% (SE = 0.34%, $P < 0.01$) from 1998 to 2006.

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 2006 (Table 9) was about 679,000 fur seals. The total stock size for the United States, which includes the Pribilof, Bogoslof, and San Miguel Islands, was approximately 745,000 fur seals.

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

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 2006. Tooth samples were collected from a total of 70 fur seals: 60 on St. Paul Island and 10 on St. George Island. Appendix Table B-8 summarizes the number of dead male and female fur seals from which teeth were collected from 1972 to 2006.

Table 10.-- Number of animals older than pups found dead on the Pribilof Islands from which teeth were collected during August 2006.

Rookery	Male	Female	Unknown	Total
St. Paul				
Lukanin	8	3	0	11
Ardiguen [1]	0	2	0	2
Vostochni [1,2]	4	10	0	14
Zapadni [1,2]	11	22	0	33
Total St. Paul	23	37	0	60
St. George				
South	0	6	0	6
East Cliffs	0	2	0	2
Staraya Artil [2]	2	0	0	2
Total St. George	2	8	0	10
Total Both Islands	25	45	0	70

[1] Females, teeth not collected. Vostochni (5), Ardiquen (1), Zapadni (2).
[2] Males, teeth not collected. Vostochni (1), Staraya Artil (1)

MASS, LENGTH, AND SEX RATIOS OF NORTHERN FUR SEAL PUPS ON THE PRIBILOF ISLANDS, 2006

by

Rodney G. Towell, Rolf R. Ream, James R. Thomason, Katherine A. Call, Tonya K. Zeppelin, 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 lengths, 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 2004. 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. Significant differences in mass and length by sex between islands were compared 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 2006. Mass of male and female pups was analyzed separately because the variance for males was greater than that for females on St. Paul Island in 2006. 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 ($P = 0.13$); therefore, the sexes were analyzed together. Pup lengths (Fig. 10, Table 13) were significantly different by sex ($P < 0.01$), rookery ($P < 0.01$), and sex:rookery interaction ($P = 0.03$) on St. Paul Island (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 analysis of female mass ($P = 0.97$, Table 16) but was for male mass ($P = 0.02$). The variance in pup lengths was not significantly different between males and females ($P = 0.20$). The analysis of variance for lengths (Fig. 10, Table 17) 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 no significant difference between islands for either male (St. Paul 9.58 kg, St. George 9.69 kg, $P = 0.402$) or female (St. Paul 8.29 kg, St. George 8.31 kg, $P = 0.825$) mass. Male (St. Paul 76.02 cm, St. George 77.24 cm) and female pups (St. Paul 72.83 cm, St. George 74.27 cm) were longer on St. George Island than St. Paul Island ($P < 0.01$).

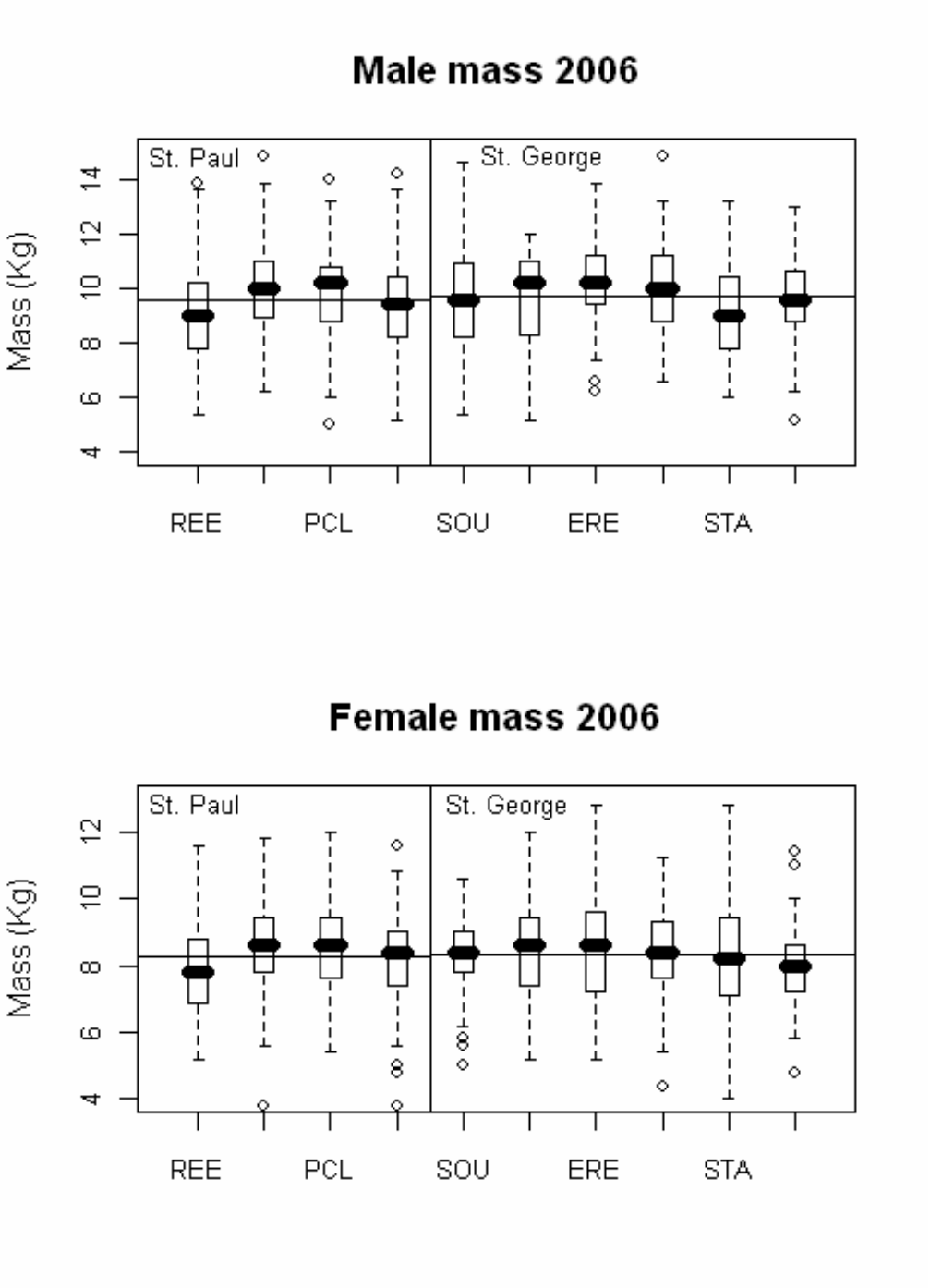


Figure 9.-- Boxplots of the median mass (dark line) and its 25% and 75% (lower and upper edge of the box) quantiles of northern fur seal pups on St. Paul and St. George Islands, Alaska, August 2006: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL), Tolstoi (TOL), South (SOU), North (NOR), East Reef (ERE), East Cliffs (ECL), Staraya Artil (STA), and St. George Zapadni (SGZ).

