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Fur Seal Investigations, 2012

by
J. W. Testa (editor)

U.S. DEPARTMENT OF COMMERCE
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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 2012, and presents an introduction to ongoing demographics research based on tagged animals on the Pribilof Islands that began in 2007.

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, 3,336 territorial male seals with females were counted in 2012, which represented a 12.9% annual decline from 2011. On St. George Island the total was 852, which represented a 1.2% increase. The subadult male harvest was 383 and 63 on St. Paul and St. George, respectively. The estimate for the total number of pups born in 2012 was 96,828 (SE = 1,260) on St. Paul Island (not including Sea Lion Rock) and 16,184 (SE = 155) on St. George Island. Pup mortality from birth to late August was 3.7% on St. Paul Island and 3.1% on St. George Island. The number of pups born on St. Paul Island in 2012 was not significantly changed from the previous estimate in 2010 ($P = 0.9$), while at St. George the number of pups born was 9.9% lower ($P < 0.01$).

From 2007 to 2012, 632 adult and sub-adult female fur seals were flipper-tagged in fall at Polovina Cliffs rookery, St. Paul Island. From 2009 to 2012, 462 were tagged at South Rookery on St. George Island. Seven hundred and thirteen female pups were tagged at Polovina Cliffs from 2008 to 2012, 1,921 were tagged from 2010 to 2012 at Zapadni Reef rookery on St. Paul; 6,605 pups of both sexes were tagged from 2009 to 2012 at South Rookery, St. George Island.

Resightings were made in July-August each year after the initial tag deployments at Polovina Cliffs and South rookeries, and in Sept.-Oct. 2012 for juveniles at South. Pupping rates at both rookeries were high (0.86-0.91 at Polovina Cliffs and 0.79-0.88 at South Rookery), consistent with recent and historic estimates of pregnancy rates in northern fur seals. Tag loss varied by tag manufacturer (Dalton Superflexitag loss > Monel metal tags > Allflex sheep tags), tag age (1^{st} year > later years) age class (pups > adults), and rookery (South > Polovina Cliffs). Estimated rates of losing both tags were low for adults (0-6%), but were ~15% for Dalton tags after 2-3 years in the first cohort of pups from South rookery. Preliminary estimates of adult survival were lower than historic estimates (0.71-0.86 at Polovina Cliffs and 0.76-0.84 at South vs. ~ 0.88 historically), without consideration of permanent emigration and tag loss, which cause negative bias. At San Miguel Island in 2012 the index count of territorial bulls was 178. On the two rookeries there, Adams Cove and Castle Rock, the estimated numbers of live pups were 1,692 (SE = 22.5) and 1,163 (SE = 2). Total pup production in 2012 was 4% higher than 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 2012 (31%). Pup weights were near the long-term average.

The estimate of the total stock for the Pribilof Islands population in 2012 was about 547,000 fur seals. The total stock size for the United States, which includes Bogoslof, the Pribilof, and San Miguel Islands, was approximately 664,000 fur seals.

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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). Since that time, the major population concentration on the Pribilof Islands has been monitored, 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, theoretically, 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 the 1980s and 90s, the St. Paul Island population fluctuated at 35-45% of its peak numbers, then began a further at decline of ~6% annually (Towell et al. 2006). The smaller population at nearby St. George declined at a more or less steady rate to less than 30% of the peak, but may have stabilized in the last decade. 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, usually on a biennial basis. This report covers only a single year, 2012, with the intent to synchronize the normal biennial cycle of publication with the most recent biennial estimate of pup production on the Pribilof Islands. In addition, the methods and progress of NMML's recent study of fur seal demographics at three Pribilof rookeries based on longitudinal study of tagged seals is described for the first time. Research by the NMML on northern fur seals in 2012 was conducted under Marine Mammal Protection Act Permit No. 782-1708-00.

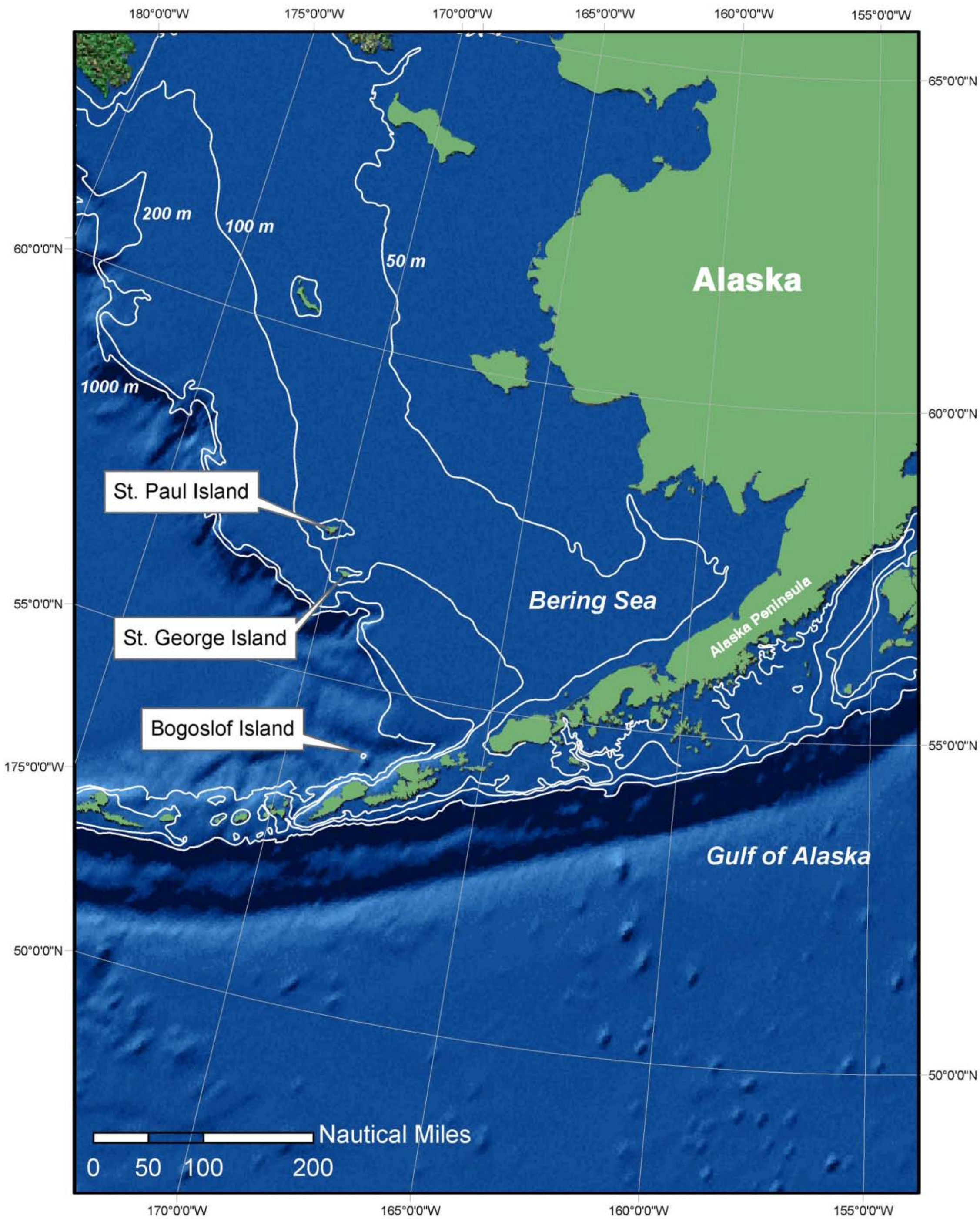


Figure 1. -- Location of the three northern fur seal breeding areas within U.S. Alaskan waters.

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.

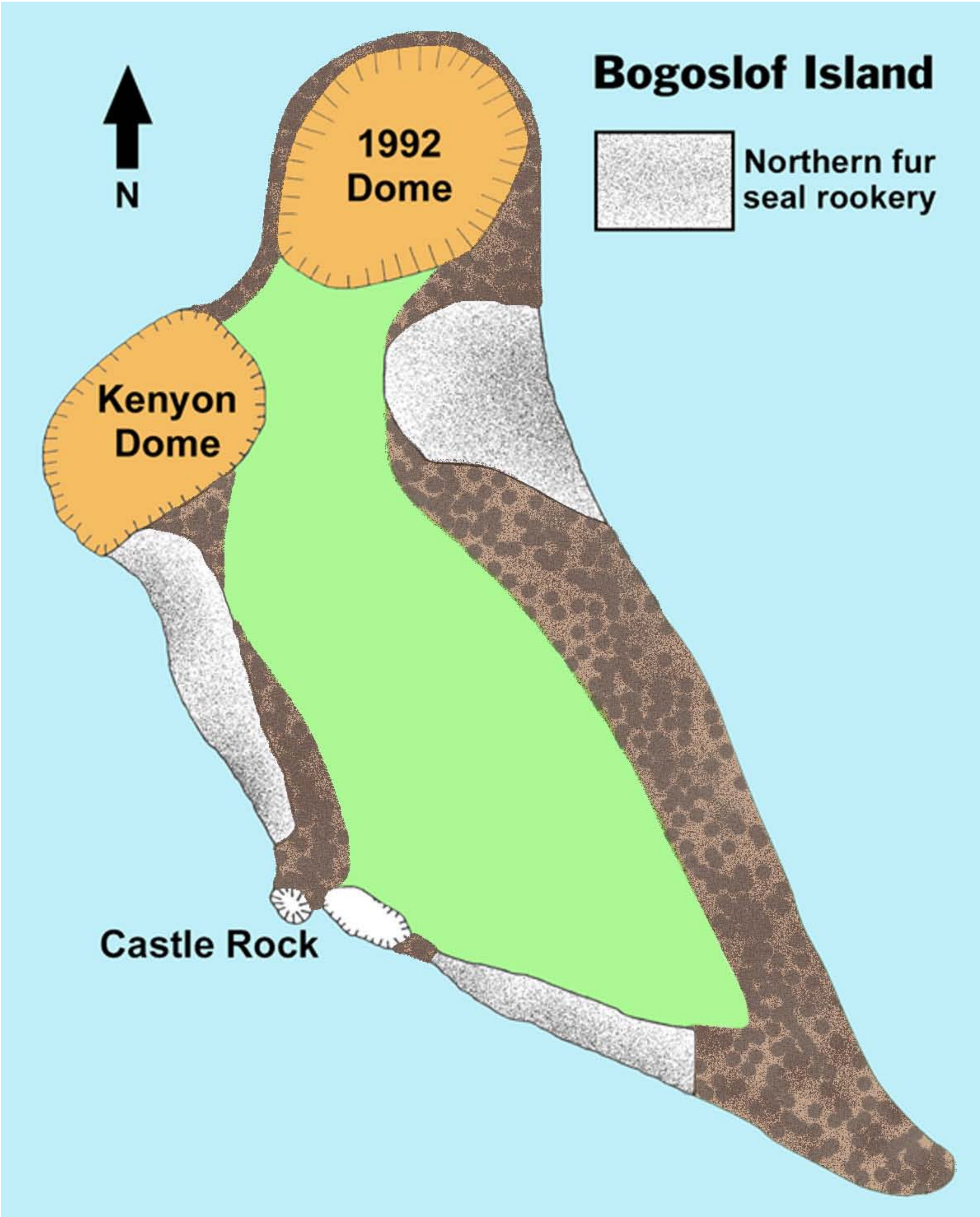


Figure 4. -- Location of northern fur seal rookeries on Bogoslof Island, Alaska.

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

POPULATION ASSESSMENT OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2012

by

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

Michael Williams, and John L. Bengtson

In accordance with provisions established by the Interim Convention on Conservation of North Pacific Fur Seals and to inform management decisions of the National Marine Fisheries Service (NMFS), the National Marine Mammal Laboratory (NMML) continues to monitor the status of northern fur seal populations on the Pribilof Islands (St. Paul and St. George), Alaska. 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 2012 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. The subsistence harvest was monitored to document 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 under a cooperative agreement and a board-certified veterinarian under contract with the NMFS. The St.

George Island Kayumixtax Eco-Office, which was also under cooperative agreement with NMFS, monitors and reports the subsistence harvest of northern fur seals on St. George Island.

Adult male fur seals were visually counted by section for each rookery on St. Paul Island from 9 to 15 July 2012 (Appendix Table A-1) and on St. George Island from 10 to 12 July 2012. Counters categorize males as territorial with (Class 3) and without (Class 2) females on the rookeries, and males on hauling grounds (Class 5; Antonelis 1992).

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 2012 using the shearing-sampling method (York and Kozloff 1987, Antonelis 1992). 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 2012. Tooth samples (usually canines) were collected from dead fur seals older than pups whenever possible. The total number of pups born was estimated using ratio estimation (Cochran 1977). From 8 to 13 August, pups were marked by shearing the guard hairs on top of the head to expose the light underfur for later observation. The number of pups sheared on each rookery was approximately 10% of the estimated pup production for the sample rookeries in 2010. Shear marks were allocated proportionally on each sample rookery by section (Appendix Tables A-2 and A-5) according to the fraction of the rookery total for breeding males counted in each section in 2012. The ratio of marked to unmarked pups was determined by two observers scanning each rookery (using binoculars when necessary) on two occasions from 14 to 23 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 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. However, no breeding males were counted on Little Polovina rookery in 2012, the estimate of zero pups born was confirmed by observers. Dead pups were counted from 14 to 16 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 13 to 22 August 2012 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 16 to 18 August and again from 20 to 22 August. Dead pups were counted on three rookeries from 16 to 17 August 2012. Tests for differences from previous estimates were two-tailed.

RESULTS AND DISCUSSION

Harvest

A total of 383 sub-adult male seals were harvested for subsistence on St. Paul Island in 2012 (Table 1). On St. George Island, 63 sub-adult males and one female seal were taken in the subsistence harvest in 2012 (Table 1).

Table 1. -- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvests on St. Paul Island, Alaska, in 2012.

