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Fur Seal Investigations, 2015-2016

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 (St. Paul and St. George) and Bogoslof Island in the eastern Bering Sea, and on San Miguel Island and the Farallon Islands off the coast of California. This report summarizes these monitoring efforts in 2015-2016.

Population parameters monitored in 2015 and 2016 on the Pribilof Islands included the size of the subsistence harvest and the number of adult male fur seals. Biennial estimates of the number of pups, including mortality, size, and sex ratio were made in 2016. On St. Paul Island, annual counts of harem males were nearly constant from 2014 to 2016. On St. George those counts increased 13% between 2014 and 2015 and decreased 9% from 2015 to 2016. The total estimated number of pups born on St. Paul Island in 2016 was 80,641 (SE = 717), a 12% decline from 2014 ($P < 0.01$) after a loss of over half the annual production from 2000 to 2010. On St. George, the estimate was 20,490 (SE = 460), an 8% increase from 2014 and continuation of the moderate upward trend that began around 2006. Pup mortality at one month of age was approximately 3% on St. Paul and 1% on St. George. The subadult male harvest on the Pribilof Islands was 373 and 345 in 2015 and 2016, respectively. Harvests of 57 and 46 male pups were made in 2015 and 2016 on St. George Island.

From 2007 to 2016, 883 adult and subadult female fur seals were flipper-tagged in the fall at Polovina Cliffs rookery, St. Paul Island. From 2009 to 2016, 536 were tagged at South Rookery on St. George Island. One thousand, two-hundred and fifty-five female pups were tagged at Polovina Cliffs from 2008 to 2016 and 4,011were tagged from 2010 to 2016 at Zapadni

Reef rookery on St. Paul Island; 8,691pups of both sexes were tagged from 2009 to 2016 at South Rookery, St. George. Re-sightings were made in July-August every year after the initial tag deployments, and in Sept.-Oct. 2012-2016 for juveniles at South and Zapadni Reef rookeries. Tag loss is a significant problem in survival estimates, but using tags with the lowest estimated loss rate (~1% annually) the average estimated survival at Polovina Cliffs was 0.80 (95% CI = 0.76-0.83); at South Rookery it was 0.81 (95% CI = 0.78-0.84). Pupping rates among adult females were high (0.80-0.90 at Polovina Cliffs and 0.80-0.88 at South), consistent with recent and historic estimates of pregnancy rates in northern fur seals. Age at first pupping was approximately 1 year younger than estimated in the 1950s and 1960s, based on age-specific rates among the tagged pup cohorts. Estimated survival of three pup cohorts to a recruitment age of 4 years ranged from 0.18 to 0.21, with 95% confidence intervals in the range of 0.15-0.21. Models incorporating these estimates produce an annual rate of decline much greater than observed during the study period, suggesting significant biases in survival estimates that may be due to emigration of tagged seals from the study sites.

At San Miguel Island the index count of territorial bulls at Adams Cove was 111 and 110 in 2015 and 2016, respectively. These were 50% less than the highest historical count of 265 obtained in 2014. In 2015 and 2016, the total numbers of pups born at Adams Cove were estimated at 2,035 and 2,325. At nearby Castle Rock those estimates were 998 and 1,709. Pup mortality from birth to 3 months was 17% and 29% in 2015 and 2016 at Adams Cove. At Castle Rock pup mortality in those years was 7% and 6%. Pup weights standardized to 1 October at Adams Cove were ~35% below the long-term average in 2015, but near that average in 2016. Counts from aerial photographs of the Farallon Islands, California, continued to increase from the first counts in 2013, reaching 1,126 pups and 2,238 in all age-sex categories in 2016.

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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 (Fig. 4) in the southeastern Bering Sea, and San Miguel Island (Fig. 5) and the Farallon Islands off California. The rookeries at the Farallon, San Miguel and Bogoslof Islands were probably colonized in 1996 (Pyle et al. 2001), 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 decline of ~6% annually (Towell et al. 2006), with a short period

of stability from 2010-2014. The smaller population at nearby St. George declined to less than 30% of the peak, but has been stable to slowly increasing since 2004. Commercial harvesting of fur seals was discontinued on St. George Island in 1973 and on St. Paul Island in 1984. A small subsistence harvest of juvenile male fur seals by Alaska Natives continues on the Pribilof Islands, managed under regulations promulgated by National Marine Fisheries Service (NMFS). 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 Marine Mammal Laboratory (MML) 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 the period 2015-2016, including the most recent biennial estimate of pup production on the Pribilof Islands. In addition, the methods and progress of MML's recent study of fur seal demographics at three Pribilof rookeries based on longitudinal study of tagged seals is described. Research by the MML on northern fur seals in 2015-2016 was conducted under Marine Mammal Protection Act Permit No. 14327-01.

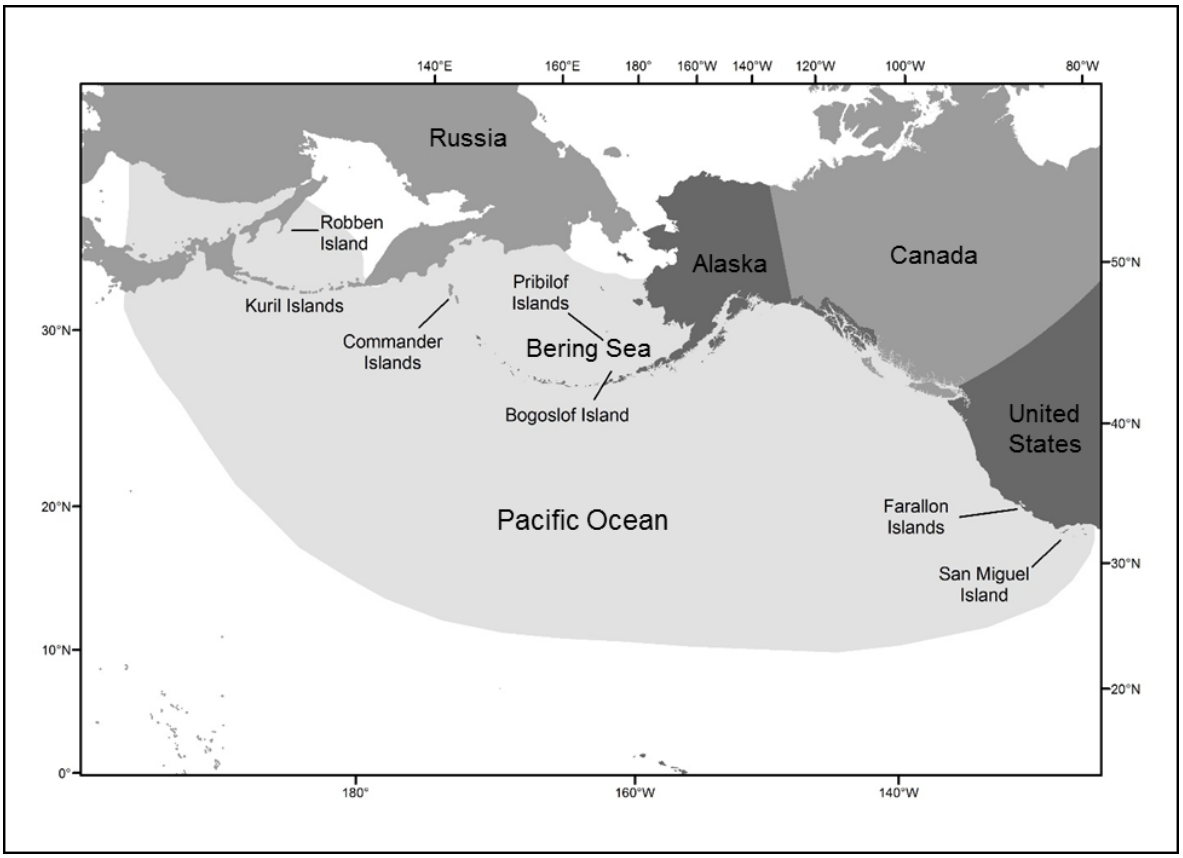

Figure 1.--Range of northern fur seals and locations of their breeding colonies.

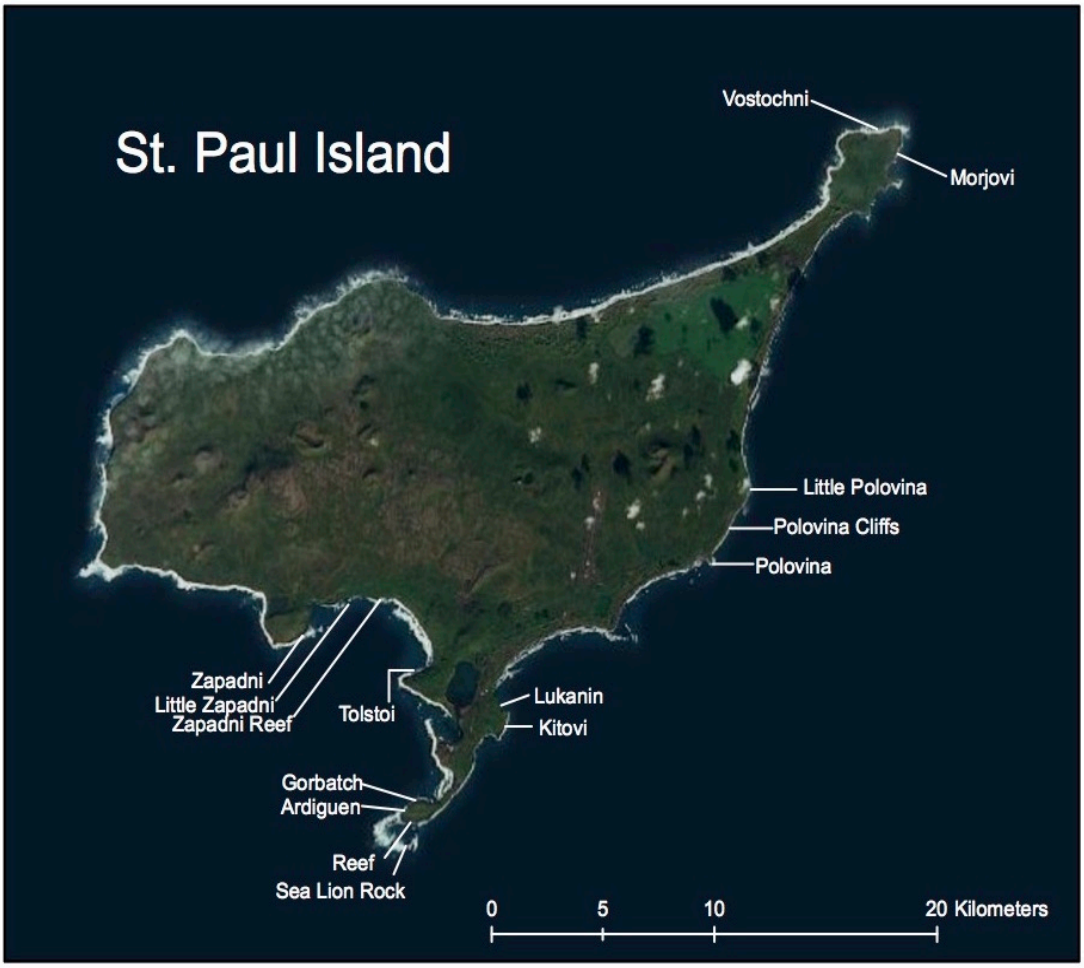

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Figure 2. -- Location of northern fur seal rookeries on St. Paul Island, Alaska.