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, 22-23 August 2006.

Rookery		Females	Males	Combined
Reef	kg	7.88	9.13	8.53
23 August	SD	1.33	1.74	1.68
	n	115	126	241
Vostochni	kg	8.54	10.10	9.37
22 August	SD	1.40	1.52	1.66
	n	116	131	247
Pol. Cliffs	kg	8.48	9.78	9.17
22 August	SD	1.34	1.61	1.62
	n	125	143	268
Tolstoi	kg	8.20	9.31	8.87
23 August	SD	1.42	1.71	1.69
	n	90	137	227
Combined	kg	8.29	9.58	9.00
	SD	1.39	1.68	1.69
	n	446	537	983

Table 12.-- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. Paul Island, Alaska, August 2006.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	3	31.76	10.59	829	442	5.65	<0.01
Males							
Rookery	3	75.68	25.23	1,445	533	9.30	<0.01

*MSS = SS divided by df

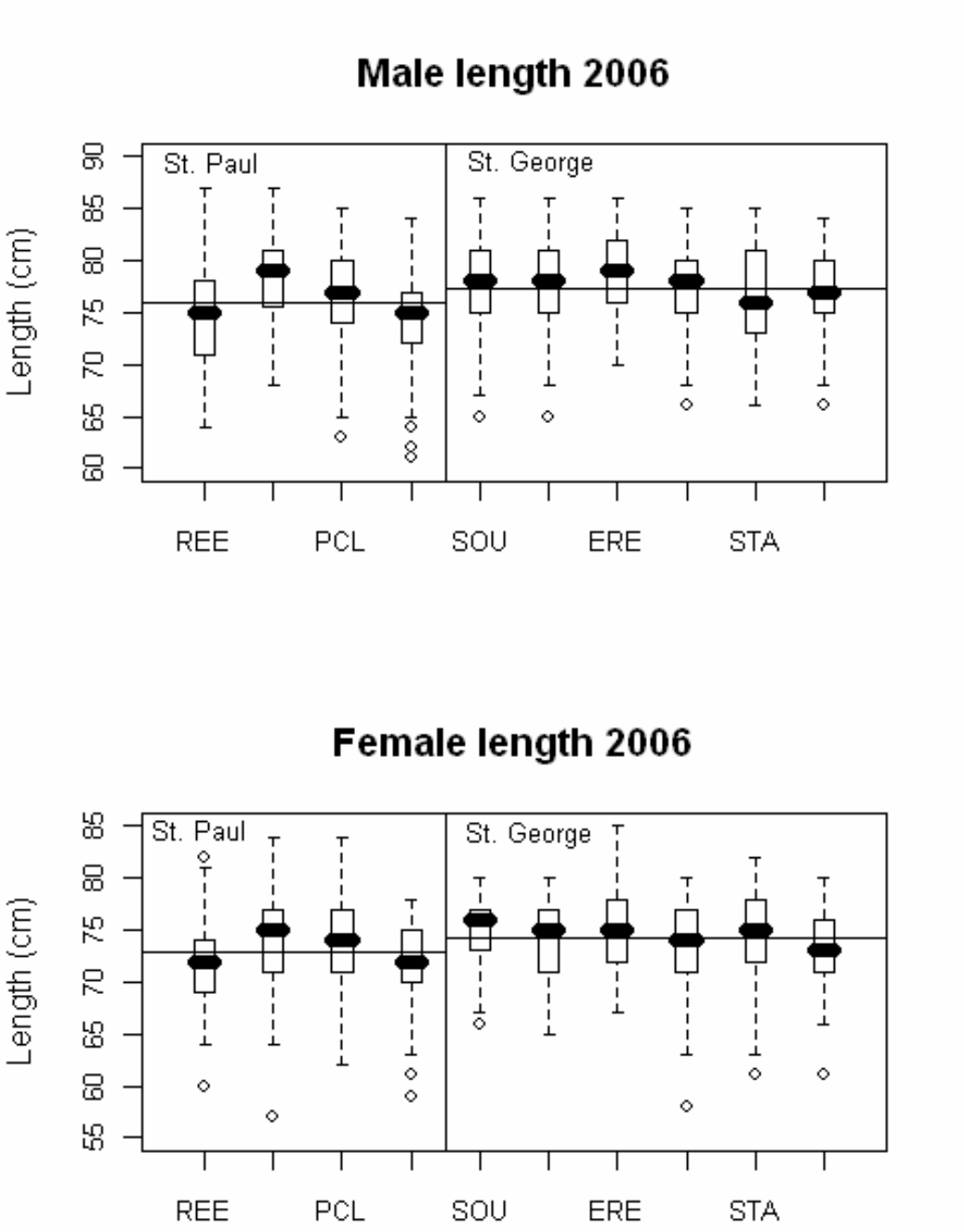


Figure 10.-- Boxplots of the median length (dark line) and its 25% and 75% (lower and upper edge of the box) quantiles of northern fur seals on St. Paul and St. George Islands, Alaska, August 2006: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL),Tolstoi (TOL), South (SOU), North (NOR), East Reef (ERE), East Cliffs (ECL), Staraya Artil (STA), and St. George Zapadni (SGZ).

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, 22-23 August 2006.

Rookery		Females	Males	Combined
Reef	cm	71.53	74.67	73.17
23 August	SD	3.92	4.43	4.47
	n	115	126	241
Vostochni	cm	73.93	78.47	76.34
22 August	SD	4.24	3.83	4.70
	n	116	131	247
Pol. Cliffs	cm	73.80	76.75	75.37
22 August	SD	4.09	4.02	4.30
	N	125	143	268
Tolstoi	cm	71.73	74.14	73.19
23 August	SD	3.67	4.37	4.27
	n	90	137	227
Combined	cm	72.83	76.02	74.57
	SD	4.20	4.49	4.64
	n	446	537	983

Table 14.-- Analyses of variance of length of male and female northern fur seal pups on St. Paul Island, Alaska, August 2006.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Sex	1	2,471	2,471	18,657	981	145.87	< 0.01
Rookery	3	1,990	663	16,667	978	39.15	< 0.01
Sex * Rookery	3	148	49	16,519	975	2.91	0.033

*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, 23-25 August 2006.