St. Paul			St. George		
Date	Rookery	Number	Date	Rookery	Number
July 13	Polovina	49	July 13	North	12
July 20	Morjovi	54	July 21	Zapadni	11
July 27	Zapadni Sands	72	July 30	North	7
August 3	Lukanin	83	August 2	Zapadni	11
August 6	Polovina	44	August 3	North	11
August 7	Reef	81	August 7*	Zapadni	12
Total		383			64

* Includes 1 female.

Adult Males Counted

The count of territorial males with females (Class 3 or harem males) on St. Paul Island decreased 12.9% between 2011 and 2012 (Table 2; Appendix Table A-3). The count of harem males on St. George Island increased 1.2% between 2011 and 2012 (Table 2; Appendix Table A-3). Owing to the larger size of the population on St. Paul Island, the Pribilof Islands total for harem males decreased by 10.3% between 2011 and 2012. Between 2011 and 2012 idle males decreased 28.8% on St. Paul Island and 5.5% on St. George Island.

Number of Pups Born on St. Paul Island in 2012

The estimated total number of pups alive on St. Paul Island at the time of marking in 2012 was 93,204 (SE = 1,185; Table 3). The number of dead pups as counted by section on four sample rookeries of St. Paul Island is given in Appendix Table A-4: the total estimated number of dead pups on all St. Paul Island rookeries was 3,624. The estimated mortality rate for late August was 3.7%. The total number of pups born on St. Paul Island in 2012 was estimated at 96,828 (SE = 1,260; 95% CI = 94,169 – 99,562). 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 2012.

The number of pups born (Table 4) and the number of harem bulls at different rookeries on St. Paul Island were significantly correlated ($r^2 = 0.99$, Fig. 6). The slope of the regression line without an estimated intercept ($P = 0.28$) was 28.38 (SE = 1.00, $P < 0.01$), representing an estimate of the ratio of pups to breeding males.

Table 2. -- 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 2012.

	Date	Class of adult male			
Rookery	(July)	2	3	5	Total
St. Paul Island					
Lukanin	12	32	116	92	240
Kitovi	12	60	169	98	327
Reef	13	170	465	278	913
Gorbatch	13/1	108	305	218	631
Ardiguen	13	7	50	7	64
Morjovi	11	105	302	176	583
Vostochni	11	167	604	337	1,108
Polovina	14	23	107	168	298
Little Polovina	14	0	0	121	121
Polovina Cliffs	14	79	296	65	440
Tolstoi	9	142	286	199	627
Zapadni Reef	10	58	129	135	322
Little Zapadni	10	99	209	132	440
Zapadni	10	210	298	371	879
Island total		1,260	3,336	2,397	6,993
St. George Island					
South	11	55	174	84	313
North	10	120	268	197	585
East Reef	12	55	95	88	238
East Cliffs	12	60	213	199	472
Staraya Artil	11	25	34	71	130
Zapadni	11	28	68	73	169
Island total		343	852	712	1,907

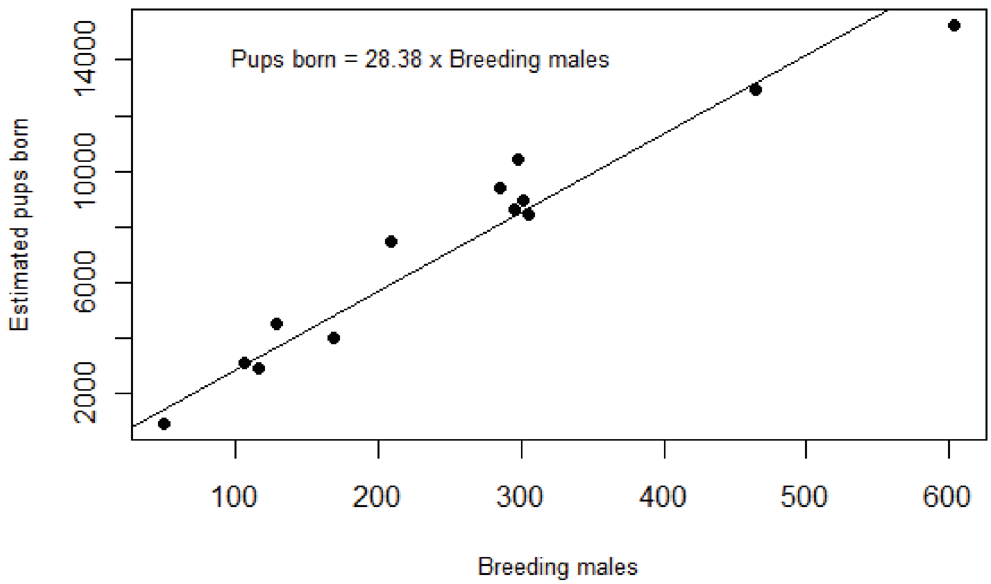
Table 3. -- Total number of northern fur seal pups sheared, number of pups estimated on two occasions (E1 and E2) to be alive at the time of marking, mean number alive (Mean) and standard error (SE), on sampled rookeries of St. Paul Island, Alaska, 2012.

Rookery	Sheared	E1	E2	Mean	SE
Lukanin	289	2,832	2,727	2,780	52.5
Kitovi	349	4,065	3,656	3,861	204.5
Reef	1,194	11,943	12,897	12,420	477.0
Gorbatch	896	8,088	8,124	8,106	18.0
Ardiguen	106	981	762	872	109.5
Morjovi	737	9,567	7,703	8,635	932.0
Vostochni	1,382	14,809	14,529	14,669	140.0
Polovina	274	2,866	3,100	2,983	117.0
Little Polovina*				0	
Polovina Cliffs	797	8,562	7,996	8,279	283.0
Tolstoi	1,049	8,968	9,071	9,020	51.5
Zapadni Reef	504	4,505	4,149	4,327	178.0
Little Zapadni	735	7,506	6,921	7,214	292.5
Zapadni	1,059	9,907	10,169	10,038	131.0

* Little Polovina estimated from the regression of live pups on number of harem males. No harem males were counted on Little Polovina in 2012.

Table 4. -- 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, 2012.

Rookery	Pups alive at marking	Total pups born	Harem males	Ratio pups/males
Lukanin	2,780	2,888	116	24.9
Kitovi	3,861	4,011	169	23.7
Reef	12,420	12,903	465	27.8
Gorbatch	8,106	8,421	305	27.6
Ardiguen	872	906	50	18.1
Morjovi	8,635	8,971	302	29.7
Vostochni	14,669	15,239	604	25.2
Polovina	2,983	3,099	107	29.0
Little Polovina	0	0	0	0.0
Polovina Cliffs	8,279	8,601	296	29.1
Tolstoi	9,020	9,371	286	32.8
Zapadni Reef	4,327	4,495	129	34.8
Little Zapadni	7,214	7,495	209	35.9
Zapadni	10,038	10,428	298	35.0
St. Paul Total	93,204	96,828	3,336	29.0



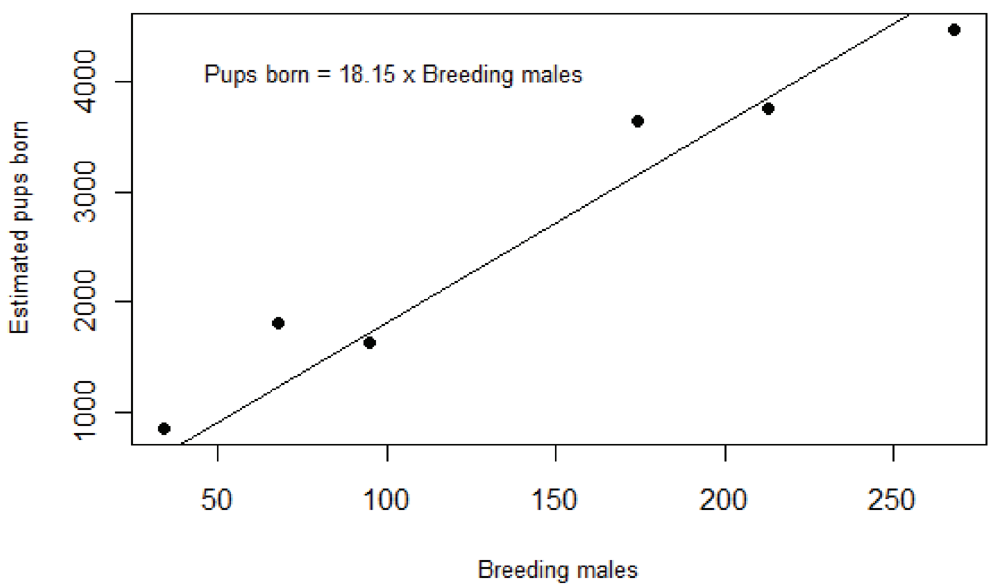


Figure 6. -- Pups born versus number of breeding males on St. Paul Island (top) and St. George Island (bottom), Alaska, 2012. Solid regression lines are shown for both locations.

Number of Pups Born on St. George Island in 2012

Estimated total number of pups alive on St. George Island at the time of marking was 15,687 (SE = 142; Table 5). The total number of dead pups was estimated to be 497 and the estimated mortality rate was 3.1%. The total number of pups born on St. George Island was 16,184 (SE = 155, 95% CI = 15,821 – 16,555).

The number of pups born and the number of harem males on St. George Island rookeries were highly correlated ($r^2 = 0.99$; Fig. 6). The intercept of the regression line was not significantly different from zero ($P = 0.16$) and was not included in the regression equation. The slope of the regression line was 18.15 (SE = 0.98, $P < 0.01$) representing an estimate of the ratio of pups born to breeding males.

Trends in Numbers of Pups

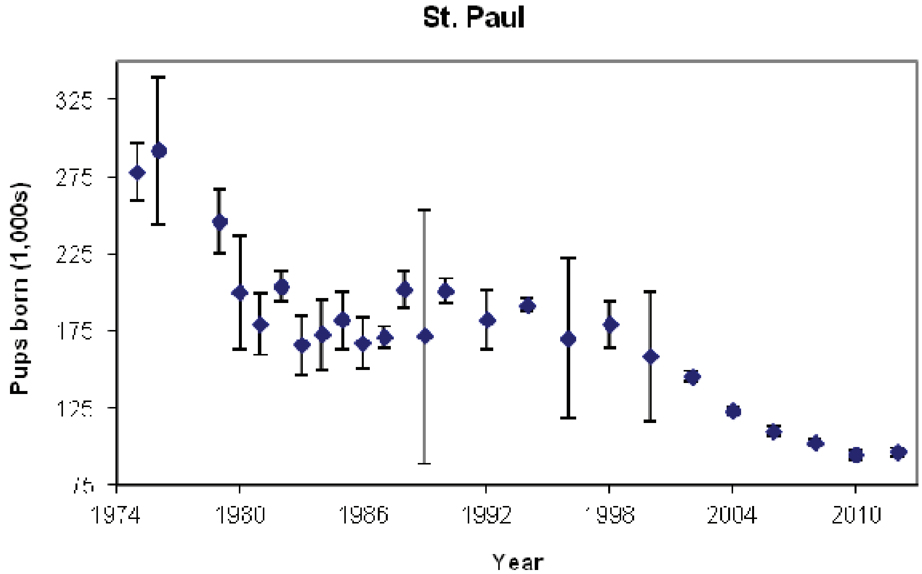
The total estimated number of pups born on St. Paul Island in 2012 (not including Sea Lion Rock) was 2.5% greater than in 2010 (Fig. 7; $P = 0.9$). On St. Paul Island, estimated numbers of fur seal pups born in 2010 were 8.0% less than in 2008 (Appendix Table A-3). On St. George Island there was a 1.0% decrease between 2008 and 2010, and a 9.9% decrease between 2010 and 2012. The 2012 estimate of pups born on St. George Island (Table 6) was significantly less than the estimates of pups born in 2010 or 2008 (two-tailed, $P < 0.01$). Since 2002, pup production has been below estimated pup production in 1919 on St. Paul Island and below the estimated pup production in 1916 on St. George Island, when the population was recovering at 8% annually from a pelagic harvest that ended in the early 20th century.

Table 5. -- 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, 2012.

Rookery	Sheared	E1	E2	Mean	SE
South	397	3,460	3,622	3,541	81.0
North	528	4,433	4,260	4,347	86.5
East Reef	159	1,624	1,532	1,578	46.0
East Cliffs	412	3,609	3,686	3,648	38.5
Staraya Artil	116	784	868	826	42.0
Zapadni	206	1,717	1,776	1,747	29.5

Table 6. -- 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, 2012.

Rookery	Pups alive at marking	Total pups	Harem males	Ratio pups/males
South	3,541	3,653	174	21.0
North	4,347	4,485	268	16.7
East Reef	1,578	1,628	95	17.1
East Cliffs	3,648	3,764	213	17.7
Staraya	826	852	34	25.1
Zapadni	1,747	1,802	68	26.5
Total	15,687	16,184	852	19.0



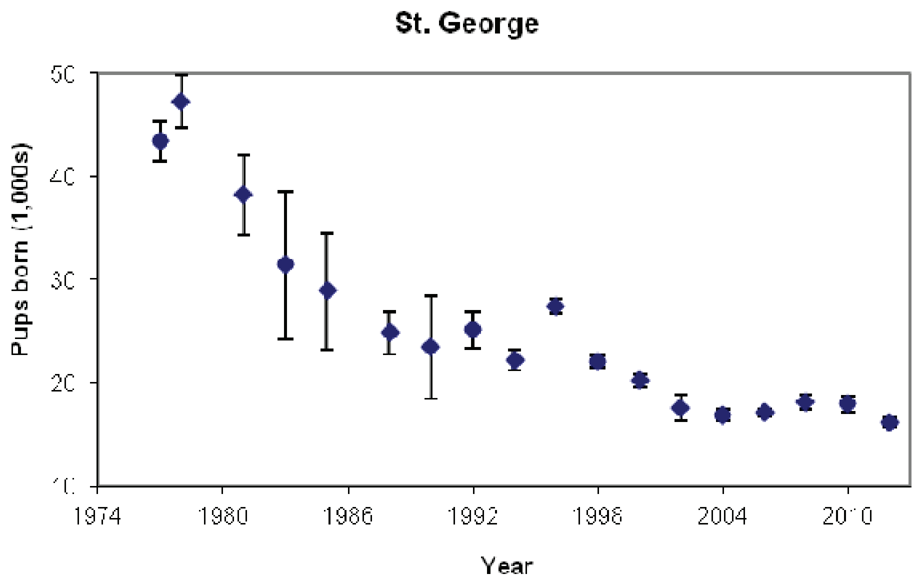


Figure 7. -- Estimated number of pups born (± 95% confidence intervals) on St. Paul and St. George Islands, Alaska, 1975 to 2012.