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

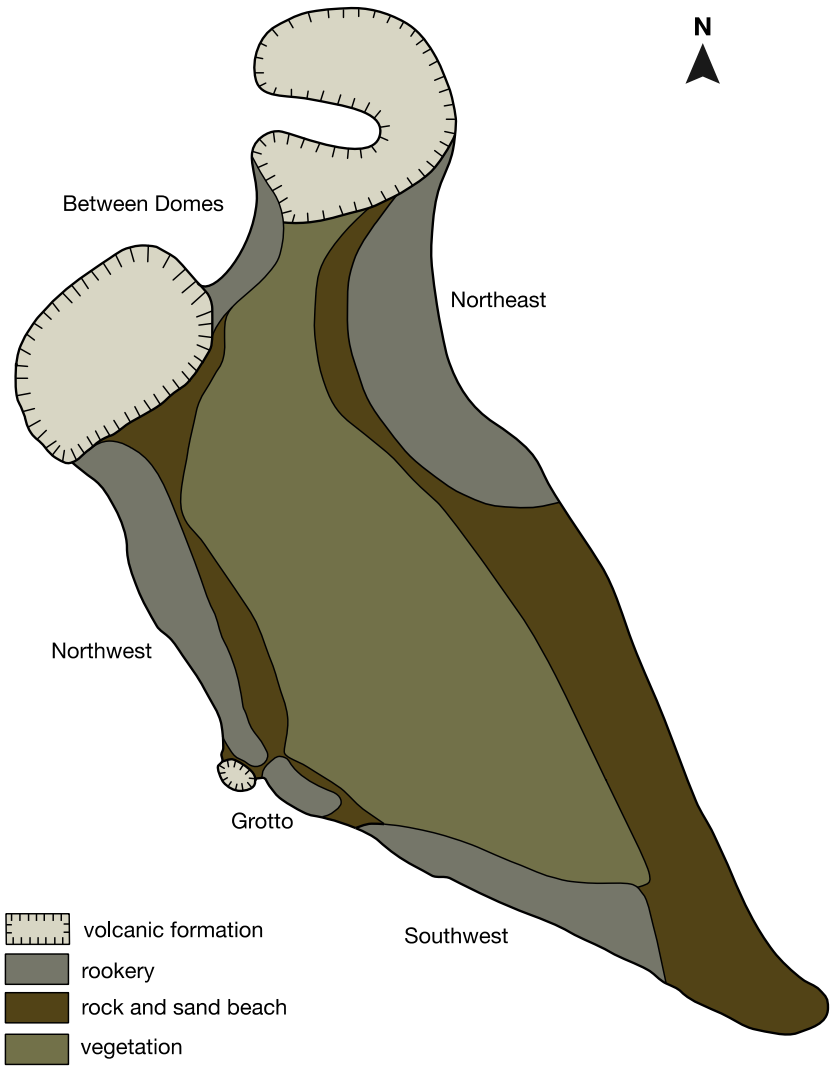


Figure 4. -- Location of northern fur seal rookeries on Bogoslof Island, Alaska.

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

POPULATION ASSESSMENT OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2015 - 2016

by

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

John L. Bengtson, and Michael Williams

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

METHODS

Population characteristics monitored in 2015 on St. Paul and St. George islands included the size of the subsistence harvest and counts of adult males. The subsistence harvest, numbers of adult males and pups, and mortality rates of fur seal pups were monitored in 2016.

The subsistence harvest was monitored for the number of sub-adult males and male pups, killed for consumption, any other fur seals inadvertently killed, injured or compromised (e.g., hyperthermia) by harvest activities, harvest waste, sample collection, entanglement, and any unusual conditions among animals on targeted haulouts. The Aleut Community of St. Paul Island, Tribal Government's Ecosystem Conservation Office provides the primary subsistence

harvest monitoring and reporting on St. Paul Island under a grant from the National Marine Fisheries Service (NMFS). The Traditional Council of St. George Island's Kayumixtax Eco-Office, also under a grant from NMFS, monitors and reports the subsistence harvest of northern fur seals on St. George Island. NMFS staff independently monitored a sample of harvests on both islands. NMFS and independent contractors monitored subsistence harvests of pups on St. George Island during the entire 10-week season (15 September through 30 November) in 2015 and 2016.

Adult male fur seals were visually counted by section for each rookery on St. Paul Island from 9 to 14 July 2015 and 10 to 19 July 2016 (Appendix Tables A-1 and A-2, respectively**)** and on St. George Island from 13 to 15 July 2015 and 10 to 12 July 2016. 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 four sample rookeries and the numbers of live pups were estimated on 13 rookeries in August 2016 using the shear-sampling method (York and Kozloff 1987, Antonelis 1992). Tooth samples (usually canines) were collected from dead fur seals older than pups whenever possible. Additionally, sample rookeries and adjacent beaches of St. Paul were surveyed for dead fur seals older than pups during surveys for dead pups in August 2016. 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 make the light underfur conspicuous to later observers. The number of pups sheared on each rookery was approximately 10% of the last estimate of pup production for the sample rookeries in 2014. Shear marks were allocated proportionally on each rookery by section (Appendix Table A-3) according to the fraction of the rookery total for breeding males counted

in each section of the sampled rookery. The ratio of marked to unmarked pups was determined by two observers scanning (with the aid of binoculars when necessary) on two occasions for each rookery from 12 to 25 August. Each observer counted marked and unmarked pups independently to ensure that the entire rookery was well sampled. Each sampling day was considered an independent replicate; the variance was computed for each rookery based on these replicates (York and Kozloff 1987). Little Polovina rookery was not sampled due to the absence of territorial males with females since 2011. In the past, the number of pups born on Little Polovina rookery was estimated from a regression of total pups born versus numbers of breeding adult males. However, no breeding males were counted on Little Polovina rookery in 2016. Dead pups were counted from 16 to 19 August on four rookeries**.** The estimated variance for total pups born was calculated using ratio estimation techniques (Cochran 1977).

The number of pups born on St. George Island was estimated from the shear-sampling method conducted on all rookeries from 15 to 25 August 2016 in the same manner as applied on St. Paul Island. The ratio of marked to unmarked pups on each rookery was determined by two observers from 18 to 21 August and again from 22 to 25 August. Dead pups were counted on three rookeries from 18 to 21 August 2016.

RESULTS AND DISCUSSION

Harvest

A total of 312 and 308 sub-adult male seals were harvested for subsistence on St. Paul Island in 2015 and 2016, respectively (Table 1). On St. George Island, 61 subadult male seals were taken in the subsistence harvest in 2015 and 37 were killed in 2016 (Table 2a). Two females were killed in 2015 and one female in 2016 on St. Paul Island; no females were killed on

Table 1. -- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvests on St. Paul Island, Alaska, in 2015 and 2016.

2015			2016		
Date	Rookery	Number	Date	Rookery	Number killed
July 7	Polovina	19	June 23	Zapadni Sands	23
July 9	Zapadni Reef	26	July 1	Polovina	28
July 10	Zapadni Sands	23	July 15	Polovina	22
July16	Polovina	35	July 21	Zapadni Sands	25
July 17	Zapandi Sands	18	July 22	Polovina	24
July 23	Polovina	31	July 29	Lukanin	17
July 24	Lukanin	36	July 29	Polovina	10
July 30	Zapadni Sands	36	August 4	Zapadni Sands	51
July 31	Gorbatch	27	August 5	Polovina	49
August 6	Polovina	5	August	Zapadni Sands	60
August 7*	Morjovi	58			
Total		314	Total		309

* Includes 2 females.
** Includes 1 female.

Table 2a. -- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvest drives on St. George Island, Alaska, in 2015 and 2016.

2015			2016		
Date	Rookery	Number killed	Date	Rookery	Number killed
July 7	North	10	July 18	East	4
July 16	East	10	July 21	East	6
July 23	North	10	July 29	East	5
August 3	East	8	August 3	East	6
August 5	Zapadni	13	August 4	Zapadni	7
August 7	North	10	August 8	East	9
Total		61			37

Table 2b. -- Date, location, and number northern fur seal pups killed in subsistence harvest drives on St. George Island, Alaska, in 2015 and 2016. A suffix of S# at the end of the site name indicates historical section designations within a rookery.

2015			2016		
Date	Location	Number killed	Date	Location	Number killed
September 24	Old Dock	5	September 22	Old Dock	4
October 2	Harbor	4	September 28	East Reef W	8
October 6	East Reef W	6	October 7	East Reef	3
October 9	Old Dock	5	October 14	East Reef	5
October 16	East Reef W	6	October 19	North S2	2
October 19	North S3	6	October 26	East	6
October 23	Harbor	3	November 3	Zapadni S1	3
October 30	Harbor	1	November 14	East	6
November 6	East Reef	4	November 18	North	6
November 18	East Reef & Cliffs	3	November 21	East	3
November 20	East Reef	3			
November 24	East Cliffs	6			
November 25	East Reef	5			
Total		57			46

St. George Island. All females taken were consumed and included as part of the subsistence harvest.