Rookery		Females	Males	Combined
South	kg	8.28	9.56	8.95
24 August	SD	1.12	1.95	1.72
	n	55	60	115
North	kg	8.32	9.58	8.89
23 August	SD	1.43	1.78	1.71
	n	58	48	106
East Reef	kg	8.44	10.36	9.33
25 August	SD	1.61	1.76	1.93
	n	56	49	105
East Cliffs	kg	8.35	9.99	9.23
25 August	SD	1.53	1.78	1.85
	n	47	54	101
Staraya Artil	kg	8.27	9.17	8.72
23 August	SD	1.68	1.89	1.84
	n	55	55	110
Zapadni	kg	8.15	9.57	9.11
24 August	SD	1.48	1.57	1.67
	n	33	70	103
Combined	kg	8.31	9.69	9.03
	SD	1.48	1.81	1.79
	n	304	336	640

Table 16.-- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2006.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	5	2.0	0.4	660	303	0.18	0.970
Males							
Rookery	5	44.2	8.8	1,053	330	2.77	0.018

*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, 23-25 August 2006.

Rookery		Females	Males	Combined
South	cm	74.89	77.77	76.39
24 August	SD	3.05	4.70	4.24
	n	55	60	115
North	cm	74.28	77.27	75.63
23 August	SD	3.91	4.43	4.40
	n	58	48	106
East Reef	cm	74.93	78.51	76.60
25 August	SD	4.18	3.97	4.44
	n	56	49	105
East Cliffs	cm	73.57	77.44	75.64
25 August	SD	4.47	4.03	4.64
	n	47	54	101
Staraya Artil	cm	74.35	76.31	75.33
23 August	SD	4.40	4.48	4.53
	n	55	55	110
Zapadni	cm	72.97	76.47	75.35
24 August	SD	3.98	4.14	4.39
	n	33	70	103
Combined	cm	74.27	77.24	75.83
	SD	4.03	4.34	4.45
	n	304	336	640

Table 18.-- Analyses of variance of length of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2006.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Sex	1	1,412	1,412	11,232	638	81.38	<0.01
Rookery	5	250	50	10,982	633	2.88	0.01

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

Sex Ratios

The proportions of pups that were females differs significantly from 50% on one of the four sample rookeries on St. Paul Island in 2006 (Table 19)**.** One of six sample rookeries on St. George Island had a fraction of females significantly different than 50%. The fraction of total females was significantly different than 50% (45.4% , P = 0.004%) on St. Paul Island and for both islands combined (46.2%, P = 0.002). The observed proportions were not significantly different on St. George Island (47.5%, P = 0. 22).

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 on St. George Island were significantly longer than those on St. Paul Island. The proportion of females was significantly different than 50% on St. Paul Island (45.4%, Table 20) but not on St. George Island (47.5%, Table 20) in 2006. 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. The large difference in length measurements between islands may be attributed to measurement technique. The protocol for taking length measurements is subjective and the process should be more closely examined.

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 2004. The fraction of females is significantly less than 50% (P = 0.05) for bold items.

Rookery	Females	Total	Fraction
St. Paul			
Reef	115	241	0.477
Vostochni	116	247	0.470
Polovina Cliffs	125	268	0.467
Tolstoi	**90**	**227**	**0.396**
Total	**446**	**983**	**0.454**
St. George			
South	55	115	0.478
North	58	106	0.547
East Reef	56	105	0.533
East Cliffs	47	101	0.465
Staraya Artil	55	110	0.500
Zapadni	**33**	**103**	**0.320**
Total	304	640	0.475

Table 20.-- Numbers of female pups, total number of pups, and fraction (that are female) of live northern fur seals pups captured during weighing operations on St. Paul and St. George Islands, Alaska, for the years 1992-2006. Bold numbers indicate the fraction of females significantly different than 50%.

	St. Paul			St. George		
Year	Females	Total	Fraction	Females	Total	Fraction
1992	**494**	**1118**	**0.442**	**291**	**634**	**0.459**
1994	926	1926	0.481	430	886	0.485
1995	**939**	**2040**	**0.460**	**294**	**653**	**0.450**
1996	**520**	**1149**	**0.453**	**331**	**749**	**0.442**
1997	495	1020	0.485	311	639	0.487
1998	**506**	**1100**	**0.460**	**344**	**745**	**0.462**
1999	**462**	**1081**	**0.427**	--	--	--
2000	543	1079	0.503	**292**	**640**	**0.456**
2001	**510**	**1095**	**0.466**	--	--	--
2002	**424**	**1016**	**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

THE STATUS OF THE NORTHERN FUR SEAL POPULATION AT SAN MIGUEL ISLAND, CALIFORNIA, 2006 AND 2007

by

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

Demographic studies of northern fur seal population at San Miguel Island, California (34° 01'N, 120° 26'W), have been conducted since the discovery of the colony in 1968. The population originated from the Pribilof and Russian Islands populations during the late 1950s or early 1960s (DeLong 1982). The marine environment around San Miguel 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. It is this characteristic of the environment that makes San Miguel Island habitable for this species, which is adapted to a colder climate than that found along most of the southern California coast (DeLong 1982).

The northern fur seal population has thrived at San Miguel Island except for two severe declines during 1983 and 1998 that were associated with El Niño events (DeLong and Antonelis 1991, Melin and DeLong 2000). El Niño events cause changes in marine communities by altering the sea level height, sea surface temperature, thermocline and nutricline depth, current flow patterns, and upwelling strength of marine ecosystems (Norton et al. 1985, Arntz et al. 1991). In response to these changes in oceanographic conditions, prey species of fur seals move farther north and deeper in the water column (Arntz et al. 1991) and thereby become difficult for fur seals to obtain. Consequently, fur seals at San Miguel Island are in poor physical condition during El Niño 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 El Niño events occur periodically along the California coast and impact the population growth of fur seals at San Miguel Island, they play an influential role in the dynamics of this population (DeLong and Antonelis 1991, Melin and DeLong 1994, Melin et al. 1996).