Pup production has been declining since 1998 at an annual rate of 4.84% (SE = 0.49%, $P < 0.01$) on St. Paul Island and 1.95% (SE = 0.50%, $P < 0.01$) on St. George Island. The overall rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 4.33% (SE = 0.46%, $P < 0.01$) from 1998 to 2012.

Estimate of Total Stock Size

Rough estimates of the total northern fur seal abundance have been presented in the past (Loughlin et al. 1994). These were calculated by multiplying the average estimate of pups born over the past three censuses by a correction factor of 4.47 (See Table 7 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. Because 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 2012 was about 547,000 fur seals (Table 7). The total stock size for the United States, which includes the Pribilof, Bogoslof, and San Miguel Islands, was approximately 664,000 fur seals.

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

A total of 58 dead adults were counted on rookeries sampled for dead pups. Teeth were collected from a total of 50 dead adult fur seals: 44 on St. Paul Island and 6 on St. George Island (Table 8). Appendix Table A-7 summarizes the number of dead male and female fur seals from which teeth were collected from 1977 to 2012.

Table 7. -- Details of the computation of stock size estimates of fur seals on U.S. rookeries in 2012. 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 2008[1], 2010, 2012	122,181	26,255	Pups
(Pups) × 0.5	61,091	13,128	Yearlings
(Yearlings) × 0.8	48,873	10,502	Age 2 year
(2-year old females) × 0.86 / 2	21,015	4,516	Females age 3 year
(2-year old males) × 0.8 / 2	19,549	4,201	Males age 3 year
(Pups) / 0.6	203,635	43,758	Females 3+ years
(3-year old males) × 3.6	70,376	15,124	Males 4+ years
Total	546,720	117,484	

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

[2] The 2010, 2011, and 2012 estimates for San Miguel Island and the 2011 estimate for Bogoslof Island were used.

Table 8. -- Number of animals older than pups found dead and from which teeth were collected during August 2012 on the Pribilof Islands.

Rookery	Male	Female	Unknown	Total
St. Paul				
Lukanin	0	3	0	3
Reef [1]	8	17	0	25
Morjovi[2]	2	8	0	10
Little Zapadni[3]	5	9	0	14
Total St. Paul	15	37	0	52
St. George				
South	0	2	0	2
East Reef	0	0	0	0
Staraya Artil	0	4	0	4
Total St. George	0	6	0	6
Total Both Islands	15	43	0	58

[1] No teeth collected from 2 females and 2 males.
[2] No teeth collected from 1 male.
[3] No teeth collected from 1 female and 2 males.

DEMOGRAPHIC STUDIES OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2007-2012

by

J. Ward Testa, James R. Thomason, Rolf R. Ream, and Thomas S. Gelatt

From 1958 to 1980, the population of northern fur seals on the Pribilof Islands, as indexed by pup production estimates, declined by over 60% (Towell 2007). On St. Paul Island , the population was stable from 1980 to 1998, before entering a second period of decline of ~ 6% annually (Towell et al. 2006) that continues through the most recent estimate (Fig. 7). For the smaller population at St. George Island, the initial decline was continuous to about 1990, with a lesser decline beginning about the same time as on St. Paul (Fig. 7). In response to the most recent decline, the National Marine Mammal Laboratory convened a panel of experts to evaluate the feasibility and likely success of a long-term tagging program to address demographic questions about the decline, given the life history of northern fur seals and past tagging programs (Melin et al. 2006). In 2007, a long-term demographics research program was begun on St. Paul, and in 2009 on St. George, based primarily on tagging and re-sighting of fur seals at a few rookeries where it was deemed feasible. The objectives were to estimate age-specific survival and reproductive rates of female northern fur seals in order to determine which life-history stage or stages, in comparison with historic age-specific rates, were driving the decline. In doing so, it is hoped that critical ecological or anthropogenic causal mechanisms for the decline might be either excluded or identified for further research and mitigation. The purpose of this report is to describe the study sites, captures, tag deployments and re-sighting efforts from 2007 to 2012 at three study sites on St. Paul and St. George Islands, with some preliminary estimates of age structure, survival, and reproductive rates.

STUDY SITES

The primary criteria for the selection of study sites was that they be representative of population trends on St. Paul and St. George Islands, and that terrain be favorable for re-sighting and identification of tagged fur seals by means of high-powered optics and cameras without significant disturbance to the seals. On St. Paul Island, nearly all rookeries either lack natural overlooks or have major obstructions (e.g., large rocks). However, the northernmost end (Section 7) of Polovina Cliffs rookery has low (5-15 m) overlooking banks with few obstructions (Fig. 9). That section (57° 10’ 11”N, 170° 9’ 54”W to 57° 10’, 19”N, 170° 9’ 43”W), which had ~1,800 pups born in 2006, was selected for studies beginning in 2007. South rookery (Fig. 2, 56° 32’ 40” N, 169° 40’ 32” W to 56° 32’ 4” N, 169° 38’ 43”W, Fig. 10) on the south side of St. George Island has excellent viewing cliffs ~20 m in height along most of its length, though the beach is wider than at Polovina Cliffs and has larger rocks that can obstruct visibility. Approximately 3,800 pups were born at South rookery in 2008 and demographic studies began there in 2009. It is known that foraging areas and diet of fur seals differ on St. Paul and St. George by rookery (Robson et al. 2004, Zeppelin and Ream 2006), with fur seals generally foraging in waters matching the direction faced by their rookery shore. Zapadni Reef rookery (57° 9’, 14”N, 170° 18’ 15”W to 57° 9’, 13”N, 170° 18’ 29”W), with ~4,900 pups born in 2008, lies at the head of English Bay on the west side of St. Paul Island. Surrounded by larger rookeries, it was selected in 2010 to represent the large breeding population in English Bay where many of the fur seals are known to forage westward, both on and off the continental shelf, in contrast to Polovina Cliffs where most foraging by fur seals occurs eastward on the Bering Sea Shelf. Zapadni Reef has no natural vantages for tag viewing (Fig. 11), but the beach is narrow without large rocks that would block viewing, provided some elevated structures could be built there. Tagging of female pups began there in 2010, and infrastructure for resighting (Fig. 11) is being tested in 2013.

Figure 9. -- Blinds at Section 7 of Polovina Cliffs rookery on St. Paul Island viewed from the southeast.

Figure 10. -- South end of South rookery on St. George Island viewed from the bluff.

Figure 11.-- Zapadni Reef rookery on St. Paul Island, with new observation blinds, viewed from the northwest.

METHODS

Our focus is primarily on the female segment of the population in both pups and non-pups (which will be referred to as “adult”, though some may be sexually immature), but male pups were included at St. George Island because of the availability of comparative historical data from harvests, and because juvenile males were thought to return to haulouts and be recovered in subsistence harvests and haulout roundups in summer. This might give earlier conclusions on juvenile survival than a study focusing exclusively on females. Adult female fur seals were captured by noose-pole and restrained with a neoprene vest and a wooden stock (Gentry and Holt 1982), usually in late September and early October, though captures in 2007 and 2008 extended into mid-November (Testa et al. 2010). They were weighed on the restraining board with a digital scale, subtracting the weight of the board and vest, and tagged in both foreflippers. Procedures performed and samples collected varied by year and location, but included gas anesthetization with isoflurane (Haulena and Heath 2001), extraction of lower first premolar tooth for aging (Arnbom et al. 1992), transrectal ultrasonography for reproductive status (Adams et al. 2007), blood collection from flipper veins, fecal, vaginal, nasal or oral swabs, gluing of satellite or VHF transmitters to the pelage, and expression of milk to determine lactation status. The color of vibrissae (dark, mixed, and white) was noted as an index to age (Scheffer 1962). Pups were captured and restrained by hand, tagged in both foreflippers, and weighed in a large bucket from a suspended scale (Antonellis 1992).

Tooth sections were prepared and mounted on glass slides by Matson’s Laboratory LLC (Milltown, MT, USA). Ages were estimated from cementum annuli by two readers (JWT & JRT) experienced with other pinniped teeth according to a step-wise protocol. Independent reads that were within a year of each other were assigned age in an alternating pattern (low, high) throughout the record. Read discrepancies of >1 year were re-read and assigned in the same manner. Remaining discrepancies of >1 year were evaluated collaboratively to within a year, with larger discrepancies discarded from analysis. Estimates are considered preliminary until the criteria for aging of premolar teeth from northern fur seals can be evaluated more thoroughly with known-age samples.

In their review of fur seal marking methods, Melin et al. (2006) concluded that livestock tags applied to the flippers remain the most viable means of identifying northern fur seals for longitudinal study of their demography. However, little is known about the effectiveness of contemporary tags for long-term studies in northern fur seals. Earlier studies relied primarily on Monel steel tags that were either not well-retained or were difficult to read without recapturing the seals (Scheffer 1950a, York 2006). While several studies have examined the issue of tag retention in other pinnipeds (e.g., Testa and Rothery 1993, Bradshaw et al. 2000, McMahon and White 2009), we were concerned here with the retention and readability of tags over periods that might encompass a long absence for juvenile seals between tagging as pups and possible first return 5-8 years later, and a study duration greater than a fur seal lifespan (Melin et al. 2006). Tag visibility (for detection), readability from distances of 5-80 m, resistance to breakage, wear and fading of printed characters, as well as resistance to tears or necrosis of the foreflippers where tags are applied are all unresolved issues that could bias or invalidate mark-recapture analyses of fur seal re-sighting data. Therefore, several different tag types were used and evaluated in this study. We focused on tags with good performance on other pinnipeds: Allfex large and Allflex sheep tags (Allflex USA, Dallas, TX, USA), Dalton Superflexitags (Dalton ID Systems Ltd., Oxfordshire, United Kingdom), and Monel self-piercing round-post tags (National Band and Tag Company, Newport, KY, USA) (Fig. 4). These were sometimes paired with VHF radio-tags applied for other purposes, but the radio-tags were not considered a reliable means of visual identification.

In both pups and adults, tags were applied to the trailing edge of both foreflippers next to the hairline (Gentry and Holt 1982, Antonellis 1992; Fig. 12) with the male component of the tag on the ventral surface of the flipper. The penetrating point of male Dalton tags was flattened by clipping off the pointed tip after application, but in the other tags the point was protected by a collar (Allflex) or cap (Monel) on the female side of the tag (Fig. 12).

Figure 12. --Tag types applied to northern fur seals on the Pribilof Islands (from left to right): Allflex "narrow" sheep tag (AN), Allflex Large tag (AL), Monel metal tag (M), and Dalton Superflexitag (DS).

Re-sighting and identification of tagged seals was accomplished visually with the aid of binoculars, spotting scopes and digital telephoto photography from late June or early July to the end of August (2008-2011) or middle early August (2012). Effort in 2010 at St. George was only from July 8 to Aug. 1, due to the small number of adult tags deployed in 2009. At St. George, additional effort to re-sight returning juveniles that were tagged as pups was made from Sept. 26-Oct. 2, 2011, and Oct. 2-18, 2012. In 2010-2013 on Section 7 of Polovina Cliffs rookery and in

2011-2012 on South Rookery, daily counts were taken of pups, adult females and adult territorial males.

Observers assigned an arbitrary "seal number", unique for the seal and day, to each tagged seal detected. This seal number was used to link multiple observations that might occur. Time of recording, sighting conditions (1-3, from excellent to poor), section of the rookery, foreflipper side (left, right or both) observed, tag type, tag number, tag color, and associations with possible offspring (0 = unknown, 1 = apparently alone, 2 = passive association with a single pup without behavioral interaction, 3 = active association with non-aggressive maternal behavioral, 4 = nursing, 5 = parturition, 6 = association with dead pup). Parturition was attributed to a female for pup association codes 3-5, but in the initial year (2008) the distinction between codes 2 and 3 was not yet explicit, and observers recorded only when they were "confident" of a maternal bond based on the behavior observed. In practice, most mother-pup associations during a season (> 90%) are made on the basis of observed suckling or parturition. Beginning in 2009, a second visual confirmation of each recorded tag was also recorded. In 2012, a second confirmation field was added for tag side. Suspect records are rare, but can be excluded from analyses if confirmation was not obtained. Photographs that verified the tag were also noted and archived. Absence of a tag on the flipper opposite a recorded tag was also recorded by codes for open tears or "slots", holes (usually also commented upon for their size as allowing for tags to fall out or be absent only by tag breakage), closed scars, or no evidence of tagging. Protocol also called for distinguishing whether the flipper was seen sufficiently to positively determine if there was no tag, had the tag been missing. This was done as a filter for assessing tag loss, as it is easier to spot a tag than it is to positively determine its absence, and this can create bias in estimating tag loss rates. A small number of re-sightings came from other fur seal monitoring activities (bull counts, harvests), occasional search of other rookeries or haulouts, and a few roundups of juvenile males on haulouts.

Tagging and re-sighting effort are reported for our primary study rookeries in terms of the numbers of tags deployed and the numbers re-sighted. All analyses are considered preliminary. Tag loss estimates were based on the assumption that tag loss from opposite flippers was independent (Testa and Rothery 1993). Pupping rates were estimated as the proportion of female seals seen each year that were positively associated with a pup. Cormack-Jolly-Seber analyses of adult female re-sightings were performed with program “marked” (Laake et al. 2013) in R statistical software (R Core Team 2012) using Maximum Likelihood Estimation (MLE). Models incorporating constant and time-varying survival (Phi) and probability of sighting (p), as well as covariates for tag type and juvenile versus adult status when first tagged (based on vibrissae color or weight < 25 kg) were compared using the minimum Akaike’s Information Criteria (AIC) to select the best model or models (Burnham and Anderson 2002). Pup survival analyses are not presented due to possible heterogeneity of re-sighting among the early returns (ages ≤ 3 years).