Whenever possible, northern fur seal pups on St. George Island were harvested in areas away from the rookeries to minimize disturbance to adult fur seals. Those areas include the old dock (Old Dock) between Zapadni rookery and the working harbor, and the inner arm of the working harbor (Harbor) north of Zapadni rookery (Table 2b, Fig. 3). Pup harvests also occur at other gathering places near, but distinct from rookery areas such as a small pup hauling area west of East Reef (East Reef W, Table 2b, Fig. 3). A total of 57 male northern fur seal pups were harvested for subsistence on St. George Island during the 10-week season in 2015 and 46 were harvested in 2016 (Table 2b).

Adult Males Counted

The count of territorial males with females (Class 3 or harem males) on St. Paul Island decreased by less than 1% between 2014 and 2015 and increased by less than 1% between 2015 and 2016 (Tables 3 and 4; Appendix Table A-4). The count of harem males on St. George Island increased 12.9% between 2014 and 2015, and decreased 9.2% between 2015 and 2016 (Tables 3 and 4; Appendix Table A-4). Owing to the larger size of the population on St. Paul Island, the Pribilof Islands total for harem males increased by 2.5% between 2014 and 2015 and decreased 1.4% between 2015 and 2016.

Number of Pups Born on St. Paul Island in 2016

The estimated total number of pups alive on St. Paul Island at the time of marking in 2016 was 78,460 (SE = 627) (Tables 5 and 6). The number of dead pups as counted by section on four sample rookeries of St. Paul Island is given in Appendix Table A-5: the total estimated dead on all rookeries on St. Paul was 2,181. The estimated mortality rate for late August was

Table 3. -- Number of adult male northern fur seals counted by rookery and behavior class (2 = territorial without females, 3 = territorial with females, 5 = non-territorial on hauling grounds), Pribilof Islands, Alaska, July 2015.

Rookery	Date (July)	Class of adult male 2	3	5	Total
St. Paul Island					
Lukanin	14	27	113	55	195
Kitovi	14	38	181	139	358
Reef	10	138	392	350	880
Gorbatch	10	83	264	306	653
Ardiguen	10	6	51	7	64
Morjovi	13	85	288	277	650
Vostochni	13	134	686	300	1,120
Polovina	12	26	113	181	320
Little Polovina	12	0	0	98	98
Polovina Cliffs	12	62	257	37	356
Tolstoi	9	128	277	232	637
Zapadni Reef	11	66	160	122	348
Little Zapadni	11	81	214	200	495
Zapadni	11	126	360	370	856
Island total		1,000	3,356	2,674	7,030
St. George					
South	15	73	165	38	276
North	13	69	323	162	554
East Reef	14	36	120	26	182
East Cliffs	14	70	242	80	392
Staraya Artil	13	7	57	25	89
Zapadni	15	25	82	77	184
Island total		280	989	408	1,677

Table 4. -- Number of adult male northern fur seals counted by rookery and behavior class (2 = territorial without females, 3 = territorial with females, 5 = non-territorial on hauling grounds), Pribilof Islands, Alaska, July 2016.

	Date	Class of adult male			
Rookery	(July)	2	3	5	Total
St. Paul Island					
Lukanin	12	26	105	47	178
Kitovi	12/19	48	136	95	279
Reef	18	126	464	212	802
Gorbatch	18	65	299	213	577
Ardiguen	18	4	30	7	41
Morjovi	16	75	292	194	561
Vostochni	16	96	649	193	938
Polovina	14	27	100	150	277
Little Polovina	14	0	0	83	83
Polovina Cliffs	14	57	236	26	319
Tolstoi	19	78	321	128	527
Zapadni Reef	10/19	49	143	122	314
Little Zapadni	17	66	242	121	429
Zapadni	17/19	93	369	242	704
Island total		810	3,386	1,833	6,029
St. George					
South	11	61	158	37	256
North	10	73	254	121	448
East Reef	12	33	110	23	166
East Cliffs	12	54	250	77	381
Staraya Artil	10	19	35	22	76
Zapadni	12	22	91	46	159
Island total		262	898	326	1,486

Table 5. -- Total number of northern fur seal pups sheared, number of pups estimated to be alive at the time of marking (E1 and E2), mean number alive (Mean) and standard error (SE), on sampled rookeries of St. Paul Island, Alaska, 2016.

Rookery	Sheared	E1	E2	Mean	SE
Lukanin	318	2,451	2,529	2,490	39.0
Kitovi	363	3,601	3,468	3,535	66.5
Reef	1,114	9,970	10,598	10,284	314.0
Gorbatch	796	7,215	6,943	7,079	136.0
Ardiguen	75	543	703	623	80.0
Morjovi	931	7,906	7,481	7,694	212.5
Vostochni	1,545	13,514	14,301	13,908	393.5
Polovina	321	3,061	3,228	3,145	83.5
Little Polovina*					
Polovina Cliffs	658	6,487	6,486	6,487	0.5
Tolstoi	911	7,355	7,007	7,181	174.0
Zapadni Reef	411	3,183	3,145	3,164	19.0
Little Zapadni	608	5,389	5,170	5,280	109.5
Zapadni	906	7,472	7,708	7,590	118.0

* Little Polovina was not estimated since no harem males were counted in July.

Table 6. -- Number of pups alive at the time of marking, estimated total pups born, harem males and the ratio of pups alive at marking to harem males, on sampled rookeries of St. Paul Island, Alaska, 2016.

Rookery	Pups alive at marking	Total pups born	Harem males	Ratio pups/males
Lukanin	2,490	2,559	105	24.37
Kitovi	3,535	3,633	136	26.71
Reef	10,284	10,570	464	22.78
Gorbatch	7,079	7,276	299	24.33
Ardiguen	623	640	30	21.33
Morjovi	7,694	7,908	292	27.08
Vostochni	13,908	14,295	649	22.03
Polovina	3,145	3,232	100	32.32
Little Polovina				
Polovina Cliffs	6,487	6,667	236	28.25
Tolstoi	7,181	7,381	321	22.99
Zapadni Reef	3,164	3,252	143	22.74
Little Zapadni	5,280	5,427	242	22.43
Zapadni	7,590	7,801	367	21.26
Total	78,460	80,641	3,386	23.82

2.7%. The total number of pups born on St. Paul Island in 2016 was estimated at 80,641 (SE= 717; 95% CI = (79,135 – 82,176)). 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 method used to estimate the total pups born. The above total does not include the pups born on Sea Lion Rock, which was not surveyed in 2016.

The number of pups born 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 ($P = 0.07$) was 23.16 (SE = 0.59, $P < 0.01$), representing an estimate of the ratio of pups to breeding males.

Number of Pups Born on St. George Island in 2016

Estimated total number of pups alive on St. George Island at the time of marking was 20,261 (SE = 454, Tables 7 and 8). The total number of dead pups was estimated to be 229 (Appendix Table A-7) and the estimated mortality rate was 1.1% (Table 8). The total number of pups born on St. George Island was 20,490 (SE = 460, 95% CI = (19,395 – 21,646)).

The 2016 estimate of pups born on St. George Island was significantly higher than the estimate of pups born in 2014 ($P < 0.01$) and 2012 ($P < 0.01$). The number of pups born and the number of harem males on St. George Island rookeries were highly correlated ($r^2 = 0.98$; Fig. 6). The intercept of the regression line was not significantly different from zero ($P = 0.68$) and was not included in the regression equation. The slope of the regression line was 22.45 (SE = 1.42) representing an estimate of the ratio of pups born to breeding males.