El Niño events are short-term events that affect a population on the order of 1 to 2 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). These shifts are often referred to as 'warm' or 'cool' phases of an ecosystem and occur about every 20 years, affecting several generations of fur seals. The California Current shifted into a 'warm' phase in 1976, where it remained until 1999, when it transitioned into a 'cool' phase (Hayward et al. 1999). Since then regional and local processes in the system have had a greater impact on biological productivity than large basin-scale processes, but have remained consistent with a 'cool' phase (Goerick et al. 2007). In 2006 and 2007, the basin-scale indicators were neutral and no single state (e.g., El Niño or La Niña) could be defined for the current (Goerick et al. 2007). Based on fishery landing data (see California Department of Fish and Game 2007), prey species of northern fur seals were abundant in 2006. If available to fur seals, the high abundance of prey should have produced high production and survival of pups. However, hookworm disease in the population dampened the positive effects of the favorable foraging environment for northern fur seals at San Miguel Island. Here, we present the results of the 2006 and 2007 population monitoring studies at San Miguel Island and discuss the factors influencing the population trends during the past 10 years.

METHODS

Census

Fur seal censuses were conducted at two rookeries at San Miguel Island: Adams Cove on the mainland and Castle Rock located offshore. The Castle Rock rookery was only visited once each July, to conduct a census of live pups. Daily censuses were conducted at the Adams Cove rookery between 1 June and 27 July 2006 and 27 May and 29 July 2007. 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.

Counts of live and dead pups were used as an index of the number of pups born at the Castle Rock and Adams Cove 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. Live pup censuses were conducted during late July. Dates of the censuses were determined by the frequency of births observed during daily surveys in the Adams Cove rookery. When no births were documented over 3 days, pupping was considered complete and the live pup census was conducted. In Adams Cove, the live pup census was conducted on 29 July 2006 and 26 July 2007. The live pup census was conducted on 25 July 2006 and 2 August 2007 at Castle Rock. In Adams Cove, 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 compared counts after each section to ensure that they were counting the same group of animals. At Adams Cove, the substrate is sandy and there are no markers to delineate counting areas. Pups are often moving between territories or are

located outside a territory boundary and large errors in counts can often be attributed to differences in the areas that the observers counted. The mean of the observers' counts was used as an estimate for each group of pups. The mean number of pups for the colony was the sum of the group estimates.

Fur seal pup mortality surveys were conducted between June and November in Adams Cove in 2006 and 2007. 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 the season. Because pups died and disappeared between surveys, the observed count underestimated 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 Adams Cove based on a daily disappearance rate of dead pups (1.33 pups per day). Thus, the total births and pup mortality reported will not agree with those in previous reports (Melin and DeLong 2001, Melin et al. 2002, Melin et al. 2005). Observed pup mortality at Castle Rock was obtained from one survey conducted at the time of the live pup count (25 July 2006, 2 August 2007). Pup mortality at Castle Rock was a minimum estimate of pup mortality because only one survey was conducted and carcasses that decomposed or disappeared were not accounted for.

Tagging and Pup Condition

Between 100 and 300 northern fur seal pups have been flipper-tagged in Adams Cove annually since 1975 with Dalton Jumbo Rototags. At the time of tagging, pups were 2 to 3 months old. Pups were tagged on each foreflipper, weighed, sexed, measured, and released. We used pup weight at the time of tagging as an index of pup condition. To account for differences in average pup weights due to different weighing dates among years, we developed a predictive

model that used an average annual daily growth rate to predict pup weights on 1 October for each year between 1975 and 2007. The model was sex-specific and accounted for El Niño effects. The El Niño years were defined as 1976, 1983, 1992, 1997, 1998, and 2002.

Between June and August in each year, up to 13 surveys of tagged breeding animals were conducted from a mobile blind in Adams Cove. The blind was moved through sections of the rookery at least once a week and tag numbers and reproductive status were recorded for each tagged individual observed.

RESULTS

Census

The maximum number of territorial bulls counted in Adams Cove was 115 in 2006 and 147 in 2007, representing a 27.8% increase between the two years (Table 21). The maximum number of territorial bulls fluctuated between 1997 and 2007, with annual increases ranging from 2.2% to 32.8% and declines between 1.7% and 45.5%. The decline between 1997 and 1998 was the greatest (45.5%) observed; the highest increase occurred between 2001 and 2002 (32.8%). Even with increases in 5 years since 1997, the number of territorial bulls in 2007 remained 41.9% below the number observed in 1997, when the population was at its highest recorded level.

The first live pup was observed on 8 June in 2006 and 11 June in 2007, similar to previous years (1997 to 2005: n = 9, mean = 9 June, SD = 3.3 days). The median pupping dates were 3 July 2006 and 30 June 2007. The mean median pupping date between 1997 and 2005 was 2 July (SD = 2.3 days).

Table 21.--Maximum number of territorial northern fur seal bulls at San Miguel Island, California, 1997-2007.

Year	Maximum number of territorial bulls	Annual percent change in maximum number of territorial bulls	Percent change from maximum number of territorial bulls in 1997
1997	253		
1998	138	-45.5	-45.5
1999	141	2.2	-44.3
2000	108	-23.4	-57.3
2001	119	10.2	-53.0
2002	158	32.8	-37.5
2003	184	16.5	-27.3
2004	127	-31.0	-49.8
2005	117	-7.9	-53.8
2006	115	-1.7	-54.6
2007	147	27.8	-41.9

After 2 years of high pup production (2005 and 2006), the mean number of live pups counted in Adams Cove decreased slightly (1.6%) between 2006 and 2007 (Table 22). Early pup mortality (birth to 1 month old) has fluctuated over the past 10 years ranging from 5.8% (in 2001) to 43.1% (in 2007) (Table 22). Total mortality (birth to 3 months old) ranged between 5.8% (in 2001) and 64.6% (in 2007) (Table 22).

In 2006, the mean number of live pups counted at Castle Rock was 634. In 2007, a mean of 758 pups was counted (Table 22). An increase in pup births (15.7%) occurred at Castle Rock between 2006 and 2007. Early pup mortality was 21 pups in 2006 (3.2%); early pup mortality at Castle Rock was not estimated in 2007.

Total births at Adams Cove and Castle Rock remained depressed from the historical highs in 1997. The 2007 total births were 22.9% below 1997 at Adams Cove and 24.8% below 1997 at Castle Rock (Table 22). Total pup mortality reached its highest level in the past 10 years in 2007 (64.6%) and represented the fourth consecutive year of pup mortality near 50% at Adams Cove.