RESULTS

Tags Deployed

At Section 7 of Polovina Cliffs rookery on St. Paul, 632 adult female fur seals were tagged from 2005 to 2012 (Table 9). Female pups were targeted beginning in 2008 (Table 10), but numbers obtainable in Section 7 of Polovina Cliffs (708 over 5 years; maximum of 457 in 2009) were insufficient to meet our objectives for precision of pup survival estimates. From 2010-2012, 1,915 female pups were tagged at Zapadni Reef rookery (Table 11). At St. George Island, 445 adult females and 6,605 pups of both sexes were tagged at South rookery from 2009 to 2012 (Tables 12 and 13).

Table 9. -- Adult (non-pup) female northern fur seals tagged at Polovina Cliffs rookery on St. Paul Island, 2005-2012. Tag types refer to Allflex narrow sheep tags (AN), Allflex large tags (AL), Monel steel tags (M), Dalton Superflexitags (DS) and VHF transmitter tags (TX). Tags in combination are separated by "/"; all others were tagged with the same tag type on both foreflippers.

Year	Adult females	New	Retags	Tooth collected	Tag type
2005*	5	5	0	0	AN
2006*	24	24	0	0	AL
2007	230	230	0	0	AN/M, AL/TX
2008	94	92	2	51	DS/TX
2009	155	131	24	107	DS
2010	31	25	6	0	DS/TX
2011	94	84	10	0	AN, AN/TX
2012	44	41	3	0	AN, AN/TX
Total	677	632	45	158	

* Seals tagged for other research purposes, but still present at the start of this study and incorporated into sample.

Table 10. -- Pups tagged at Polovina Cliffs rookery on St. Paul Island, 2006-2012. Tag types refer to Allflex narrow sheep tags (AN), monel steel tags (M), and Dalton Superflexitags (DS). Tags in combination are separated by "/"; all others were tagged with the same tag type on both foreflippers.

Year	Pups	Male	Female	Tag Type
2008	18	0	18	DS/M
2009	460	3	457	DS
2010	138	0	138	AN
2011	58	1	57	AN
2012	39	0	38	AN
Total	713	4	708	

Table 11. -- Pups tagged at Zapadni Reef rookery on St. Paul Island, 2010-2012. Tag type "AN" refers to Allflex narrow sheep tags (AN) applied on both foreflippers.

Year	Pups	Male	Female	Tag type
2010	656	3	653	AN
2011	703	3	700	AN
2012	562	0	562	AN
Total	1921	6	1,915	

Table 12. -- Adult (non-pup) females tagged at South rookery on St. George Island, 2009-2012. Tag types refer to Allflex narrow sheep tags (AN) and Dalton Superflexitags (DS). Seals were tagged with the same tag type on both foreflippers.

Year	Adult females	New	Retags	Tooth collected	Tag type
2009	92	92	0	85	DS
2010	171	162	9	155	DS , AN
2011	199	191	8	0	AN
2012	0	0	0	0	
Total	462	445	17	240	

Table 13. -- Pups tagged at South rookery on St. George Island, 2009-2012. Tag types refer to Allflex narrow sheep tags (AN) and Dalton Superflexitags (DS) applied to both foreflippers.

Year	Pups	Male	Female	Tag Type
2009	1963	979	984	DS
2010	1763	846	917	DS , AN
2011	1840	950	890	AN
2012	1039	567	471	AN
Total	6605	3342	3262	

Sample Age Structure

A total of 158 female fur seals from Polovina Cliffs rookery in 2008-2009 and 235 (five of those listed in Table 12 could not be aged) from South rookery in 2009-2010 were aged by tooth annuli (Fig. 13). The age structures, when pooled into juvenile (ages 1-3), young adult (4-10) and old adult (11+) were significantly different between sites ($X^2 = 17.34$, 2 d.f., $P \leq 0.0002$). The temporal pattern was of higher presence of 2-3 year-old (~2006-2008 cohorts) and older females (~1991-1996 cohorts) at South rookery, and greater representation of young adults (~1998-2004 cohorts) at Polovina Cliffs.

Re-sightings

Dates of systematic re-sighting effort, staffing and number of individually identified fur seals are summarized in Table 14 for Polovina Cliffs rookery on St. Paul Island and in Table 15 for South rookery on St. George Island. The number of observers was increased from mid-July to early August, when the number of adult females on the rookeries was highest (Fig. 14). The timing of peak counts and the cumulative proportions of uniquely tagged adult fur seals identified (Fig. 15) suggest a slightly earlier (~ 3 days) median date of arrival at South rookery.

Approximately 11% of the female and 10% of male juveniles tagged as pups in 2009 have been re-sighted in 2011 or 2012, and 8% of both sexes tagged in 2010. Only 1% of the 2011 cohort has been re-sighted. The timing of their arrival differs by sex and age, with 3-year-olds preceding 2-year-olds, and males preceding females (Fig. 16).

Pupping Rates

Estimated pupping rates from 2008 to 2012 at Polovina Cliffs rookery ranged from 0.86 to 0.91 from 2008 to 2012 (Table 16). At South rookery, rates from 2010 to 2012 ranged from

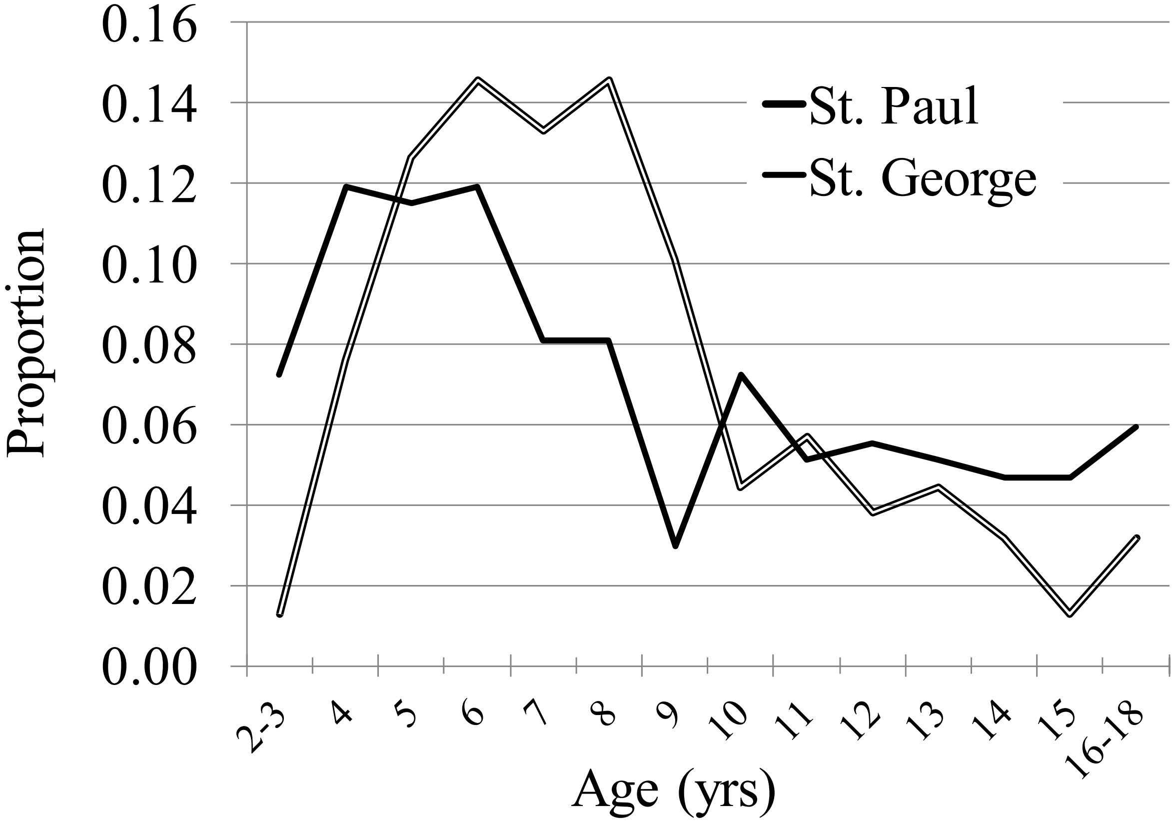


Figure 13. -- Age distribution from tooth annuli of 158 adult female fur seals from Polovina Cliffs rookery on St. Paul, 2008-2009, and 235 from South rookery on St. George, 2009-2010, expressed as a proportion of the total sample from each rookery.

Table 14. -- Dates of systematic re-sighting effort, minimum and maximum number of observers, and the number of northern fur seals re-sighted in each year at Polovina Cliffs rookery, St. Paul Island.

Year	Early season	Min staff	Max staff	Tagged seals
2008	6/30-8/31	2	3	205
2009	7/1-8/25	3	3	218
2010	7/1-8/31	2	3	271
2011	6/28-8/31	3	4	196
2012	6/29-8/7	2	3	196

Table 15. -- Dates of systematic re-sighting effort, minimum and maximum number of observers, and the number of northern fur seals re-sighted during the early season and added during the late seasons shown for each year at South rookery, St. George Island. New seals added after the early season were mostly juveniles.

Year	Early season	Min staff	Max staff	Tagged seals	Late season	Seals added
2010	7/8-8/1	1	1	56		
2011	6/28-9/1	2	2	233	9/26-10/2	36
2012	7/4-8/12	2	3	320	8/13-9/1, 10/2-10/18	160, 87

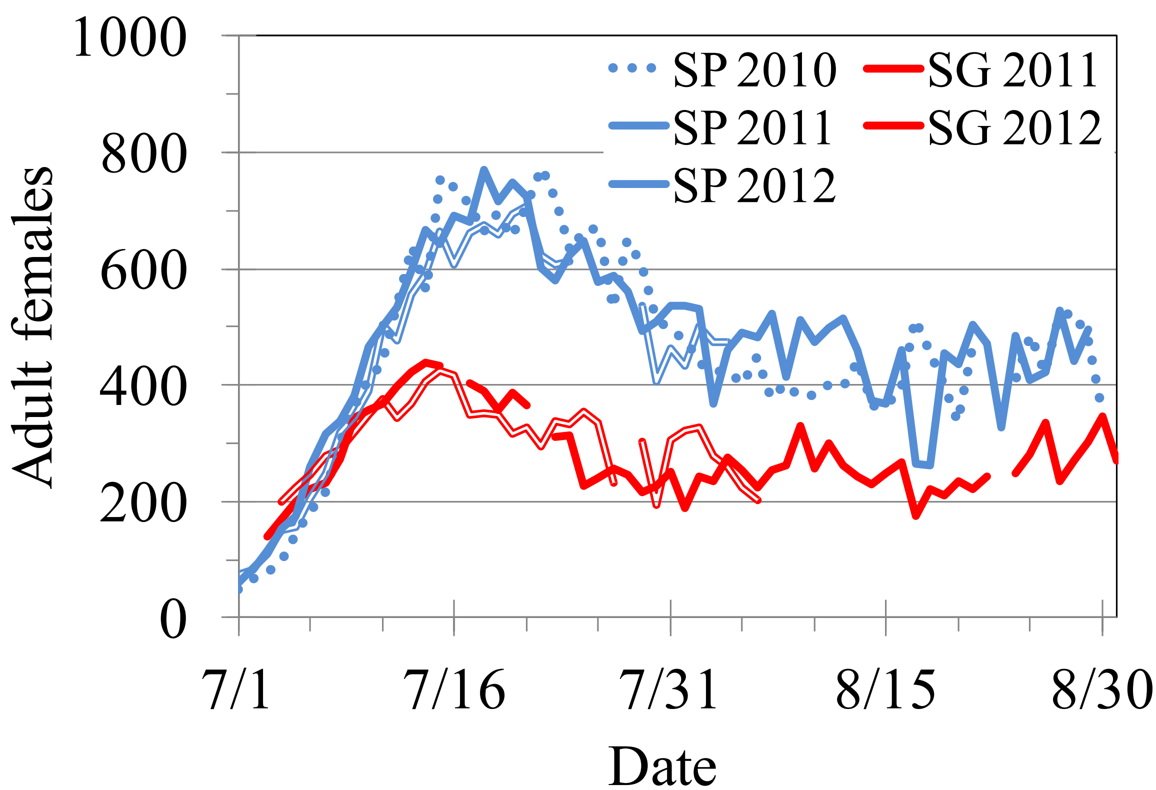


Figure 14. -- Daily counts of adult females at Section 7 of Polovina Cliffs rookery, St. Paul Island (SP), and Section 1 of South rookery, St. George Island (SG).