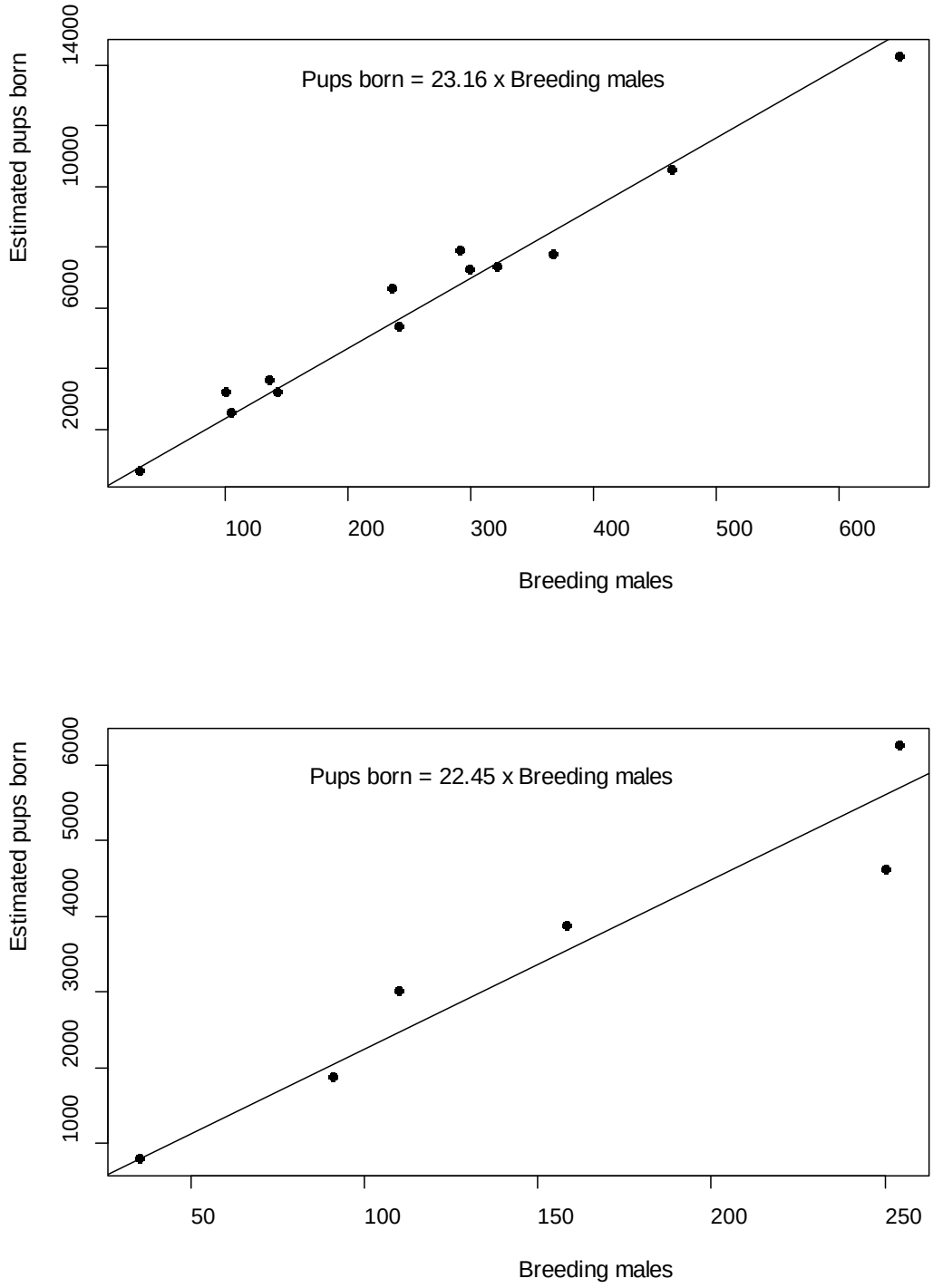


Figure 6. -- Pups born versus number of harem males on St. Paul Island (top) and St. George Island (bottom), Alaska, 2016. Solid regression lines are shown for both locations.

Table 7.-- Number of pups sheared, number of pups estimated to be alive at the time of marking (E1 and E2), mean number alive (Mean) and the standard error of the mean (SE), for St. George Island, Alaska, 2016.

Rookery	Sheared	E1	E2	Mean	SE
South	355	3,600	4,096	3,848	248.0
North	622	6,148	6,262	6,205	57.0
East Reef	246	3,066	2,916	2,991	75.0
East Cliffs	450	4,886	4,259	4,573	313.5
Staraya Artil	76	779	786	783	3.5
Zapadni	207	1,668	2,054	1,861	193.0

Table 8. -- Number of pups alive at the time of marking, total pups born, harem males, and the ratio of pups alive at marking to harem males for St. George Island, Alaska, 2016.

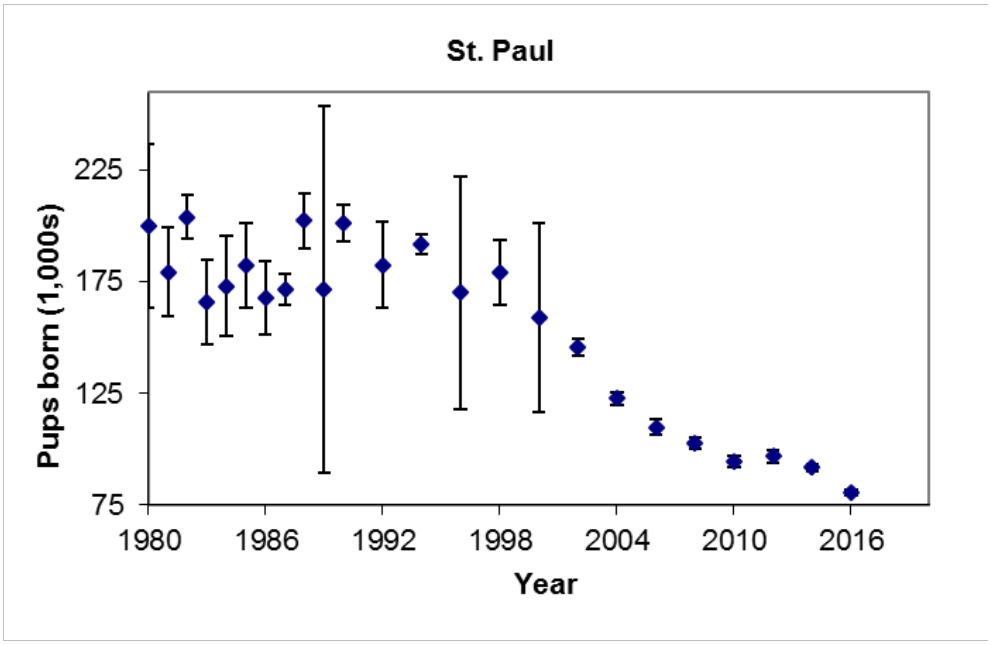
Rookery	Pups alive at marking	Total pups	Harem males	Ratio pups/male
South	3,848	3,891	158	24.63
North	6,205	6,275	254	24.70
East Reef	2,991	3,025	110	27.50
East Cliffs	4,573	4,625	250	18.50
Staraya Artil	783	792	35	22.63
Zapadni	1,861	1,882	91	20.68
Total	20,261	20,490	898	22.82

Trends in Numbers of Pups

The total estimated number of pups born on St. Paul Island in 2016 (not including Sea Lion Rock) was 12.1% less than in 2014 (Fig. 7; $P < 0.01$), which was 5.3% less than in 2012 (Appendix Table A-4). On St. George Island there was an 8.2% increase between 2014 and 2016, following a 17.0% increase between 2012 and 2014. Pup production has been declining since 1998 at an average annual rate of 4.12% (SE = 0.40%, $P < 0.01$) on St. Paul Island and shows no significant trend (SE = 0.57%, $P = 0.13$) on St. George Island over the same time period. The overall rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 3.50% (SE = 0.40%, $P < 0.01$) annually from 1998 to 2016. Since 2002, pup production has been lower than was estimated in 1921 on St. Paul Island and in 1918 on St. George Island, when the populations were recovering at 8% annually from a pelagic harvest that ended in the early 20th century. On a positive note, St. George Island pup production has shown an increase for two censuses in a row, resulting in an increase of 26.6% in 2016 from 2012.

Estimate of Total U.S. Population Size

Rough estimates of total fur seal abundance have been presented in the past (Loughlin et al. 1994). These were calculated by multiplying the average number of pups born over the past three censuses by a factor of 4.47 (See Table 9 for the calculation method). That correction factor was derived from estimates of survival and fecundity (Loughlin et al. 1994) using data collected at sea during 1958-74. Its application here rests on the assumption that those vital rates remain valid. Since we cannot verify this assumption, the estimate must be viewed as a rough approximation. The estimated total northern fur seal population size for the Pribilof Islands in2016 (Table 9) was about 508,000 fur seals. The total stock size for the United States, which



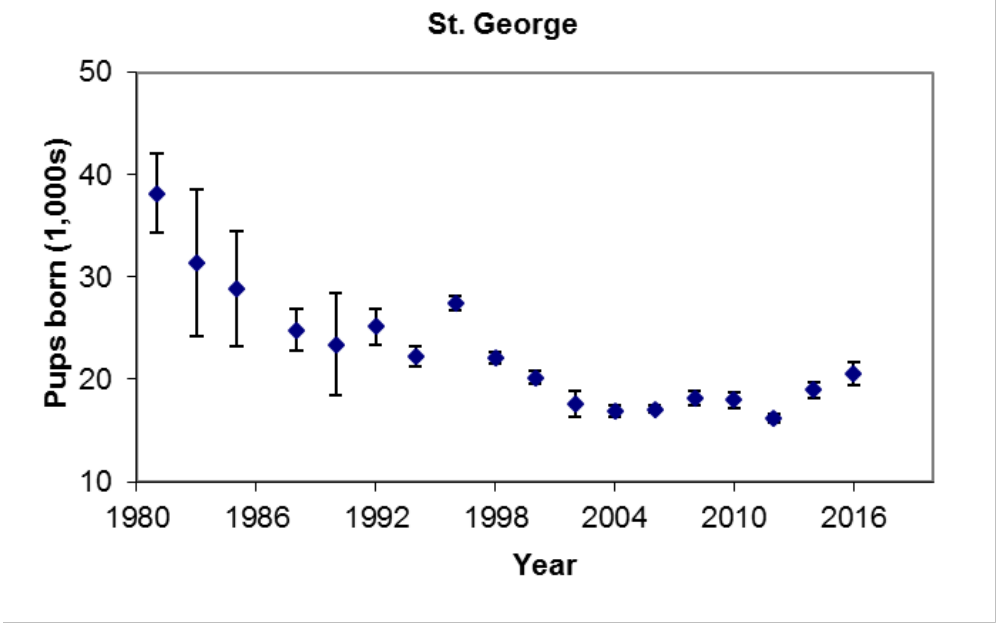


Figure 7. -- Estimated number of pups born (± 95% confidence intervals) on St. Paul and St. George Islands, Alaska, 1980 to 2016.

Table 9. -- Details of the computation of population size estimates of fur seals in U.S. rookeries Loughlin et al. 1994). 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[1]	San Miguel and Bogoslof Islands[2]	Component
Average for 2012, 2014, 2016	113,522	28,910	Pups
(Pups) × 0.5	56,761	14,455	Yearlings
(Yearlings) × 0.8	45,409	11,564	Age 2 year
(2-year-old females) × 0.86 / 2	19,526	4,973	Females age 3 year
(2-year-old males) × 0.8 / 2	18,164	4,626	Males age 3 year
(Pups) / 0.6	189,203	48,183	Females 3+ years
(3-year-old males) × 3.6	65,390	16,654	Males 4+ years
Total	507,975	129,365	

[1] The 2014 estimates for Sea Lion Rock was added to the St. Paul estimates of pup production for all years because it was the most current. The average of the last three estimates in the remaining rookeries was used.

[2] The 2013, 2015-2016 estimates for Castle Rock and 2014-2016 estimates for Adams Cove, both on San Miguel Island and the 2011 and 2015 estimates for Bogoslof Island were used.

includes the Pribilof, Bogoslof, and San Miguel Islands was approximately 637,000 fur seals.

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

Thirty-five dead adult fur seals were counted on rookeries sampled for dead pups (27 on St. Paul Island and 8 on St. George Island; Table 10) and tooth samples were collected from 30. Appendix Table A-8 summarizes the number of dead male and female fur seals from which teeth were collected from 1979 to 2016.