Tagging and Pup Condition

Adult females and males tagged as pups were resighted in 2006 (females = 100; males = 89) and 2007 (females = 186; males = 143) in Adams Cove (Fig. 11). The females were between 3 and 18 years old. Females sighted with pups (27 in 2006; 73 in 2007) ranged between 4 and 14 years old. The males ranged between 2 and 12 years of age. Territorial males (19 in 2006; 82 in 2007) were between 5 and 12 years old. Few sightings of females (8%) and no males older than

Table 22.--Summary of pup counts of northern fur seals at Adams Cove and Castle Rock during 1997-2007. Mortality rates are based on observed mortality, which is likely underestimated. Standard error about the mean is in parentheses. A dash (-) preceding the percent change indicates a decline.

Colony/Year	Mean number of live pups	Early season pup mortality[1]	Total births	Annual percent change in total births	Percent change from births in 1997	Early season pup mortality rate	Late season pup mortality[2]	Total pup mortality	Season pup mortality rate[3]
Adams Cove									
1997	1765 (8.5)	448	2213			20.2	717	1165	52.6
1998	308 (2.1)	154	462	-79.1	-79.1	33.3	142	296	64.1
1999	604 (3.4)	225	829	79.4	-62.5	27.1	32	257	31.0
2000	962 (5.7)	145	1107	33.5	-50.0	13.1	41	186	16.8
2001	1226 (2.1)	76	1302	17.6	-41.2	5.8	0	76	5.8
2002	1126 (3.5)	102	1228	-5.7	-44.5	8.3	109	211	17.2
2003	1083 (2.8)	302	1385	12.8	-37.4	21.8	82	384	27.7
2004	810 (3.5)	606	1416	2.2	-36.0	42.8	219	825	58.3
2005	1133 (14.1)	504	1637	15.6	-26.0	30.8	521	1025	62.6
2006	1129 (36.8)	606	1735	6.0	-21.6	34.9	244	850	49.0
2007	972 (4.2)	735	1707	-1.6	-22.9	43.1	368	1103	64.6

Table 22.--Continued.

Colony/Year	Mean number of live pups	Early season pup mortality[1]	Total births	Annual percent change in total births	Percent change from births in 1997	Early season pup mortality rate	Late season pup mortality[2]	Total pup mortality	Season pup mortality rate[3]
Castle Rock									
1997	940 (5.4)	68	1008			6.8	---	---	---
1998	194 (1.2)	39	233	-76.9	-76.9	16.7	---	---	---
1999	300 (1.8)	15	315	35.2	-68.8	4.8	---	---	---
2000	562 (4.2)	17	579	83.8	-42.6	2.9	---	---	---
2001	708 (4.5)	57	765	32.1	-24.1	7.5	---	---	---
2002	724 (2.0)	28	752	-1.7	-25.4	3.7	---	---	---
2003	---	---	---	---	---	---	---	---	---
2004	804 (4.2)	28	832	10.6	-17.5	3.4	---	---	---
2005	782 (3.5)	24	806	-3.1	-20.0	3.0	---	---	---
2006	634 (36.8)	21	655	-18.7	-35.0	3.2	---	---	---
2007	758 (9.1)	---	758	15.7	-24.8	---	---	---	---

[1]Estimated number of dead pups at the time of the live pup census.
[2]Estimated number of dead pups after the live pup census.
[3]Rate calculated based on estimated total number of dead pups in early and late season surveys.

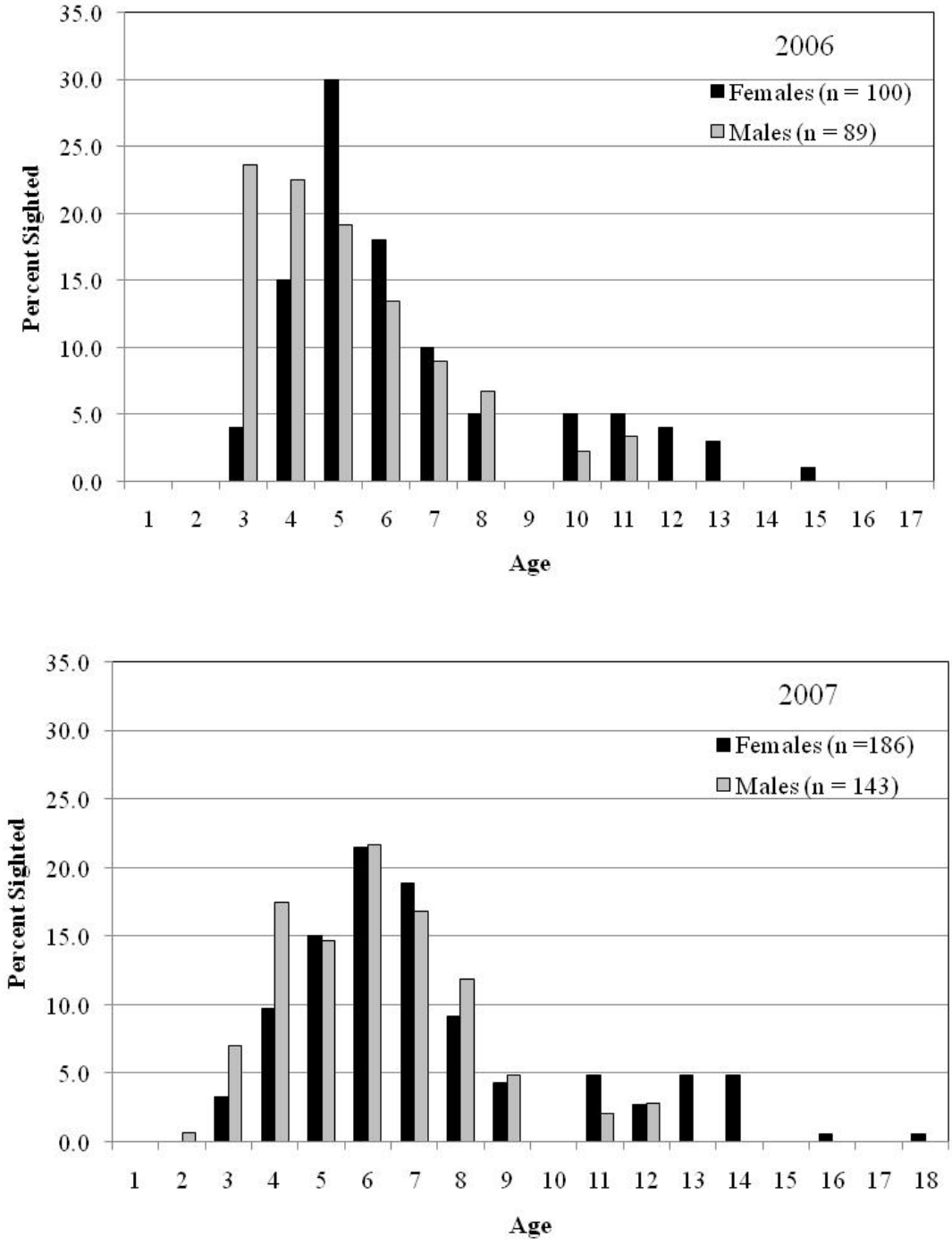


Figure 11.--Distribution of sightings of northern fur seals, tagged as 3 month old pups between 1989 and 2005, in 2006 and 2007.