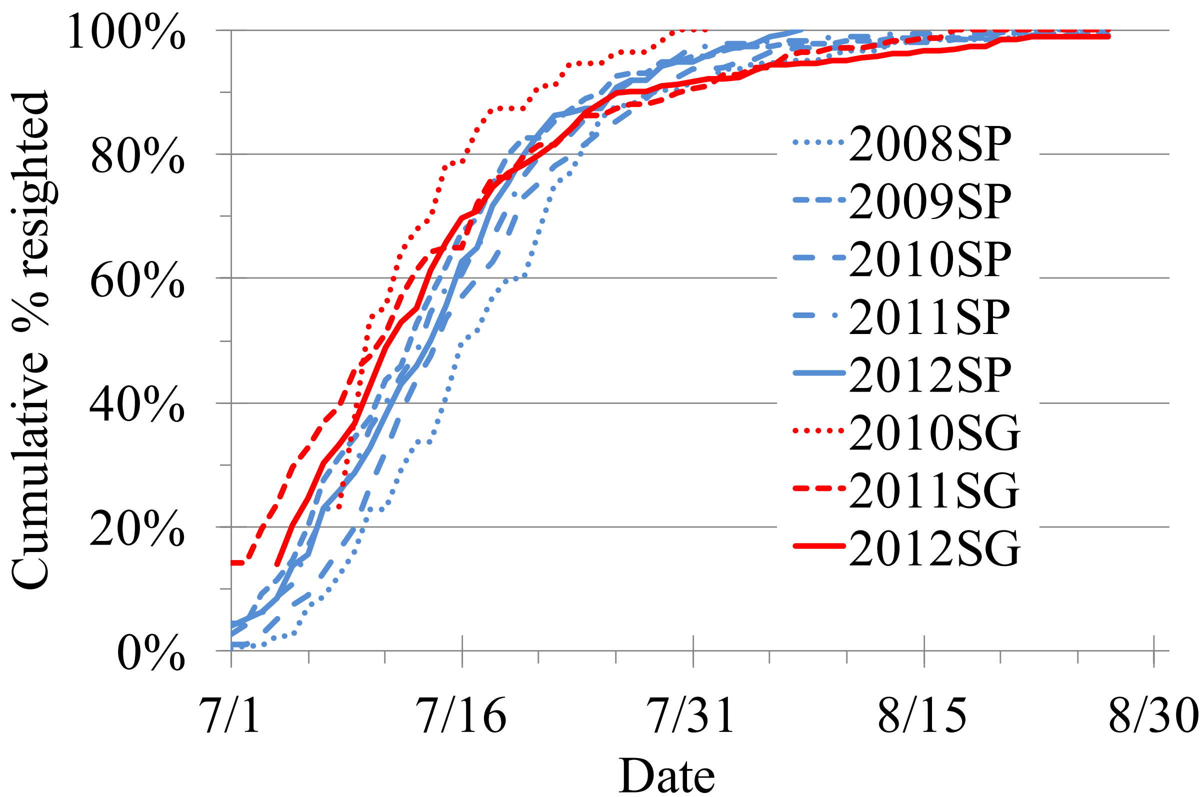


Figure 15. -- Cumulative re-sights of female fur seals tagged as adults in the years shown on Polovina Cliffs rookery, St. Paul Island (SP) and at South rookery, St. George Island (SG) as a percentage of total re-sights to the end of August (Tables 14 and 15). In 2010, re-sighting ended on August 9 at St. George.

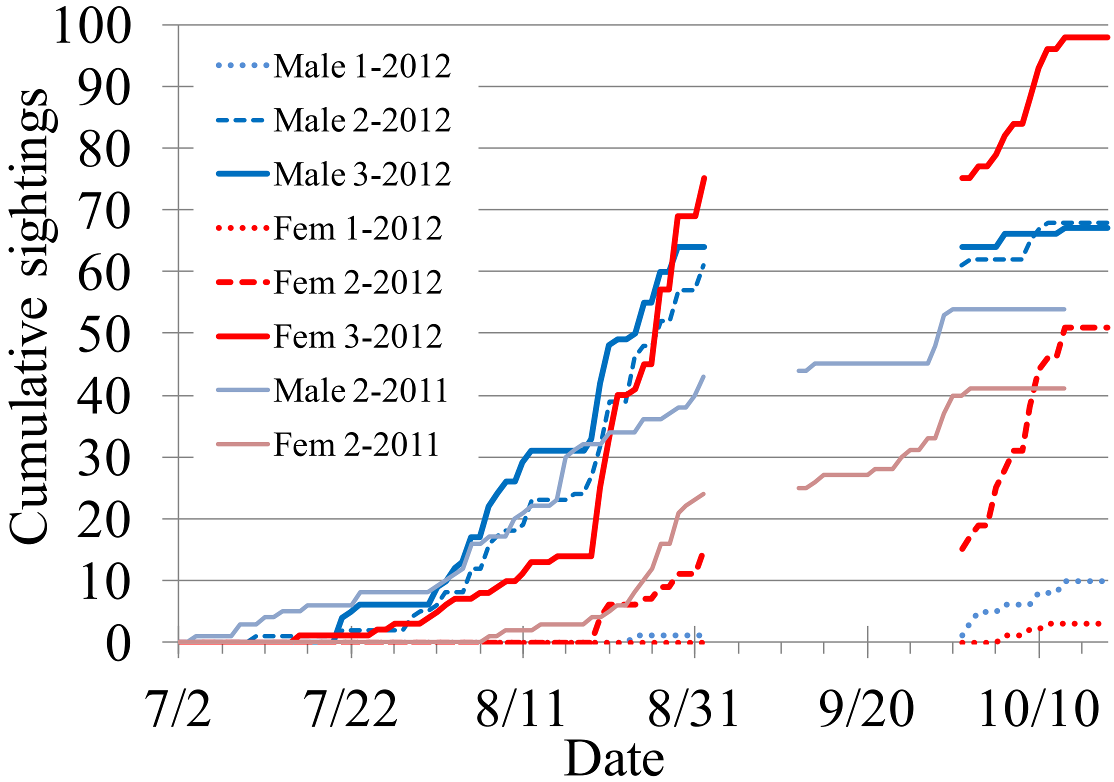


Figure 16. -- Cumulative numbers of re-sighted male (Male) and female (Fem) fur seals that were tagged as pups at South rookery, St. George Island, with their age in years and the year of re-sighting shown in the legend. Re-sighting effort was either absent (2012) or very low (2011) from early to late September.

Table 16. -- Annual sample sizes (n) and apparent pupping rates of adult females at Polovina Cliffs rookery, St. Paul Island, from 2008 to 2012.

Year	n	Rate	SE
2008	198	0.864	0.024
2009	205	0.907	0.020
2010	239	0.874	0.021
2011	175	0.863	0.026
2012	163	0.865	0.027

Table 17. -- Annual sample sizes (n) and apparent pupping rates of adult females at South rookery, St. George Island, from 2008 to 2012.

Year	n	Rate	SE
2010	56	0.875	0.044
2011	166	0.855	0.027
2012	267	0.787	0.025

0.79-0.88 (Table 17). Due to the heavier tagging effort over fewer years at South, juveniles may have been over-represented in that sample. When newly tagged animals judged to be juveniles (by tooth annuli, vibrissae color or small body size) were excluded from the South rookery data in the year following capture, pupping rates were 3-4% higher.

Tag Loss

AL tags were not evaluated because they offered little advantage in readability or likely retention over AN tags, and they were only paired with radiotransmitters, which were not considered a reliable visual identifier. Assuming independent loss from opposite sides, estimated rates of tag loss in adult females was generally low, with an estimated probability of losing both tags (hence, becoming indistinguishable from mortality) ≤ 0.01 even after 3-5 years at Polovina Cliffs. DS tags (Table 18) were lost at a higher rate than AN or M tags (Table 19) at the same site, and appear to accumulate in the first 2 years after application, but not from year 2 to 3. In contrast, estimated rate of loss for M tags increased each year after application, but the rates were lower (Table 19). Estimated loss of AN tags was evident at Polovina Cliffs from the loss by only a single seal in year 3, which implies a double tag loss in the AN+M tag cohort of only 0.0085 by year 5.

Tag loss among adult females at South rookery was marked by striking differences between the left and right side. Bootstrap estimates of DS loss showed significantly higher loss rates from the left (Table 20, $P(Loss_{Right} \geq Loss_{Left}) = 0.025, 0.002, 0.043$ after 1, 2 and 3 years, respectively). Loss of AN tags by adults at South was very low, being confined to just two individuals that lost their left tag (Table 21). Loss of DS tags in the 2009 pup cohort was both higher than in adults, and biased in the opposite direction with regard to flipper side (Table 22,

Table 18. -- Numbers of adult female fur seals observed 1-3 years after tagging that retained 1 (n1) and both (n2) Dalton Superflexitags (DS) at Polovina Cliffs rookery, St. Paul Island, with estimated single and double-tag loss rates (SE = standard error) under assumption that probability of loss is independent of loss on opposite flipper.

Tag age	n1	n2	Single rate	SE	Double rate	SE
1	10	98	0.049	0.015	0.002	0.001
2	13	59	0.099	0.027	0.010	0.004
3	9	43	0.095	0.031	0.009	0.004

Table 19. -- Numbers of adult female fur seals observed 1-5 years after tagging that retained single Allflex Narrow (AN), single Monel (M), and both tags at Polovina Cliffs rookery, St. Paul Island, with estimated single and double-tag loss rates (SE = standard error) under assumption that probability of loss is independent of loss on opposite flipper.

Tag age	Retained AN	Retained M	Retained both	Loss-M	SE	loss-AN	SE	Double Loss	SE
1	5	0	100	0.048	0.021	0.000	0.000	0.0000	0.000
2	3	0	83	0.035	0.020	0.000	0.000	0.0000	0.000
3	3	1	61	0.047	0.026	0.016	0.016	0.0008	0.001
4	4	1	48	0.077	0.037	0.020	0.020	0.0016	0.002
5	3	1	33	0.083	0.046	0.029	0.029	0.0025	0.003

Table 20. -- Numbers of adult female fur seals observed 1-3 years after tagging that retained a single Dalton Superflexitag (DS) on the left (n_{Left}), right (n_{Right}) or both (n_{Both}) flippers at South rookery, St. George Island, with bootstrap median single and double-tag loss rates (bootstrap 95% confidence interval).

	Tags retained			Estimated rates of loss		
Tag age	n_{Left}	n_{Right}	n_{Both}	Right	Left	Both
1	4	11	43	0.083 (0.020-0.170)	0.204 (0.096-0.321)	0.015 (0.002-0.043)
2	5	17	32	0.125 (0.029-0.243)	0.344 (0.217-0.479)	0.047 (0.011-0.109)
3	5	14	25	0.161 (0.037-0.308)	0.355 (0.214-0.513)	0.057 (0.013-0.133)

Table 21. -- Numbers of adult female fur seals after 1-2 years that retained a single Allflex narrow sheep tag (AN) on the left (n_{Left}), right (n_{Right}) or both (n_{Both}) flippers at South rookery, St. George Island, with estimated single and double-tag loss rates (SE = standard error) under the assumption that loss is independent on opposite flippers.

Tag age	Retained left	Retained right	Retained both	Loss(R)	SE	Loss(L)	SE
1	0	2	231	0	0	0.009	0.006
2	0	1	87	0	0	0.011	0.011

Table 22. -- Numbers of northern fur seal pups after 2-3 years that retained a single Dalton Superflexitag (DS) on the left (n_{Left}), right (n_{Right}) or both (n_{Both}) flippers at South Rookery, St. George Island, with bootstrap median single and double-tag loss rates (bootstrap 95% confidence interval).

	Tags retained			Estimated rates of loss		
Tag age	n_{Left}	n_{Right}	n_{Both}	Right	Left	Both
2	29	15	34	0.460 (0.338-0.585)	0.304 (0.180-0.438)	0.139 (0.072-0.238)
3	42	26	51	0.452 (0.352-0.554)	0.338 (0.233-0.446)	0.151 (0.091-0.233)

bootstrap P($Loss_{Left} \geq Loss_{Right}$ = 0.0, 0.021 in years 2 and 3, respectively). No losses of AN tags have been observed among 31 juveniles 1-2 years in age.

The best fitting model for adult female survival at Polovina Cliffs rookery included a constant probability of sighting and annual variation in survival, and additive effects of DS tag type and whether captured the preceding year as a juvenile (Table 23). All competing models were significantly poorer than the model selected (ΔAIC > 2). The apparent survival of juveniles was lower than that of adults, and that of DS tags was lower than that of other tags (Table 23).

At South Rookery, the best model included lower probability of sighting in 2010, when re-sighting effort was limited to just 3 weeks. Estimated survival differed with year, and was lower for fur seals tagged the previous year as a juvenile. Two competing models that included an effect of DS tags had some AIC support (AIC = 2), but produced estimates barely differing from those of the best model. There was little power in the data to discern higher tag loss of DS tags due to confounding of DS tag deployments with first year survival, and the conservative loss rates estimated in Table 20 suggest that most such loss occurs in the first year and would produce a negative bias in the survival estimate for 2010 of ~5%.

DISCUSSION

The work reported here was undertaken with specific objectives relevant to northern fur seal conservation. The establishment of several marked populations represents a long-term commitment to improved monitoring of fur seal demography on the Pribilof Islands. Results should be considered preliminary, and likely to be revised.

While there were significant differences in the age structure of adult females at Polovina Cliffs and South rookeries, these may include both true differences reflective of past cohort

Table 23. -- Estimated survival from best-fit CJS model(year, year*age of tag (1 or 1+), and tag type (DS or non-DS)) of adult females at Polovina Cliffs rookery, St. Paul Island, from 2007 to 2012. Probability of sighting was 0.95 (SE = 0.009) in all years.

Year	Adult	DS tag	Estimate	SE	Lower CI	Upper CI
2008	1	0	0.86	0.025	0.80	0.90
2009	1	0	0.80	0.026	0.74	0.84
2010	1	0	0.77	0.027	0.72	0.82
2011	1	0	0.75	0.031	0.69	0.81
2012	1	0	0.77	0.032	0.71	0.83
2009	1	1	0.74	0.037	0.66	0.80
2010	1	1	0.71	0.030	0.65	0.77
2011	1	1	0.68	0.033	0.62	0.75
2012	1	1	0.71	0.039	0.63	0.78
2008	0	0	0.70	0.117	0.44	0.87
2009	0	1	0.76	0.156	0.37	0.95
2010	0	1	0.68	0.105	0.45	0.84
2011	0	1	0.00	0.002	0.00	1.00
2012	0	0	0.27	0.078	0.15	0.45

Table 24. -- Estimated survival from best-fit CJS model (year + first year after tagging if juvenile (0 or 1) of adult females at South rookery, St. George Island, from 2009 to 2012. Estimated probability of sighting was 0.74 (SE = 0.057) in 2010, and 0.96 (SE = 0.016) in 2011 and 2012.