Table 10. -- Number of animals older than pups found dead and from which teeth were collected during August 2016 on the Pribilof Islands.

Rookery	Male	Female	Unknown	Total
St. Paul				
Lukanin[1]	1	4	0	5
Reef[2]	1	8	0	9
Morjovi	1	5	0	6
Zapadni Reef[3]	0	2	0	2
Total St. Paul	3	19	0	22
St. George				
South	0	0	0	0
North	1	5	0	6
East Reef	2	0	0	2
Total St. George	3	5	0	8
Total Both Islands	6	24	0	30

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

STATUS OF THE CALIFORNIA STOCK OF NORTHERN FUR SEALS DURING 2015 – 2016

by

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The California stock of northern fur seals includes breeding colonies at San Miguel Island (SMI) and the Farallon Islands (FI) located off the coast of California. Demographic studies of the northern fur seal population at SMI 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). The population of northern fur seals at the FI numbered more than 100,000 individuals before being decimated by American, Russian, and British sealers during the 1800s (Starks 1922, Townsend 1931, Scheffer and Knaus 1964). After an absence of more than a century and a half, northern fur seals started to reappear during the 1970s. The first pup born after recolonization was confirmed in 1996 (Pyle et al. 2001). The population of northern fur seals at FI includes flipper-tagged individuals primarily from SMI (an individual from the Commander Islands, Russia has been seen).

During the breeding season, the majority of northern fur seals in the United States are found on the Pribilof (St. George and St. Paul) and Bogoslof islands, which are located in the cool, subarctic waters of the Bering Sea (Fig. 17). Northern fur seals are able to inhabit SMI and FI because the marine environment around the islands 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 California stock of northern fur seals has been increasing, with the exception of two severe declines at SMI 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 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, which adversely affect abundance and availability of prey species of northern fur seals. These species generally move to more productive areas farther north and deeper in the water column (Arntz et al. 1991) and thereby become less accessible for northern fur seals. Consequently, northern fur seals at SMI are in poor physical condition during EN events and the population experiences reduced reproductive success and increased pup (and occasionally adult) mortality (DeLong and Antonelis 1991, Melin and DeLong 1994, Melin et al. 1996, Melin and DeLong 2000). Because EN events occur periodically in the California Current System and impact the population growth of northern 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 (*Uncinaria* sp.) disease has increased pup mortality for the past 18 years and is a major factor affecting the population dynamics of northern fur seals at this southernmost rookery (Lyons et al. 2001).

Since the first birth post recolonization of the FI was affirmed in 1996, annual ground surveys were conducted in early fall to document population trends of the colony until 2012 (Tietz 2012); aerial surveys have been conducted since that time (Berger et al. 2013). The colony increased steadily from 1996 to the early 2000s; however, since 2003 the population appears to

have grown exponentially excluding a relatively stable period from 2006 to 2010 (Tietz 2012). Because counts at FI are conducted during the fall after the breeding season, population trends are not directly comparable to SMI and are a relative measure of the population because many of the animals using FI may no longer be present at the time of census.

Here, we present the results of the 2015 and 2016 northern fur seal population monitoring studies at SMI and summarize FI census and tag re-sight information. We summarize data from a long-term study that was initiated during 1975 to examine the condition of northern fur seal pups and discuss the importance of environmental influences and diseases on the SMI population trends for the past 20 years.

METHODS

Census

Northern fur seal censuses were conducted at two rookeries of SMI (34.03° N, 120.38° W): Adams Cove (ACV) on the main island and Castle Rock (CR), located ~1 km northwest of SMI. The CR rookery was visited once during both years (8 August 2015 and 10 August 2016), to conduct a census of pups. Daily censuses were conducted at ACV or in East Adam's Cove Study area (EACS; a focal area within ACV) between 30 May and 6 August 2015, and 28 May and 4 August 2016. For the long-term comparisons, territorial bull counts were used as an index of the maximum number of breeding males. Additionally, the cumulative live pup count in EACS 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 ACV and CR rookeries. Total births each year was the sum of the number of live pups counted at the live-pup 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 30 July at CR and on 8 August at ACV during 2015. During 2016, a live-pup census was conducted at ACV on 2 August and at CR on 10 August. In ACV, the live-pup counts were conducted from a mobile blind by two observers using binoculars. At CR, pups were counted by two observers walking through the colony. At both locations, 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 entire 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 October in 2015 and between June and November in 2016. 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. We estimated total mortality (up to three months of age) by calculating a correction factor (1.33) 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 re-sighted during subsequent mortality surveys (Melin et al. unpublished data). During 2016, we started a study to estimate a species-specific mortality correction factor for northern fur seal pups at SMI, which should be completed by 2018. The environmental conditions contributing to disappearance of dead pups (e.g., surf, sand, flooding) for the two species are similar except 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 beach crest. Additionally, northern fur seals are smaller than CSLs, so they are likely to disappear faster. Therefore, the mortality correction factor is a minimal approximation of the disappearance rate of dead northern fur seal pups.

At CR, pup mortality during both years was estimated from one survey conducted at the time of the live-pup count (8 August). Pup mortality at CR was a minimum estimate because only one survey was performed and the number of carcasses that decomposed completely or disappeared was not determined. A mortality correction factor was not applied to counts at CR because the CSL mortality correction factor would not be appropriate based on a single survey and different disappearance rates due to substrate.

At the FI (37.72°N, 123.03°W), lighthouse, ground, and aerial surveys were conducted. The lighthouse survey is a year-round survey that started in 1970. Observers counted and identified all pinnipeds to species, sex, and age-class that were visible from the lighthouse, which provides the highest vantage point at SE Farallon Island. The survey included a ground-survey component during which observers hiked around accessible areas of Southeast FI to count pinnipeds not visible from the lighthouse. Aerial photographic surveys of the South Farallon Islands were started in 2013 to determine northern fur seal abundance. The fur seals were counted from aerial photographs taken on 6 August 2013, 5 August 2014, and 4 August 2015 and

2016. They were identified to an age-sex category based on morphological and behavioral characteristics (Berger et al. 2013). Age-sex categories included adult males, subadult males, adult females and juveniles combined, pups, and "unknown". Adult males were identified by their relatively large size and location in the middle of the rookery. Subadult males were determined by their relatively large size and location on the fringes of the rookery. Adult female and juveniles were classified together because they were difficult to differentiate by size unless a pup was associated with the adult female. Pups were determined by their relatively small size. If an individual could not be classified by any of the aforementioned characteristics it was considered unknown. Additionally, animals in the water were considered unknown.

Pup condition

Pups were sexed, measured (length), and weighed ($n_{2015} = 191$, $n_{2016\text{-}Oct} = 100$, $n_{2016\text{-}Nov} = 193$) in ACV to continue survival and condition studies that began in 1975. To account for differences in mean pup weight due to different sampling dates among years, we used a predictive linear mixed-effects model with normal errors to adjust the observed mean mass to 1 October for each year (Jeffrey Laake, AFSC-MML, pers. comm.). The model used an estimated sex-specific daily growth rate and a random cohort effect to incorporate annual variation in growth rate to estimate mass. We used adjusted pup weights as an index of pup condition.

Pup condition was examined in relation to the Oceanic Niño Index (ONI), which is the primary index used by NOAA to identify EN (warm) and La Niña (LN; cool) conditions in the east-central equatorial Pacific Ocean (Golden Gate Weather Services 2017, http://www.cpc.ncep.noaa.gov/data/indices/). The ONI is a 3-month mean sea-surface temperature (SST) anomaly for the region. EN and LN events are characterized as five overlapping 3-month periods ≥ the +0.5°C anomaly or ≤ the -0.5°C anomaly, respectively. Events are classified as "Weak" (0.5 to 0.9 SST anomaly), "Moderate" (1.0 to 1.4), "Strong" (1.5 to 1.9), and "Very Strong" (≥ 2.0; Golden Gate Weather Services 2017).

Sightings of marked individuals

Northern fur seals were flipper tagged as pups between 3 to 4 months old (Fig. 13) and the number of marked pups varied annually (range = 97 – 300) based on how many pups could be collected (Table 13). Surveys of tagged individuals were conducted from a mobile blind in ACV during 3 July – 10 August, 2015 (n = 22) and 24 June – 17 August, 2016 (n = 24). The blind was moved through sections of the rookery and hauling sites at least once a week. Tag numbers and reproductive status (if possible) were recorded for each tagged individual observed. Reproductive status included: "territorial" or "idle" for males, and "pregnant" and "with a pup" for females. Identification of tagged animals was also recorded opportunistically when observers were engaged in other activities from May through October ($n_{2015} = 9$, $n_{2016} = 12$).

Surveys of tagged individuals at the FI were done by hiking to various places on the survey route. Re-sighting surveys were conducted on 1, 15, and 30 September, 15 October, and 1 and 23 November, 2015, and on 1 and 20 October, and 22 November 2016.

Tag-loss assessment

We began a study in 2006 to evaluate different types of flipper tags for retention and

readability. Pups at ACV were tagged with the historically used jumbo pink rototag (Dalton Supplies, Ltd, Oxon, United Kingdom) on one foreflipper and a "test" tag on the other foreflipper (Fig. 13). From 2006 to 2013, metal monel tags (National Band and Tag Co., Newport, Kentucky, United States) were the test tag; in 2014 we used pink Allflex (Allflex USA, Dallas, Texas, United States) sheep tags instead of the metal tags. The flipper assigned a particular tag type varied throughout the study period, however pink rototags were on the left flipper a majority of years (Table 14). After 2014, due to the unavailability of rototags, we tagged all individuals with Allflex tags on both flippers.

Table 13. -- Number of northern fur seal pups tagged at Adams Cove on San Miguel Island, California during 1997 – 2016.

Year	Female	Male	Unknown	Total
1997	79	75		154
1998	85	78		163
1999	81	78		159
2000	95	105		200
2001	147	139	1	287
2002	140	160		300
2003	98	102		200
2004	104	96		200
2005	105	95		200
2006	53	51		104
2007	52	45		97
2008	74	77		151
2009	95	105		200
2010	79	87		166
2011	105	96		201
2012	107	93		200
2013	87	83		170
2014	69	132		201
2015	103	88		191
2016 (Oct.)	39	61		100
2016 (Nov.)	92	101		193

Figure 13. -- Northern fur seal tagged with pink roto (left flipper) and silver monel (right flipper) tags.