12 years were recorded. No tagged animals from the 1997 cohort were observed (age 9 in 2006; age 10 in 2007) (Fig. 11), indicating near total mortality of this cohort due to El Niño conditions in 1997.

We tagged and weighed 3-month-old pups in 2006 (n = 104) and 2007 (n = 146) to continue the survival and condition studies. In 2006, estimated mean (± SE) pup weights of female (8.9 kg ± 0.25) and male (10.1 kg ± 0.26) pups were lower than the long-term averages and fell within El Niño averages. In 2007, the estimated mean weights (females, 9.6 kg ± 0.21; males, 11.8 kg ± 0.25) were within the long-term average (Fig. 12).

DISCUSSION

Hookworm disease and the residual effects of the 1997-98 El Niño, such as low survival of the 1997 cohort and adult mortality, are suppressing fur seal population growth even though the California Current system is in a cool phase of the Pacific Decadal Oscillation, which should benefit northern fur seals at San Miguel Island. The number of territorial bulls in Adams Cove and pup production at both rookeries remained depressed from the recorded high in 1997 even though both indices showed years of increase within the 10-year period. Since 1999 when the system shifted into a cooler pattern, the pup production has generally increased but pup mortality has also increased during this period. In 2006, pup mortality was high (49%) and pup weights indicated that pups were in poor condition with mean weights similar to weights of pups reared during El Niño conditions. This was followed by the highest recorded level of pup mortality in the past 10 years in 2007 (64.6%). Yet, pups that survived to 3 months of age appeared to be in good condition in 2007, with pup weights similar to the long-term average.

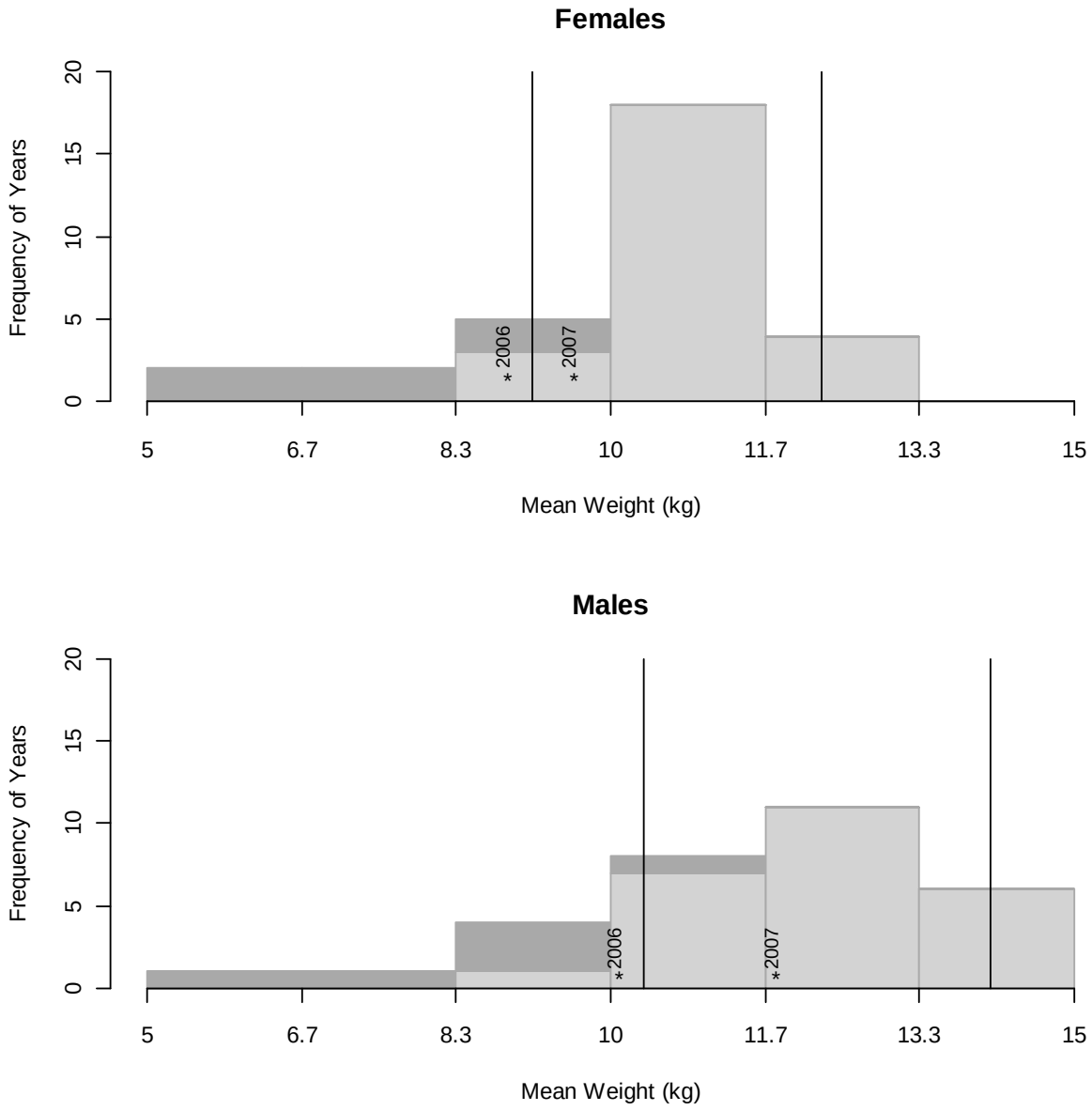


Figure 12.--Distribution of predicted annual mean weights of 4-month-old female and male northern fur seal pups at Adams Cove, San Miguel Island, California, on October 1 between 1975 and 2007. Dark shading represents El Niño years and light shading represents non-El Niño years. Vertical lines indicate 95% confidence intervals for the sample of all years excluding El Niño years.