Year	Adult	Estimate	SE	Lower CI	Upper CI
2010	1	0.86	0.042	0.76	0.93
2011	1	0.77	0.029	0.71	0.82
2012	1	0.81	0.026	0.75	0.85
2010	0	0.64	0.087	0.45	0.78
2011	0	0.48	0.066	0.35	0.61
2012	0	0.54	0.056	0.43	0.65

strengths and survival, and possible behavioral differences affecting our sampling. The large numbers of 2- and 3- year-old females at South rookery is a feature noted anecdotally by observers, and documented in the return rates of tagged juveniles (Fig. 16). However, at Polovina

Cliffs the re-sighting effort has been earlier and number of tags applied on pups may be too small to positively rule out poor recruitment of these ages until more re-sighting data of the pup cohorts are collected. The asymmetric fluctuations in post-recruitment age-class strengths between sites seems to conform with some strong pup production that occurred at St. George in the mid-1990s and more pronounced decline in production that occurred between then and the period ending in 2004, when some recovery in pup production occurred (see Fig. 6 in Towell et al.). The more gradual decline that occurred over that same period on St. Paul should produce less of a shift in adult age-class strengths.

Apparent pupping rates among tagged females at both study sites have been high and comparable to the highest historic estimates (Lander 1981). None of the estimated rates include correction for adult females not seen in a given year, or for inclusion of some possibly nulliparous juveniles (Testa et al. 2010). In the former case, the degree of potential negative bias must be small, given that re-sighting rates at both rookeries are ~0.95, allowing for only a small amount of bias even if none of the missing females pupped elsewhere. In the latter case, we found that excluding females that were most likely to be juveniles (as indicated by dark whiskers or small body size at the time of capture) at South rookery, where the proportion of newly tagged females was relatively high each year, increased the apparent pupping rate by only 3-4%. Given the small size and countervailing direction of these biases, the potential for pupping rates to differ markedly from those observed is limited. Considered with the high pregnancy rates reported by Testa et al. (2010), it appears unlikely that reduced adult reproduction is contributing to the ongoing population decline.

Survival estimates depend crucially on two assumptions that we have not resolved with northern fur seals: that permanent emigration does not occur or can be estimated, and that tag loss does not occur or can be estimated. There is evidence for movement of tagged adult females that have never been seen at their original tagging site, but the effort to search other rookeries and haulouts is extremely low. Of 13 non-pup females that were never seen in subsequent years at their tagging site but were re-sighted at other locations; 8 were probably juveniles (dark vibrissae or mass < 25 kg). Of the remaining 5, 4 were seen on neighboring sections of their tagging site at Polovina Cliffs, or Zapadni rookery adjacent to their tagging site at South. One fully adult seal tagged at Polovina Cliffs in 2007 is known to have pupped at South rookery every year since then. A greater proportion of juveniles permanently emigrating from the capture site is consistent with the statistical inclusion of juvenile status at tagging in the survival models, while the permanent emigration of a small number of adults suggests that some bias in estimated survival may remain in this group. As a proportion of fully adult seals tagged, 5 seals is only 0.005 of those newly tagged, but our re-sighting effort is too low to know what the upper bound on such emigration is. Still, our estimates of adult survival appear quite low compared to historic estimates at population stability (e.g,, Lander 1981, Towell 2007). While very preliminary, this result would have important conservation implications.

Tag loss was estimated here by methods assuming loss from opposite flippers is independent, but that assumption is suspect. In southern elephant seals (*Mirounga leonina*) tagged in the hindflippers at Macquarie Island, McMahon and White (2009) demonstrated that non-independence was substantial in a situation where estimated single-tag loss rates annually were similar to our estimates for DS tags in pups at South rookery, but higher than DS tags in adults at South. In that study, the probability of losing both tags was ~2-5 times greater than predicted under an independence assumption, and resulted in negative bias of ~0.1-0.3 to age-specific survival estimates. Oosthuizen et al. (2010) argue that the effect of non-independent loss is much less where the apparent single-tag loss rate is small, as applied to their study at Marion Island where double-tag loss rates were ~0-0.05. Our observed loss rates of AN tags has been extremely small and might require no correction to survival estimates of these tag cohorts at either rookery, if Oosthuizen et al. (2010) are correct. However, Bradshaw et al. (2000) also found evidence for dependence of loss of the left and right AN tags in New Zealand fur seal (*Arctocephalus forsteri*) pups over ~5 months after birth, with ~8% higher loss of both tags than were calculated under the assumption of independence, which were close to 0. Our loss rates in pups might be higher than calculated over the longer time period of our study due to similar non-independence of loss, or could be lower given that Bradshaw et al. (2000) tagged shortly after birth and we did not apply the tags until pups were over 2 months old.

Loss of DS tags calculated for adults at Polovina Cliffs appears to decline by year 3, with rates of double-tag loss that are trivial if the assumption of independence is made. However, survival estimates suggest that loss of both DS tags was ~0.06 higher than for other tags, and there may therefore be a higher probability of losing the second DS tag. Single tag loss rates of AN tags in both pups and adults appears extremely low, and this may serve as a baseline for comparison with DS tag cohorts in future survival analyses. That a covariate for DS tags did not enter the model of adult survival at South Rookery in spite of higher estimated tag loss there is unexplained, but may result from the almost complete confounding of DS tag deployments in the first year of study and the apparent reduction in tag loss after the first year. It may also indicate higher than calculated loss of AN tags (i.e., non-independence of tag loss). The higher estimated loss of DS tags at South than at Polovina Cliffs suggests that tag loss is primarily influenced by conditions on the rookery. The higher loss from the left side in adults, and from the right side in pups at South rookery but not at Polovina Cliffs also suggests a physical mechanism for loss related to seal behavior and the conditions at the rookery, where mother-pup behavioral interactions occur. Bradshaw et al. (2000) found tag loss to be related to the rookery substrate, with larger rocks being associated with higher loss (likely due to rocks catching and pulling on tags), and tags with the lowest vertical profile against the underside of the flipper having the least loss. DS tags have a higher profile than AN tags, and South rookery has larger rocks and a much wider expanse from the sea to the cliffs than at Polovina Cliffs, allowing for more movement of the seals and more opportunity for dragging and catching of the tags on rocks. The opposite pattern of loss in pups and adults also suggests that seals orient themselves on the beach such that left tags of adults, and right tags of pups are subjected to more contact with the substrate than their opposing flippers. Nursing commonly leads to adults lying on one side, and mother pup pairs are often oriented with their ventral sides facing each other and their heads uphill. Weather conditions can also cause females to shelter their pups from wind and rain. If such conditions most commonly occur with winds from one direction on the beach, this could cause greater wear and stress on one side for mothers, and the opposite side for pups. The smaller difference between loss from opposite sides in pups would result from the shorter period between pup tagging and weaning in comparison to rookery occupancy across many seasons by nursing adult females. While this mechanism can be tested with observations, mitigation is unlikely and DS tag loss estimates will need to assume differential loss from opposite flippers at South rookery. If larger flipper tags, such as VHF radiotags were to be applied to adults at South rookery, the right flipper should be used.

Our expectation, based on the history of harvesting young males on hauling grounds, was that juvenile males would be available for resighting at younger ages than females, and allow for earlier conclusions about juvenile survival. In 2012 this was not the case, with juvenile females of the same ages appearing in equal or greater proportions than males, only delayed by a month or more, but this may be an artifact of not sampling the male hauling grounds to the same extent as we observed the rookeries. Expanding the period of re-sighting into September and October greatly improved the probability of sighting 2- and 3-year-old females. Survival of the 2009 female cohort to age 2 was technically feasible, but there is likely to be heterogeneity in individual probabilities of returning and being re-sighted in the first few years, causing a negative bias in estimated survival without sufficient data to test for re-sighting heterogeneity. Full recruitment of these cohorts to the breeding population will also improve the accuracy of those estimates.

Estimation of adult survival will be improved as we deploy more AN tags, which are clearly retained better than other tags in this study, and refine our mark-recapture analyses to better account for factors affecting the estimates. We have not attempted to fully account for tag types together with partial losses (single tags retained) and tag age, or for possible interactions of re-sighting rates or survival with other handling covariates, reproductive effort, re-sighting heterogeneity, and permanent emigration. Maintaining or expanding on the length of our re-sighting seasons annually may also allow within-season intervals to be included to identify mortality that occurs during the summer, as opposed to simple annual estimates that do little to identify where the major sources of mortality might occur (i.e., Bering Sea or North Pacific). While there are numerous caveats that must be acknowledged and respected in the interpretation of these and future results, we believe that these preliminary results have already demonstrated the value and promise of longitudinal study of marked fur seals on the Pribilof Islands.

STATUS OF THE NORTHERN FUR SEAL POPULATION AT SAN MIGUEL ISLAND, CALIFORNIA DURING 2012

by

Anthony J. Orr, Sharon R. Melin, Jeffrey D. Harris, 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 primary and secondary productivity that adversely affect abundance and availability of prey species of northern fur seals. Fur seal prey 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, northern 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).

Hookworm disease, which has decreased pup survival for the past 16 years, is also a major factor affecting the population dynamics of this species at its southernmost rookery. Here, we present the results of the 2012 northern fur seal population monitoring studies at SMI and discuss the importance of environmental influences and disease on the population trends during the past 16 years (1997-2012). We also provide information pertaining to a continuing long-term study that began in 1975 examining the condition of northern fur seal pups.

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 on 25 July, to conduct a census of pups. Daily censuses were conducted at ACV between 4 June and 21 July 2012. For the long-term comparisons, territorial bull counts were used as an index of the maximum number of breeding males, 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. Date of the census was 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. The live-pup census was conducted on 25 July at Castle Rock and on 30 July at ACV. 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. 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 several previous reports, we estimated total mortality (up to 3 months of age) 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 30 July) and 1.25 for late season mortality (12 August – 24 September)). Thus, the total births and pup mortality reported will not agree with those in some 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. Additionally, fur seals are smaller than CSLs, so they are likely to disappear faster. 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 (25 July). Pup mortality at Castle Rock was a minimum estimate because only one survey was performed and the number of carcasses that decomposed completely or disappeared was not determined. A correction factor was not applied to counts at Castle Rock because the CSL mortality correction factor would not be appropriate based on a single survey and different disappearance rates due to substrate.

Pup Condition

We sexed, tagged, measured (length), and weighed pups in September 2012 (n = 200) 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 2012. 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 2011 with 2012 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 2012 were not affected by EN conditions.

Sightings of Marked Individuals

Surveys of tagged northern fur seals were conducted from a mobile blind in ACV during (5 July – 13 August; n = 15). 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. Identification of tagged animals was also recorded opportunistically when observers were engaged in other activities from 4 July through 4 October.

Tag Loss Assessment

Because tag loss is a problem with northern fur seals, we began a study in 2006 to evaluate different types of tags for retention and readability. During the past 6 years, we tagged pups with a jumbo pink Roto tag on one foreflipper and a silver Monel tag on the other foreflipper in order to determine if one tag type is superior to the other. Quantitative comparison of tag loss by type (i.e., pink Roto vs. silver Monel; Fig. 17) has not been conducted due to the low recruitment of individuals from the 2006 to 2008 cohorts and the natural history of the species (i.e., they do not return to the island in sufficient numbers until after their third birthday when 70% of the surviving cohort is expected ashore), but some aspects of the study will be discussed.

Figure 17. -- Northern fur seal tagged with pink Roto (left flipper) and silver Monel (right flipper) tags.

Disease Screening of Adult Females

Between 16 and 24 September 2012, adult females were sampled for screening of diseases, specifically herpesviruses, *Coxiella burnetti*, and Phocine distemper virus (PDV) in collaboration with The National Marine Fisheries Service's Marine Mammal Health and Stranding Response Program, The Marine Mammal Center, and The National Marine Mammal Laboratory's Alaska Ecosystem Program. The objective was to establish baseline presence of these pathogens in the population at SMI for comparison to Alaska populations, and evaluation as a source population for the presence of herpesvirus in CSLs at SMI.

RESULTS

Census

The maximum number of territorial bulls counted in ACV was 178, representing a 20% increase from 2011 (Fig. 18). However, the bull count was 30% below that observed in 1997, the highest recorded (n = 253; Fig. 18).

The first live pup at ACV was observed on 4 June. The median pupping date was 7 July. The mean median pupping date between 1998 and 2011 was 6 July (SD = 3.2). The mean number of live pups was 1,692 (SE = 22.5) at ACV, and 1,163 (SE = 2.0) at Castle Rock (Table 26).

At ACV, total births were 4% below the record high estimated in 1997 (Table 26; Fig. 19). At Castle Rock, total births were 4% higher than the peak in 2011. Over the past 16 years, only in 2010 (n = 3,304) and 2012 (n = 3,346) have total births surpassed those in 1997 (n = 3,221; Table 26; Fig. 19). The number of births has increased 24.0 % at ACV, 28.1% at Castle Rock, and 25.4% in SMI total since the 1998 EN (Fig. 19). At ACV, early season (birth to ~1 month old) pup mortality rates since 1997 have ranged from 6% (in 2001) to 43% (in 2007; Table 26). At ACV, pup mortality rates from birth to 3 months of age ranged between 6% (in 2001) and 82% (in 2009); in 2012 the mortality rate was 31% (Table 26).

Pup Condition

During 2012, estimated mean (±standard error) mass of female (9.9 kg ± 0.1) and male (11.2 kg ± 0.1) pups were lower (although not significantly) than the long-term average for both females ($\text{female}_{1975\text{-}2011} = 10.5 \pm 0.1$, $(|t_{obs\ ♀}| = 0.45) < (t_{0.05(30)} = 2.04)$; Fig. 20) and males ($\text{male}_{1975\text{-}2011} = 11.8 \pm 0.1$; $(|t_{obs♂}| = 0.45) < (t_{0.05(30)} = 2.04)$; Fig. 19).