RESULTS

Census

The maximum number of territorial bulls counted in ACV was similar during 2015 (n = 111; 4 July 2015) and 2016 (n = 110; 8 July 2016), representing a 50% decrease from numbers counted during the previous year (n_{2014} = 224; Fig. 14). The largest number of territorial bulls was observed in 1997 (n = 253; Fig. 14).

The first pup born at ACV was observed on 10 June in 2015 and 11 June in 2016. The median pupping date was 10 July in 2015 and 6 July in 2016. The mean of median pupping dates between 1998 and 2014 was 6 July (SE = 0.9). During 2015, the mean number of live pups was 1,680 (SE = 12.0) at ACV and 932 (SE = 91.2) at CR (Table 15). During 2016, the mean number of live pups was 1,644 (SE = 106.1) at ACV, a 2.4% decrease from 2015. The mean number of live pups at CR was 1,615 (SE = 25.5), a 73.3% increase from 2015. At ACV, the adjusted number of dead pups was 355 in 2015. This index increased 91.8% to 681 during 2016. At CR, the observed number of dead pups was 66 in 2015 and 94 in 2016.

During 2015, total births at ACV (2,035) were 11.1% below the record high estimated in 2014 (Table 15; Fig. 15). During 2016, total births (n = 2,325) increased 14.3% from 2015-levels and was 1.6% higher than the previous high recorded in 2014. At CR during 2015, total production was 998. During 2016, total production (n = 1,709) increased 71.2% from 2015 levels and was the highest recorded at that location. The highest total production at SMI (i.e., ACV + CR) was recorded during 2016 (Table 15).

At the FI, the total number of northern fur seals has increased each year since aerial photographic surveys began in 2013 [Range = 666 (2013) – 2,238 (2016); Table 16). The percent change in population was 236.0% during that time period. Correspondingly, there was an

Table 14. -- Types of tags applied to northern fur seal pups at San Miguel Island, California, during 2006 – 2016 to evaluate retention and readability. *During 2016, 100 pups were captured and weighed in September to assess their condition. They were tagged with white Allflex tags due to the limited availability of pink Allflex tags. Left (L) and right (R) denote flipper side.

Year	Jumbo Pink Roto		Silver Monel		White Allflex		Pink Allflex		# pups
	L	R	L	R	L	R	L	R	
2006	50	54	54	50					104
2007	96	1	1	96					97
2008	97	53	53	97	1	1			150
2009	104	96	96	104					200
2010	166			166					166
2011	201			201					201
2012		200	200						200
2013	170	90		80					260
2014	1	200					200	1	201
2015							191	191	191
2016					100*	100*	193	193	293

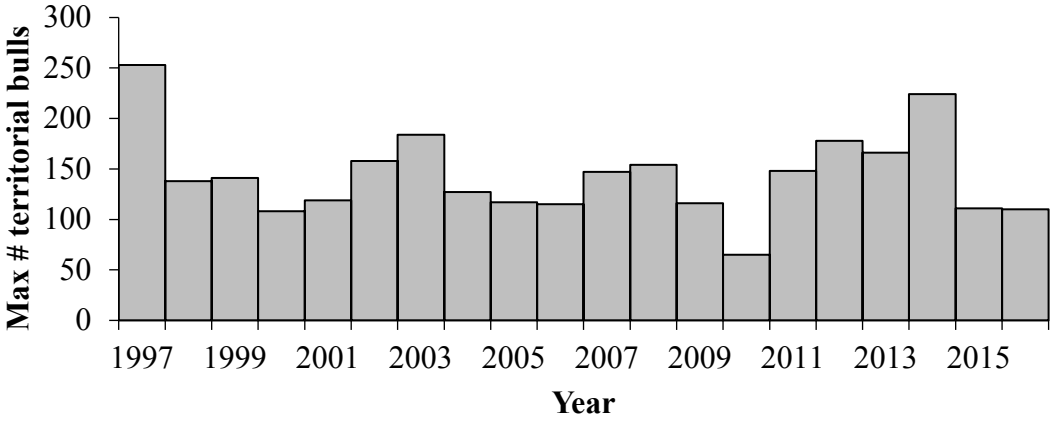

Figure 14. -- Maximum number of territorial northern fur seal bulls at Adams Cove on San Miguel Island, California, 1997-2016.

Table 15. -- Summary of live and dead pup counts and total production of northern fur seals at Adams Cove and Castle Rock (rookeries of San Miguel Island, California), 1997-2016.

Colony/Year	Number of live pups	Adjusted number of dead pups[1]	Total production
Adams Cove			
1997	1765	477	2242
1998	308	154	462
1999	604	225	829
2000	962	145	1107
2001	1226	76	1302
2002	1126	102	1228
2003	1083	302	1385
2004	810	606	1416
2005	1133	504	1637
2006	1129	610	1739
2007	972	735	1707
2008	1390	302	1692
2009	1266	625	1891
2010	1536	696	2232
2011	1402	515	1917
2012	1690	454	2147
2013	1261	790	2051
2014	1658	630	2288
2015	1680	355	2035
2016	1644	681	2325
Castle Rock			
1997	940	51	991
1998	194	29	223
1999	300	11	311
2000	562	13	575
2001	708	43	751
2002	724	21	745
2003	---	---	---
2004	804	21	825
2005	782	18	800

Table 15. -- Continued.

2006	634	16	650
2007	758	---	758*
2008	1076	---	1076*
2009	800	138	938
2010	1144	23	1167
2011	1150	19	1169
2012	1163	55	1218
2013	1242	39	1281
2014	---	---	---
2015	932	66	998
2016	1615	94	1709

[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 were missed during surveys or disappeared between surveys. Note: a correction factor was not applied to counts at Castle Rock.

*Number based on the number of live pups, only.

increase of individuals in each age/sex class in 2016 except subadult males (Table 16). The number of adult males has increased 412.5% from 2013 (n = 24) to 2016 (n = 123). The number of pups has increased 180.8% during the same period (n_{2013} = 401, n_{2016} = 1126). Only one dead pup has been observed on the FI during the past 10 years.

Pup condition

During 2015, adjusted mean (± SE) weight of female pups (6.6 kg ± 0.1) was 34.0% lower than the long-term average of 10.0 kg. Adjusted mean weight of male pups (7.2 kg ± 0.1) was 35.7% lower than the long-term average of 11.2 kg (Fig. 16). During 2016, adjusted mean weight of female pups (10.4 kg ± 0.2) was 57.6% higher than in 2015 and 4.0% higher than the long-term average of 10.0 kg. Estimated mean weight of male pups was 11.4 kg (± 0.2 kg), equal to the long-term average (Fig. 16).

Sightings of marked individuals

Northern fur seals 2-19 years of age that were tagged as pups were re-sighted (n=337) in ACV during the 2015 breeding season (Fig. 17). Females sighted with pups were 2 to 12 years of age (Fig. 18). Re-sighted males (n=151) ranged in age from 1 to 15 years old (Fig. 17). Territorial males were between 6 and 15 years old (Fig. 18). Eleven-year-old males had the highest number of territories among tagged bulls (Fig. 18). Only a small proportion of tagged females (13%) and males (2%) seen were older than 15 years of age. As in past years, there were no tagged individuals from the 1997 EN cohort (16 year olds) seen during 2015 (Fig. 17).

A total of 419 uniquely tagged northern fur seals (295 females, 124 males) were observed during 2016 (Fig. 17). Tagged females were between 3 and 20 years old, and tagged males were between 3 and 16 years old (Fig. 17). Females observed with pups were between 3 and 18 years

Table 16. -- Number of northern fur seals counted from aerial photographs taken during surveys at the South Farallon Islands, California, in 2013 through 2016. ND = not determined.

Year	Adult Male	Subadult Male	Adult Female/ Juvenile	Pup	Unknown	Total
2013	24	34	207	401	ND	666
2014	27	19	317	656	ND	1019
2015	41	33	250	665	244	1233
2016	123	23	989	1126	ND	2238

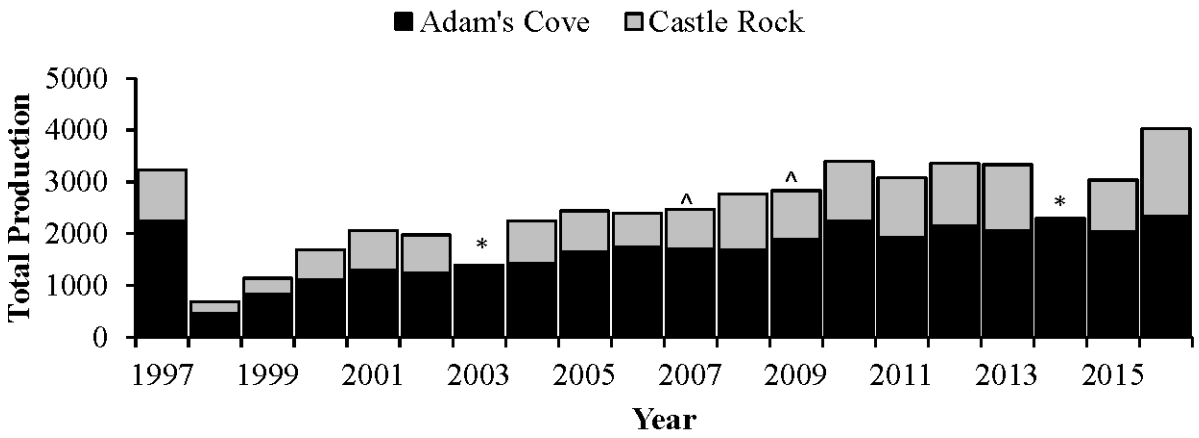

Figure 15. -- Total number of northern fur seal births (i.e. number of live pups + number of dead pups) at Adam's Cove (ACV) and Castle Rock (CR) rookeries during 1997 – 2016. Asterisk (*) indicates no counts at CR. Caret (^) indicates live-pup counts only (i.e. dead pups were not counted).