The annual variability in the indices reflects the dynamics of a population influenced by two different limiting factors.

The 1997-98 El Niño resulted in the near total mortality of the 1997 cohort and low pup production in 1998. This limiting factor has resulted in a bimodal age structure with most animals younger than age 10 years. However, interpretation of sighting data relative to age-specific mortality is complicated by high tag loss for northern fur seals. The low percentage of older animals represented in the tagged animal population may represent high cumulative tag loss for older animals. Double-tagging studies of northern fur seals were conducted in the Pribilof Islands, Alaska, to estimate tag loss and 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 than was used in our study, tag loss has been identified (but not quantified) as a problem with the tags that were used at San Miguel Island. Thus, adult mortality estimates may be positively biased due to 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 1997-98 El Niño suggests that adult mortality did occur in 1997 and 1998 (Melin and DeLong 2000, Melin et al. 2005). In addition to adult mortality, no tagged animals from the 1997 and few of the 1998 cohort have been observed, suggesting low pup and yearling survival for the these cohorts. Thus, the 1997 and 1998 cohorts did not have significant recruitment into the population, which is currently affecting the age structure of the reproductive population and its recovery to the 1997 production level.

While El Niño events generally represent an external, periodic, and density-independent limiting factor to the population, hookworm disease is generally a density-dependent regulator. Northern fur seal pup mortality associated with hookworm disease occurs within the first 6 weeks of life but residual effects may include a weakened immune system and retarded growth and weight gain once the infection has cleared. Hookworm disease was first described in San Miguel northern fur seal population in 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 the high mortality of pups in 2006 and 2007 is due to a high incidence of hookworm disease in the population. The poor condition of surviving pups in 2006 may also reflect secondary effect of a weight deficit due to a 6-week battle with the disease. Retarded growth of pups has not been observed in other years when hookworm disease was present in the population, so it is possible an unidentified environmental or disease factor also contributed to poor pup condition in 2006. We anticipate that the high mortality will continue until the population mounts an immune response to the parasite, perhaps several generations into the future. Thus, in addition to El Niño events that occur periodically along the California coast, disease appears to play an influential role in the dynamics of the northern fur seal population at San Miguel Island.

ACKNOWLEDGMENTS

The fur seal research team extends its special thanks to the communities of St. George Island and St. Paul Island who continuously support our research efforts, and to the Channel Islands National Park Service for logistical support of field operations on San Miguel Island. We are especially appreciative of the participation of youths from the stewardship program which have become integral to our field work on the Pribilof Islands. The bulk of our work on the Pribilof and Channel Islands would not be possible without the assistance of numerous volunteers and employees from affiliated universities and institutions (Appendix C). The quality of this report was greatly improved by Gary Duker and James Lee, technical editors at the Alaska Fisheries Science Center.

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APPENDIX A

Glossary

The terms defined below are used in the chapters of this report on fur seal research and management on the Pribilof Islands, Bogoslof Island, San Miguel Island, and Castle Rock.

Bachelor	Young male seals aged 2-5 years

Classification of adult male fur seals

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 counts, their pups are used as a basis for putting the adult male into Class 3 rather than Class 2.

Class 4 (territorial with females)	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.

Page

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, 10-18 July, 2006. 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	23	11													34
3	60	40													100
5	126	7													133
Kitovi[b]															
2	(12)8	5	15	28	17										85
3	(17)16	19	39	37	39										167
5	(27)4	0	8	13	182										234
Reef															
2	13	26	27	10	22	21	5	27	22	11	3				187
3	48	81	63	46	67	70	1	66	37	28	4				511
5	8	27	40	47	31	13	15	31	34	72	0				460
Gorbatch															
2	25	14	19	13	20	18									109
3	71	48	61	12	37	55									284
5	335	20	45	64	30	57									551
Ardiguin															
2	22														22
3	54														54
5	14														14
Morjovi[c]															
2	(12)15	6	18	5	15	10									81
3	(40)40	34	63	34	67	36									314
5	(16)394	28	19	8	12	155									632
Vostochni															
2	8	3	10	8	13	18	7	12	5	5	8	16	24	5	142
3	48	28	38	55	43	76	42	45	26	16	23	51	161	85	737
5	12	24	3	71	139	36	7	11	36	12	4	121	92	220	788
Little Polovina															
2	0														0
3	2														2
5	269														269
Polovina															
2	20	6													26
3	43	26													69
5	188	60													248
Polovina Cliffs															
2	11	10	6	22	15	19	26								109
3	43	26	19	49	36	53	52								278
5	38	4	9	3	6	11	16								87
Tolstoi															
2	16	20	11	13	25	29	42	31							187
3	30	33	34	51	46	51	50	38							333
5	2	3	5	7	6	21	22	252							318
Zapadni Reef															
2	42	5													47
3	122	37													159
5	51	204													255
Little Zapadni															
2	8	20	23	26	27	20									124
3	19	29	50	54	42	59									253
5	21	10	5	19	17	226									298
Zapadni[d]															
2	9	18	23	19	20	24	30	8							151
3	31	49	50	62	54	68	61	33							408
5	(62)13	7	4	17	23	63	59	444							692

[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 in Kitovi Ampitheater.
[c] Numbers in parenthesis are the adult males counted on the second point south of Sea Lion Neck.
[d] Numbers in parenthesis are the adult males counted on Zapadni Point Reef.