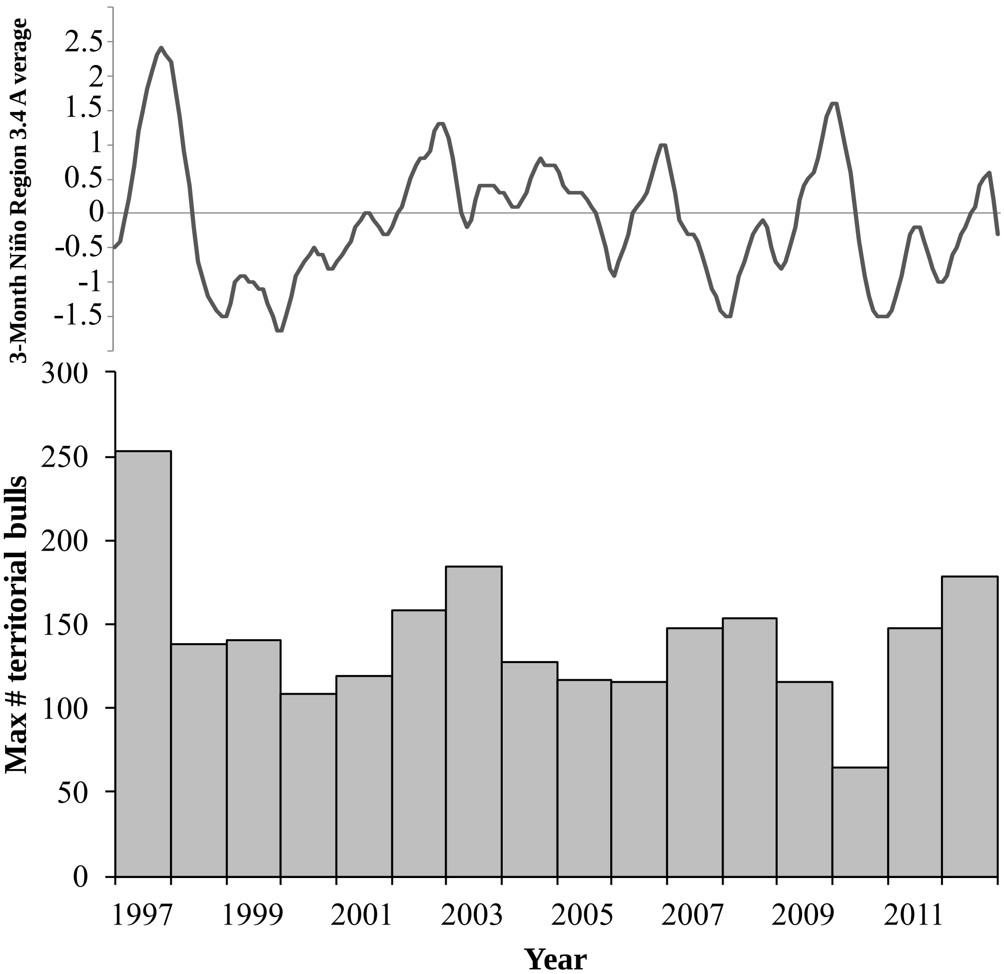


Figure 18. -- Maximum number of territorial northern fur seal bulls at Adams Cove on San Miguel Island, California, 1997-2012 (bar graph) with the Oceanic Niño Index (ONI; line graph), a running 3-month mean sea-surface temperature (SST) anomaly for the Niño 3.4 region (i.e., 5°N-5°S, 120°-170°W) that is used to identify El Niño (warm; positive values) and La Niña (cool; negative values) events in the tropical Pacific. Events are classified as "Weak" (0.5 to 0.9 SST anomaly), "Moderate (1.0 to 1.4 SST anomaly), and "Strong" (≥ 1.5 SST anomaly) (Golden Gate Weather Services 2013, National Weather Service 2013).

Table 26. -- Summary of pup counts of northern fur seals at Adams Cove and Castle Rock (rookeries of San Miguel Island), 1997-2012. Total pup mortality (mortality during early season + late season) is representative of the number of dead pups up to 3 months of age.

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)	1637	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)
2012	1,692 (22.5)	436	2,128	228	664 (31.2)

Table 26. -- 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)	1,167	---	---
2011	1,150 (8)	19 (2)	1,169	---	---
2012	1,163 (2.0)	55	1,218	---	---

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

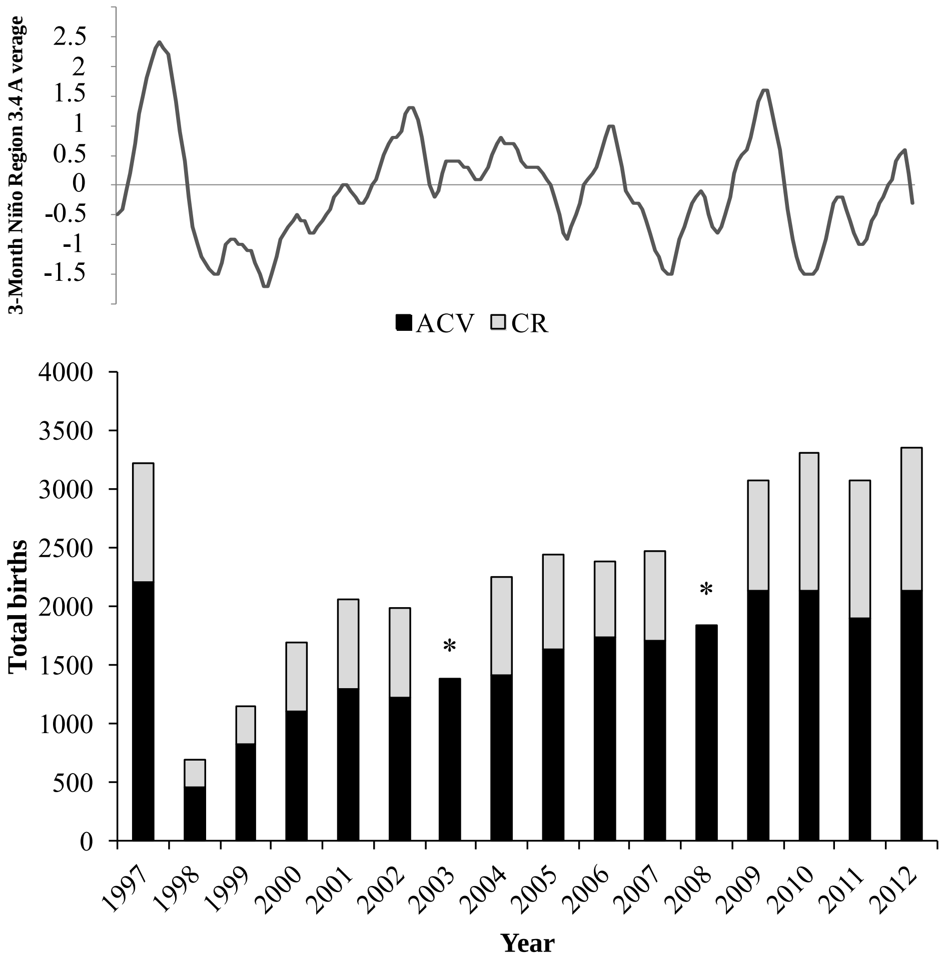


Figure 19. -- Total number of births (i.e. number of live pups + number of early-season dead pups) of northern fur seal pups at Adam's Cove (ACV) and Castle Rock (CR) rookeries during 1997 – 2012. Asterisk (*) indicates no counts at Castle Rock. Included is the Oceanic Niño Index (ONI; line graph), a running 3-month mean sea-surface temperature (SST) anomaly for the Niño 3.4 region (i.e., 5°N-5°S, 120°-170°W) that is used to identify El Niño (warm; positive values) and La Niña (cool; negative values) events in the tropical Pacific. Events are classified as "Weak" (0.5 to 0.9 SST anomaly), "Moderate (1.0 to 1.4 SST anomaly), and "Strong" (≥ 1.5 SST anomaly) (Golden Gate Weather Services 2013, National Weather Service 2013).

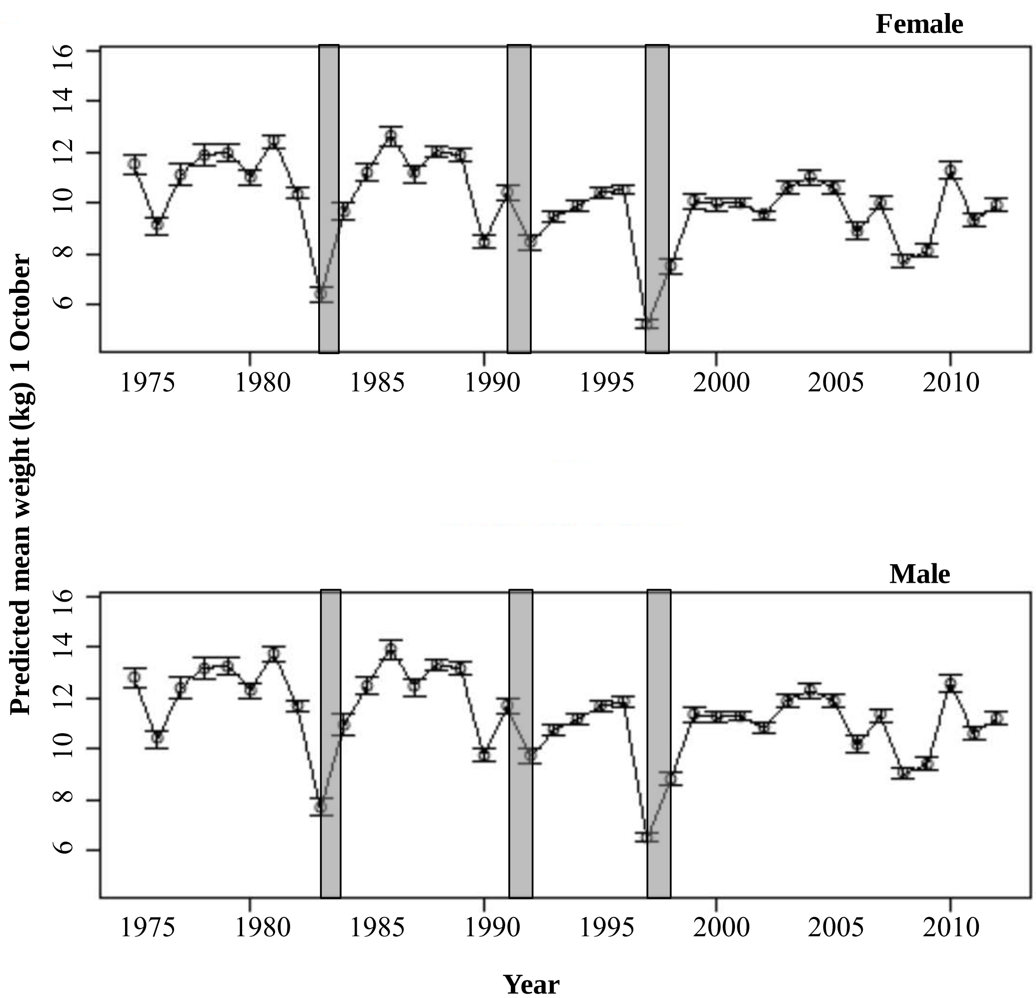


Figure 20. -- Mean mass (kg) of northern fur seal pups at 3 months of age at San Miguel Island, California, 1975-2012, adjusted for a weighing date of 1 October each year. The masses are adjusted because pups were weighed on different dates throughout the time series. The correction factor is based on growth rates calculated for years when pups were weighed in September and October. Shaded areas indicate “strong” El Niño events.

Sightings of Marked Individuals

During 2007 and 2008, 98 animals were unintentionally tagged with unique Monel tags but duplicate Roto tags. In previous reports (i.e., Orr et al. 2011, 2012) data from these individuals were not included. However, because information pertaining to these animals is important and because they could be indentified using their Monel tags, we included their data in this report. Fur seals that were tagged as pups were resighted in ACV during the 2012 breeding season (females = 275, males = 118; Fig. 4). Tagged females ranged in age from 2 to 18 years old (Fig. 4). Females sighted with pups were 4 to 17 years of age (n = 89). Seven-years-old (22%) was the modal age of tagged females with pups (Fig. 5). Tagged males ranged in age from 2 to 13 years old (Fig. 4). Territorial males were between 7 and 12 years old (n = 25; Fig. 5). Nine-year-old males had the highest number of territories among tagged bulls (Fig. 5). Only a small proportion (7%) of tagged females and no (0%) tagged males older than 14 years of age were seen. There were no tagged individuals from the 1997 (15-year-olds) EN cohorts seen during 2012 (Figs. 4 and 5).

Disease Screening of Adult Females

All adult females (n = 30) were negative for *Coxiella burnetti* (PCR) and PDV (PCR). Thirteen of the 30 animals tested positive for herpesvirus (OtHV-4) using a novel qPCR assay. To validate the results of the qPCR assay, a specific conventional PCR for OtHV-4 with product sequencing was used. Seven animals were confirmed as positive to OtHV-4. The other six animals had lower viral loads and these samples will be reanalyzed. The results for *Coxiella burnetti* (serology) and PDV (serology) are not yet available.

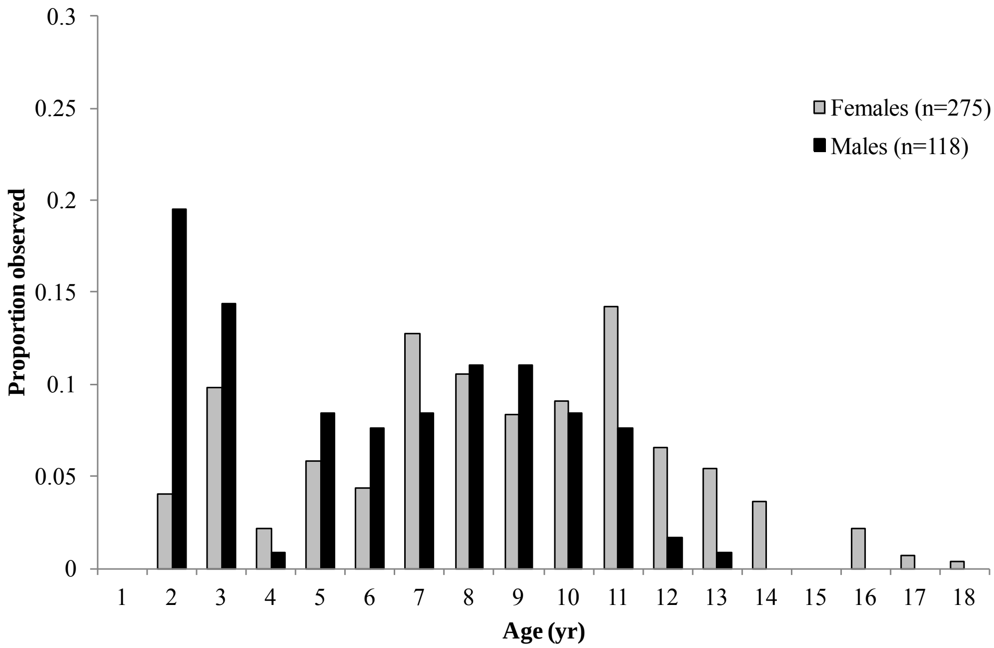


Figure 21. -- Age distribution of female (n = 275) and male (n = 118) northern fur seals that were tagged as pups since 1991 and re-sighted at San Miguel Island, California, during the reproductive season in 2012.