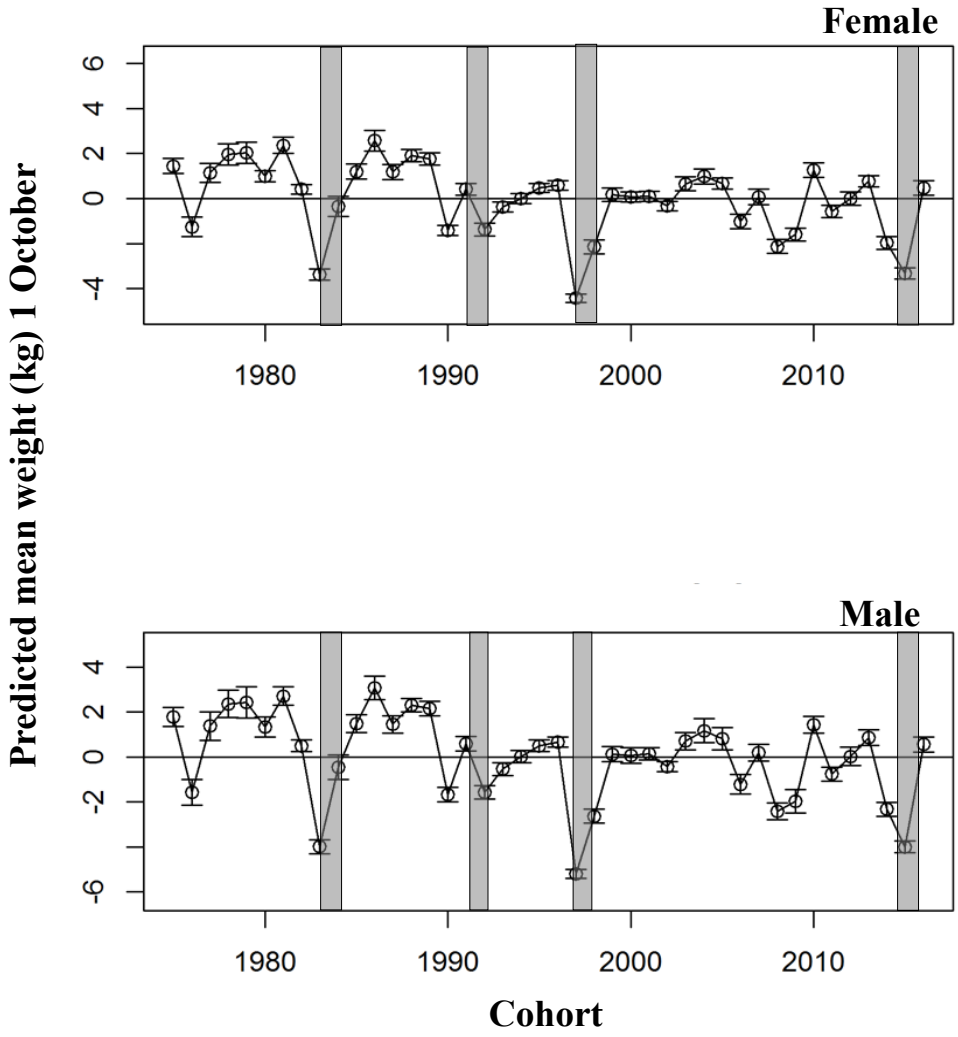

Figure 16. -- Predicted mean weights (kg) of northern fur seal pups at 3 months of age at San Miguel Island, California during 1975-2016, expressed as anomalies from the long-term mean (indicated by the horizontal line). Weights were adjusted to a standardized weighing date of 1 October of each year based on growth rates calculated for years when pups were weighed in September and October. Shaded areas indicate "strong" El Niño events (≥ 1.5 SST anomaly).

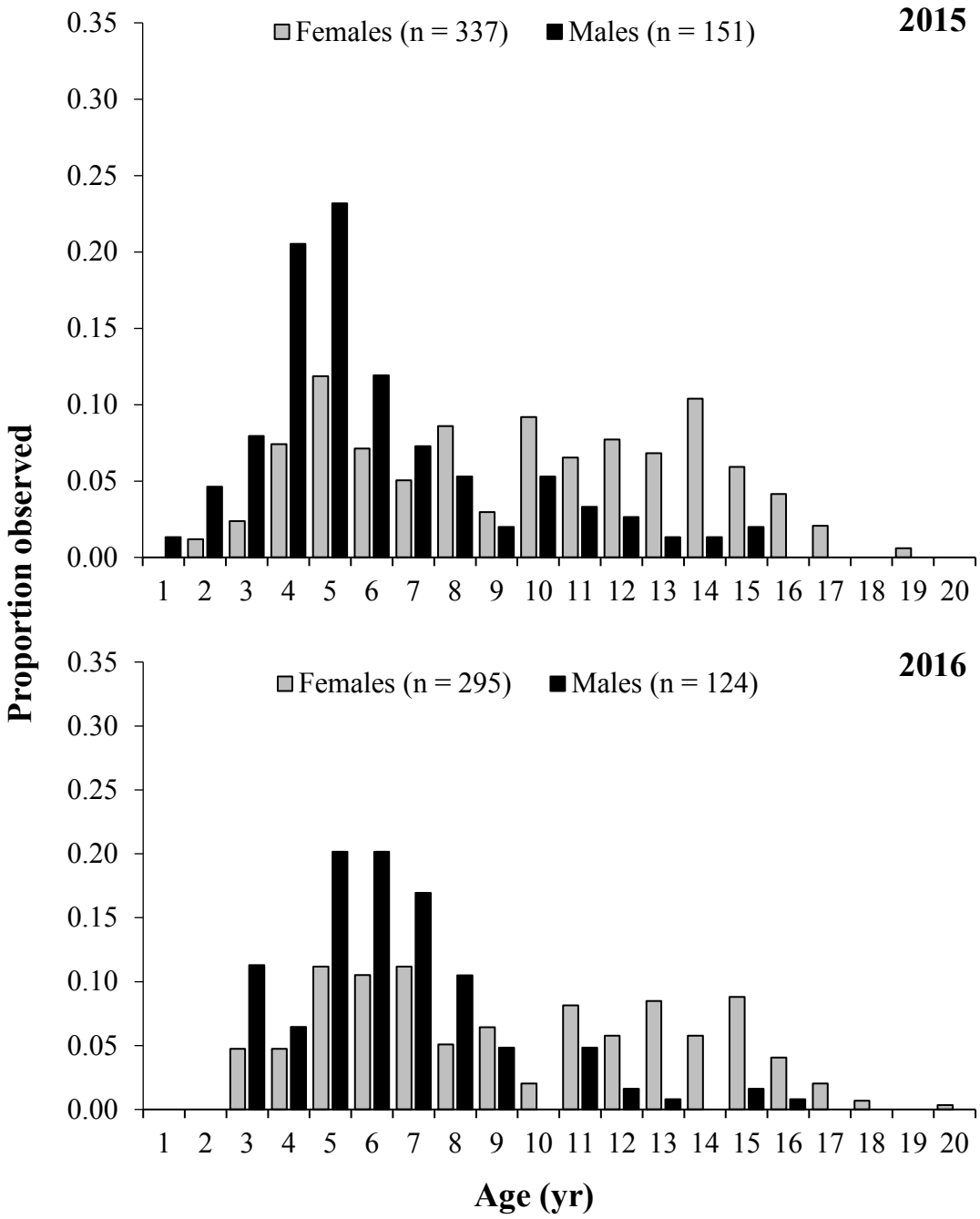

Figure 17. -- Age distribution of female and male northern fur seals that were tagged as pups and re-sighted at San Miguel Island, California, during the reproductive season in 2015 (top) and 2016 (bottom).