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,9-15 July, 2007. 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	30	15													45
3	56	35													91
5	153	15													168
Kitovi															
2	15	18	13	10	28										84
3	26	26	23	39	36										150
5	81	24	15	15	112										247
Reef															
2	14	41	39	18	15	29	3	19	18	13	2				211
3	45	60	48	41	53	53	0	61	35	27	5				428
5	7	15	34	59	85	11	8	33	8	48	41				349
Gorbatch															
2	31	18	32	11	13	23									128
3	58	34	52	12	34	42									232
5	178	29	40	34	13	18									312
Ardiguin															
2	17														17
3	48														48
5	6														6
Morjovi[b]															
2	(19) 21	28	24	12	24	10									138
3	(41) 42	39	38	26	72	47									305
5	(73) 173	19	46	19	55	78									463
Vostochni															
2	9	6	11	13	8	39	12	8	11	7	10	12	44	9	199
3	49	20	27	38	37	62	29	36	30	18	26	65	166	83	686
5	22	7	9	44	55	23	15	20	29	9	26	63	78	130	530
Little Polovina															
2	0														0
3	2														2
5	157														157
Polovina															
2	10	17													27
3	52	43													95
5	140	60													200
Polovina Cliffs															
2	21	5	10	6	16	15	13								86
3	37	33	29	57	50	72	72								350
5	45	19	10	8	13	25	31								151
Tolstoi															
2	11	11	6	9	18	26	25	40							146
3	38	28	39	60	48	70	55	65							403
5	5	3	13	15	15	36	15	223							325
Zapadni Reef															
2	48	7													55
3	110	42													152
5	104	85													189
Little Zapadni															
2	6	13	23	27	24	24									117
3	19	32	50	46	45	68									260
5	21	18	20	11	14	116									200
Zapadni [c]															
2	14	20	22	31	24	31	28	13							183
3	(1) 25	49	51	42	44	67	55	32							366
5	(73) 10	14	15	16	17	17	67	308							537

[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, 2006.

	Section														
Rookery	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Lukanin		186	125													311
Kitovi[1]	36	38	48	118	115	119										474
Reef[2]		148	256	194	144	206	209		207	114	85	5				1,568
Gorbatch		248	169	217	42	125	192									993
Ardiguen		173														173
Morjovi[1]	179	121	105	182	104	195	97									983
Vostochni		112	72	100	144	112	214	110	134	82	35	55	144	432	229	1,975
Polovina		160	100													260
Little Polovina																
Polovina Cliffs		177	107	75	192	146	210	211								1,118
Tolstoi		117	93	168	201	177	201	233	190							1,380
Zapadni Reef		407	118													525
Little Zapadni		80	125	205	391	174	255									1,230
Zapadni		128	197	217	244	218	270	270	58							1,602
Total																12,592

[1]Section 0 corresponds to 2nd Point South on Morjovi and Kitovi Amphitheater.
[2] Section 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, 1979-2007. A dash indicates no data.

	St. Paul						St. George					
Year	Harem Bulls	Idle Bulls	Pups Born	SD	Rookeries Sampled (n)	Dead Pups	Harem Bulls	Idle Bulls	Pups Born	SD	Rookeries Sampled	Dead Pups
1979	6,242	4,457	245,932	9,464	14	6,444	1,716	1,942	--	--	--	2,191
1980	5,490	4,248	203,825	11,672	4	7,859	1,563	1,795	--	--	--	2,385
1981	5,120	4,003	179,444	5,876	4	6,798	1,472	1,646	38,152	1,581	6	2,025
1982	5,767	4,009	203,581	3,482	4	7,301	1,410	1,319	--	--	--	1,600
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	24,820	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	1,029	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	4,790	899	1,265	17,593	527	6	533
2003	3,652	7,572	--	--	--	--	716	1,158	--	--	--	--
2004	3,286	5,027	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	1520	13	4,994[2]	720	650	17,072	143	6	712[2]
2007	3,568	5,270					744	559				

[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.

Table B-5.-- Number of dead northern fur seal pups counted by section on the sampled rookeries of St. Paul Island, Alaska, 2006.

		Section															
Rookery	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	necropsies	Total
Lukanin	8/17	82	68														150
Ardiguen	8/17	51															51
Vostochni	8/19	35	12	34	49	34	75	35	38	37	10	31	54	150	69	37	700
Zapadni	8/18	28	64	127	95	125	127	111	25							1	703

Table B-6.-- Number of northern fur seal pups sheared on each rookery of St. George Island, Alaska, 2006.

Rookery	Section 1	2	3	4	5	Total
South	116	128	156			400
North	93	130	187	90	51	551
East Reef	93					93
East Cliffs	247	142				389
Staraya Artil	78	35				113
Zapadni[1]	49	197[1]				246
Total						1,792

[1] Pups to be sheared in section 3 were combined with section 2 for Zapadni.

Table B-7.-- Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 2006.

Rookery	Date	Section					Total
		1	2	3	4	5	
South	8/22	61	83	44			188
East Cliffs	8/21	86	42				128
Staraya Artil	8/23	37	3				40

Table B-8.-- Number of dead northern fur seals counted that were older than pup, Pribilof Islands, Alaska, 1972-2006. Teeth (usually canines) were collected from most of these seals. A dash indicates no data.

	St. Paul Island		St. George Island		Total	
Year	Males	Females	Males	Females	Males	Females
1972	46	111	22	30	68	141
1973	61	65	7	30	68	95
1974	33	30	4	15	37	45
1975	92	99	-	-	92	99
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

[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 mode 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 Island and 34 dead adults were counted on St. George Island.
[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.

APPENDIX C

Scientific staff engaged in northern fur seal
field research in 2006-2007

National Marine Mammal Laboratory
John L. Bengtson, Director
Tom Gelatt, Leader, Alaska Ecosystem Program
Rolf R. Ream, Northern Fur Seal Task

Employees	Affiliation
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Erin Siek	NMML
Jen Sloth	NMML
Jeremy Sterling	NMML
Louise Taylor	NMML
Jim Thomason	NMML
Gretchen Thuesen	NMML
Rod Towell	NMML
Tonya Zeppelin	NMML
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Research Associates and Cooperators	
Aquilina Lestenkof	TGSP
Michael Willliams	NMFSA
Karin Holser	PISP

Masashi Kiyota	NRIFSF
John Wayne Melovidov	PISP
John R. Melovidov	PISP
Mark Rukovishnikoff	PISP
William Shane	PISP
Terry Spraker	WPI
Candace Stepetin	PISP
Kent Sundseth	NMFS/USFWS
Andrew Zacharof	PISP
Phillip Zavadil	TGSP

Affiliation Code

NMFS - National Marine Fisheries Service

NMFSA - National Marine Fisheries Service Regional Office, Anchorage, Alaska

NMML - National Marine Mammal Laboratory

NRIFSF - National Research Institute of Far Seas Fisheries, Shimizu, Japan

PISP - Pribilof Island Stewardship Program

TGSP - Tribal Government of St. Paul, St. Paul Island, Alaska

UCD - University of California, Davis

USFWS - U.S. Fish and Wildlife Service, Alaska Maritime Wildlife Refuge, Homer, Alaska

WPI - Wildlife Pathology International

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