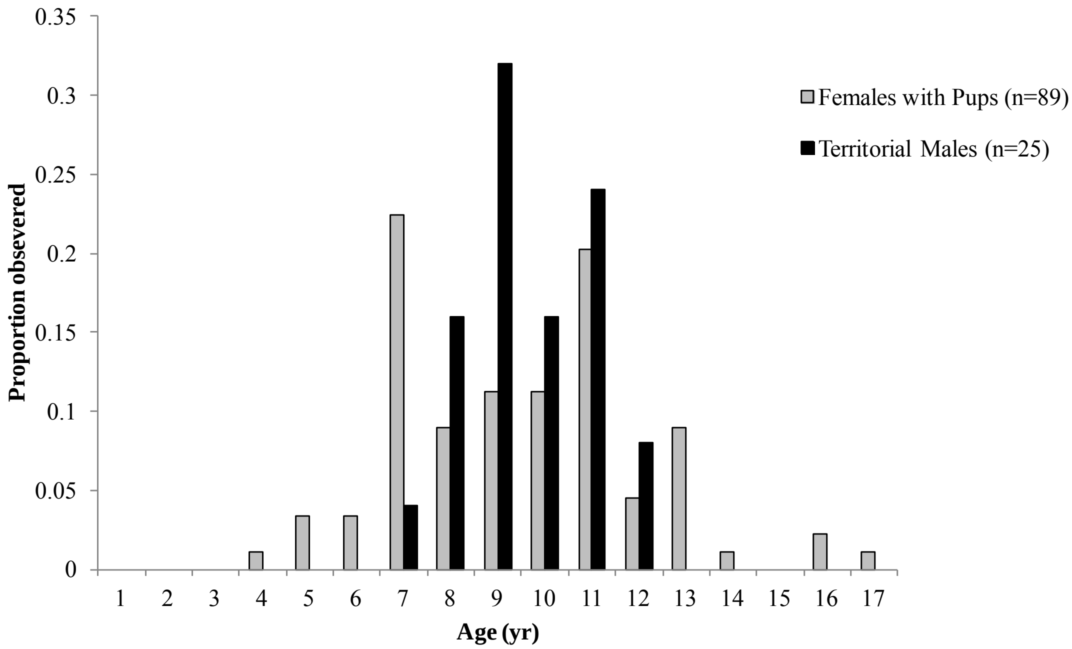


Figure 22. -- Age distribution of tagged adult female (n = 89) and male (n = 25) northern fur seals observed as reproductive at San Miguel Island, California, during 2012.

DISCUSSION

Census

Although the number of territorial bulls in ACV remained lower than the historical record high number that was attained in 1997, there was a positive trend in number during the past couple of years. 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 influenced potentially territorial males from returning to SMI. La Niña conditions in 2011 may have influenced the rebound in the number of territorial males counted in 2011 and 2012.

Pup Condition

Pup production in ACV during 2012 was only 3.8% below the record high in 1997. This represents the second highest (only nine fewer individuals from 2010) pup count since 1997. At Castle Rock, a record-setting number of pups was counted during 2012, surpassing the pup production of 1997 and the previous high set in 2011. This contributed to the highest recorded number of pup births at SMI since the colony (i.e., both rookeries combined) was discovered in 1968. The total pup population growth rates at ACV and Castle Rock have exceeded 20% from 1998 to 2011, which is encouraging considering pup mortality estimates as high as 82% (in 2009) during particular years of that period. Additionally, the masses of pups (both females and males) in 2012 were not significantly different than the long-term average.

Sightings of Marked Individuals

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 adequately 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 2012. The highest number of tagged animals resighted was from the 2005 cohort for females and the 2010 cohort for males, indicating that apparent survival for these cohorts was high. More resight effort was exerted during 2012 particularly during August, which may account for the higher numbers of 2- and 3-year-olds being resighted because they usually return to the colony during the latter part of the season. Of special note, an adult female tagged “G153” in 2010 (tooth-aged as 2 years old at the time) on St. George Island, Alaska was seen at SMI during several resighting surveys during August 2012, indicating inter-mixing of animals from the northern and southern colonies of this species’ range is still occurring.

Accounting for the biases associated with tag data, females can potentially live to 18 years of age, first breed when they are approximately 3 years old, and continue to have pups until they are 12 years old. The modal age of territorial males was 9 years. This is indicative that males must survive longer than females before breeding, attain particular morphological characteristics, and display a number of behavioral and physiological factors in order to mate at all (Gentry 1998). The oldest tagged males were only 13 years old; males as old as 12 years defended territories. These findings imply that males do not live as long as females. However, they might also be indicative that males do not return to the island to defend a territory when they get too old. Gentry (1998) noted that males on St. George Island spent a relatively small amount of their lives attempting to breed; most (75%) were seen on rookeries for only one season before they disappeared permanently. In that study, two males reappeared for eight or more seasons, but all others spent 2-7 years on territory; the mean for all males was 1.45 years of breeding.

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 six 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 prevalence of hookworm disease in the population has contributed to the high mortality of pups during the past 16 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 events), disease has an influential role in the population dynamics of the northern fur seals at SMI.

Tag Loss Assessment

Tag loss has plagued demographic studies of northern fur seals and other fur seal species. In 2006, we initiated a study to evaluate different types of tags for northern fur seals. We planned to test different tag combinations on 4-year cycles. Pink Roto tags were attached to one foreflipper and were maintained as the default tag because they have been used the most during the tagging program for this species at SMI, and if tag loss could be estimated by using new tag types, historical data could be corrected for tag loss. The problems with this tag are threefold: (1)

fading or wearing of the numbers with time such that alphanumeric digits are illegible; (2) tag loss from breaking; or (3) tearing out of the flipper. For the first evaluation, we selected Monel tags as the second tag type. This tag type was commonly used in the early years of tagging studies on the Pribilof Islands (York 2006), but because they are difficult to read from a distance they were replaced with the larger Roto tags. However, Monel tags address the shortcomings of the Roto tags. The tags are made of corrosion-resistant metal and the tag numbers are engraved so that the numbers do not fade or wear over time, the metal does not break or crack, the puncture hole is small, and the tag is bent and crimped back onto itself into a loop so it is less likely to come out of the flipper. Therefore, tag loss should be lower for this tag type and the numbers should be legible throughout the life of the animal.

Our comparison of the retention and legibility of Monel versus pink Roto tags was delayed due to low survivorship of individuals in the first few cohorts of this study and because pups from the last 2 years have not yet returned to the island in large enough numbers to provide sufficient samples sizes for analysis. However, in 2012 we did observe a greater number of animals with Monel tags and the tags are harder to read compared to Roto tags because of their smaller size, less contrast between the engraved number and rest of tag, and more glare on the tag during sunny conditions. We also had evidence that some Monel tags were lost. However, we cannot yet evaluate whether this tag loss for Monel tags is greater than that of pink Roto tags. In 2012, we began using digital-SLR cameras equipped with 42× zoom lenses to assist with reading tags on fur seals. This technique has increased the probability of reading both tag types and shows promise as a tool to improve the number of tags resighted each year. Once the Monel versus pink Roto tag evaluation is complete, we will initiate the second phase of the study comparing a temple-type plastic tag with the pink Roto tag.

Disease Screening of Adult Females

As part of a range-wide study of diseases in the northern fur seal populations, we discovered that the SMI population currently does not have the *Coxiella burnetti* virus or PDV determined using PCR, suggesting that these pathogens are not currently prevalent in the population. However, results of serological tests for these pathogens are pending. Herpesvirus OtHV-4 is in the population, but further tests need to be conducted to determine its prevalence.

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APPENDIX A

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

Table A-1. -- 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 2012. 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	15	17													32
3	86	30													116
5	85	7													92
Kitovi [b]															
2	(7) 8	4	17	12	12										60
3	(11) 12	29	33	48	36										169
5	(22)2	9	4	4	57										98
Reef															
2	22	30	16	8	25	28	2	18	8	8	5				170
3	59	82	34	52	43	72	0	66	30	23	4				465
5	25	19	18	24	55	16	6	20	21	46	28				278
Gorbatch															
2	26	13	24	10	22	13									108
3	74	43	61	13	63	51									305
5	145	14	23	29	4	3									218
Ardiguin															
2	7														7
3	50														50
5	7														7
Morjovi[c]															
2	(17) 11	17	11	13	25	11									105
3	(45) 49	44	44	26	57	37									302
5	(38) 66	8	19	8	21	16									176
Vostochni															
2	11	4	6	15	7	15	9	12	7	6	3	18	29	25	167
3	42	21	33	56	37	61	34	36	30	13	26	45	109	61	604
5	43	3	6	21	21	12	10	6	9	2	9	33	68	94	337
Little Polovina															
2	0														0
3	0														0
5	121														121
Polovina															
2	12	11													23
3	67	40													107
5	149	19													168
Polovina Cliffs															
2	19	5	7	9	10	14	15								79
3	41	21	26	48	44	67	49								296
5	12	4	12	3	10	15	9								65
Tolstoi															
2	7	14	18	14	15	25	22	27							142
3	25	20	25	36	34	51	46	49							286
5	4	6	8	8	12	22	13	126							199
Zapadni Reef															
2	46	12													58
3	93	36													129
5	47	88													135
Little Zapadni															
2	6	14	17	26	15	21									99
3	14	32	42	40	35	46									209
5	7	13	15	7	13	77									132
Zapadni															
2	12	19	35	20	30	30	42	22							210
3	22	31	33	40	42	54	36	40							298
5	94	9	13	15	18	33	29	160							371

[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.

Table A-2. -- Number of northern fur seal pups sheared on each sampled rookery of St. Paul Island, Alaska, 2012.

	Section															
Rookery	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Lukanin		209	80													289
Kitovi[1]	16	24	61	82	88	78										349
Reef[2]		157	265		149	112	208		176	93	31	3				1,194
Gorbatch		207	141	178	32	211	127									896
Ardiguen		106														106
Morjovi[1]	102	120	109	106	66	143	91									737
Vostochni		87	74	81	129	79	147	80	82	73	12	52	90	247	149	1,382
Polovina		168	106													274
Little Polovina																
Polovina Cliffs		115	56	71	126	119	192	118								797
Tolstoi		92	78	82	121	120	186	184	186							1,049
Zapadni Reef		390	114													504
Little Zapadni		43	114	144	136	121	177									735
Zapadni		82	104	120	145	153	192	128	135							1,059
Sea Lion Rock																
Total																9,371

[1]Section 0 corresponds to 2nd Point South on Morjovi and Kitovi Amphitheater.
[2] Section 7 was combined with Section 6 and Sections 2 and 3 were combined due to a logistical error.

Table A-3. -- 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, 1985-2012. 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
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	--	--	--	--
2012	3,336	3,657	96,828	1,260	13	3,624[2]	852	1,055	16,184	155	6	497[2]

[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 A-1 (FSI 2008-09) for details on Vostochni, Section 14.

Table A-4. -- Number of dead northern fur seal pups counted by section on the sampled rookeries of St. Paul Island, Alaska, 2012.

		Section															
Rookery	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	necropsies	Total
Lukanin	8/16	79	56														135
Reef	8/15	62	66	48	48	3	103		65	49	30	4				41	519
Morjovi	8/14	(25)58	38	36	26	56	18									5	262
Little Zapadni	8/16	14	32	37	54	69	85										291

Table A-5. -- Number of northern fur seal pups sheared on each rookery of St. George Island, Alaska, 2012.

	Section					
Rookery	1	2	3	4	5	Total
South	105	148	144			397
North	110	138	154	73	53	528
East Reef	159					159
East Cliffs	272	140				412
Staraya Artil[1]	116					116
Zapadni	45	106	55			206
Total						1,818

[1] Sections 1 and 2 were combined.

Table A-6. -- Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 2012.

		Section					
Rookery	Date	1	2	3	4	5	Total
South	8/17	22	34	34			90
East Reef	8/16	59					59
Staraya Artil[1]	8/16	42					42

[1] Sections 1 and 2 were combined

Table A-7. -- Number of dead northern fur seals counted that were older than pup, Pribilof Islands, Alaska, 1977-2012. 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
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
2012[m]	15	37	0	6	15	43

[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 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.
[m] Teeth were not take from 2 males and 2 females on Reef, or from 1 female and 2 males on Little Zapadni and 1 male on Morjovi.

APPENDIX B

Scientific staff engaged in northern fur seal field research in 2012

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

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ABL – Auke Bay Laboratory, Alaska Fisheries Science Center, Juneau, AK
ANSEP – Alaska Native Science and Engineering Program
DVM – Contract Veterinarian
MMC – Marine Mammal Center, California
NMFS – National Marine Fisheries Service
NMFS-AR – National Marine Fisheries Service, Alaska Region
NMFS-SWR – National Marine Fisheries Service, SW Region
NMML – National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA
OAI – Ocean Associates, Inc.
PISP – Pribilof Island Stewardship Program
SGTC – St. George Traditional Council
TGSP – Tribal Government of St. Paul, AK
UAA – University of Alaska Anchorage
USN – U.S. Navy
USFWS – U.S. Fish & Wildlife Service, Alaska Maritime Wildlife Refuge, Homer, AK
WPI – Wildlife Pathology International

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