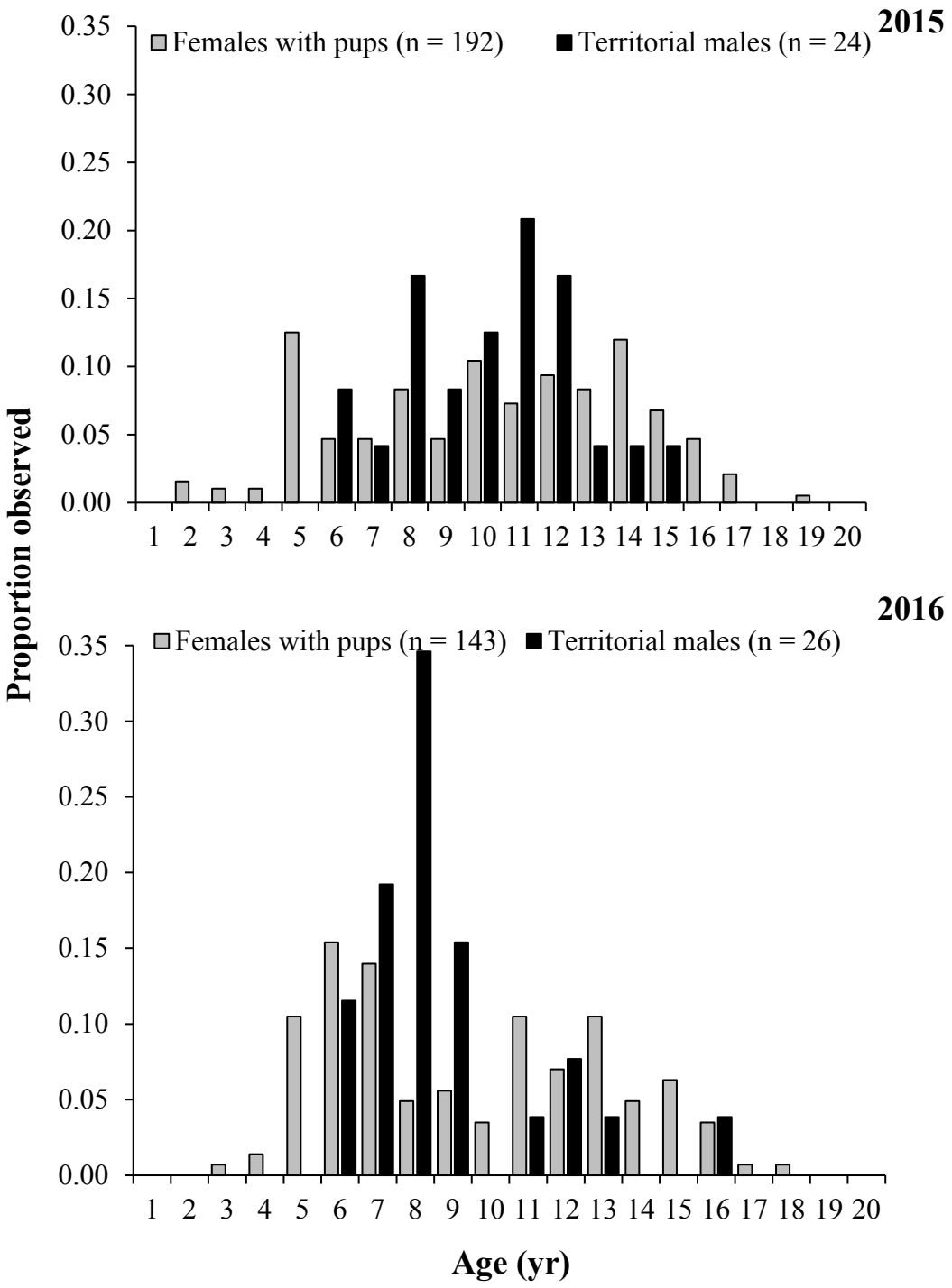

Figure 18. -- Age distribution of tagged adult female and male northern fur seals observed as reproductive at San Miguel Island, California, during 2015 (top) and 2016 (bottom).

old and territorial males were between 6 and 16 years old (Fig. 18). Tagged 6-year-old territorial males were the youngest recorded during both years. Eight-year-olds represented the highest number of territorial males among tagged bulls. The number of individuals that were over 15 years of age were comparable between in 2016 and 2015, and remained a small proportion of the total population (16% of females, 2% of males). As in 2015, there were no tagged individuals from the 1997 EN cohort (19 year olds) seen during 2016 (Fig. 17).

At the FI, all of the tagged individuals seen were originally tagged at SMI. Fifty-nine uniquely tagged northern fur seals (female = 29, male = 30) were observed during 2015 (Fig. 19). Tagged females were between 2 and 10 years of age; tagged males were between 2 and 11 years old. Modal age for both sexes was 4 years (Fig. 19). During 2016, 36 uniquely tagged northern fur seals (female = 25, male = 11) were observed (Fig. 19). Tagged females were between 3 and 9 years old, and tagged males were between 3 and 8 years old. Modal ages of tagged females were 3 and 5 years. Modal age for males was 6 years. Ninety-nine individuals that were tagged at SMI were subsequently seen at the FI. To date, 26 individuals have subsequently been seen only at the FI, 16 have been seen at both locations during different years but their last location was at the FI, 30 have been seen at both locations during different years but more recently at SMI, and 27 were seen most recently at both locations during the same year.

Tag-type assessment

A quantitative assessment of tag type (i.e., pink roto, silver monel, and pink Allflex; Fig. 13) is still being conducted. We hope to have results in a few years after more cohorts tagged with Allflex tags return to the island.

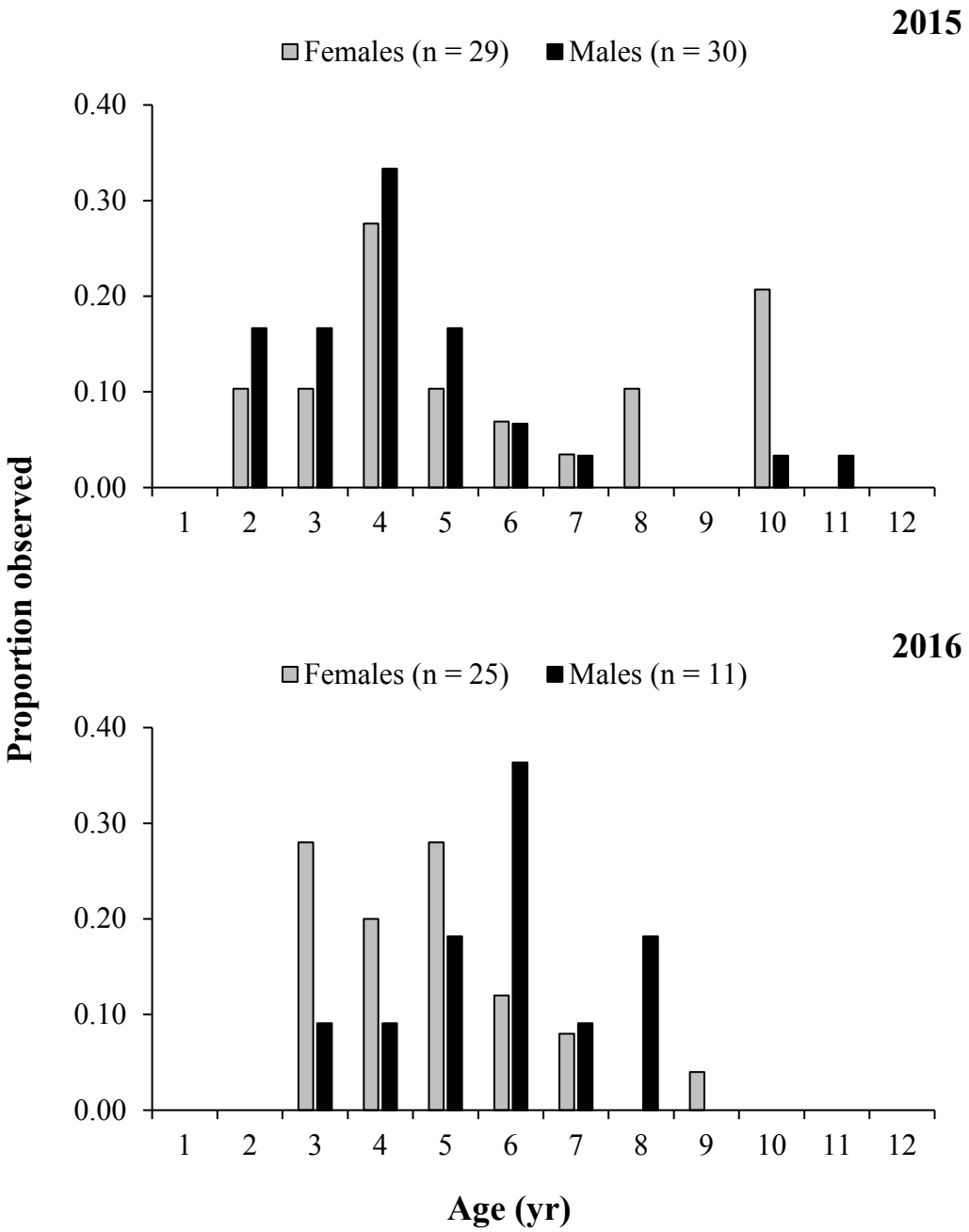

Figure 19. -- Age distribution of tagged female and male northern fur seals observed at the Farallon Islands, California, during 2015 and 2016.

DISCUSSION

Census

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 until 2014. The lowest number of territorial bulls counted since 1997 occurred during 2010. There was an EN event from mid-2009 to May 2010, which reduced the number of territorial males returning to SMI for breeding in 2010. LN conditions in 2011 may have influenced the rebound in the number of territorial males counted in 2011 and 2012. Despite warm-water conditions in part of 2014, the number of territorial bulls was the highest in 17 years. The number of territorial males decreased dramatically in 2015 and 2016, perhaps due to warm environmental conditions, such as the North Pacific marine heat wave of 2014-15 (Di Lorenzo and Mantua 2016) and the EN of 2015-16. The North Pacific marine heat wave, formerly termed "the blob" (Bond et al. 2015), consisted of a large area of abnormally high sea-surface temperature anomalies that started in the Gulf of Alaska in late 2013 (Bond et al. 2015). The North Pacific heat wave interacted with an EN in 2015, resulting in an abnormally long period of exceptionally high temperature anomalies in the California Current System from 2014 to mid-2016 (McClatchie et al. 2016). The warm-water conditions that prevailed in 2015 and parts of 2016 may have adversely affected the foraging ecology and condition of territorial bulls during the non-breeding season and their subsequent return to SMI.

Pup production at both ACV and CR declined during 2015; however, new record highs were set in 2016. The lower counts in 2015 were probably attributed to the combination of the North Pacific heat wave and EN. As with adult male northern fur seals, adult females may not

have returned to SMI. Reasons for this remain unclear, but they might have been nutritionally challenged to sustain their pregnancy. The record-high number of pups observed in 2016 at SMI occurred when the ONI was "very strong" (National Weather Service 2017). However, it is now recognized that the EN conditions in the east-central equatorial Pacific Ocean during 2016 had few recognizable effects on the physical or biological oceanography of the California Current System (McClatchie et al. 2016). The high positive SST anomalies caused by the North Pacific heat wave started to decrease by December 2015 (McClatchie et al. 2016). The more favorable environmental conditions in 2016 may have provided resources for pregnant adult females to complete their pregnancy and nurse their newborns.

The population at the FI has increased dramatically since recolonization. It is difficult for observers to differentiate between adult females and juveniles from aerial photographs, but it appears that each age-sex class increased except subadult males. Only one dead pup has been recorded on the FI. Most of the breeding area on the FI is on a terrace and not exposed to the wave zone. Therefore, it is unlikely that dead pups washed out to sea. However, dead pups may have been hidden behind rocks or in low spots not visible to observers. Regardless, it appears that pup mortality is low at the FI, which is a viable re-established colony that continues to be augmented by immigration of fur seals from SMI.

Pup condition

The estimated mean weights of pups decreased in 2015 from the long-term mean. However, estimated mean pup weights were still above the low values measured during EN years of 1983 and 1997. The cause(s) of the decline in pup weights were likely attributed to the North Pacific heat wave and EN conditions that persisted during 2015. The warmer conditions

during 2015 were associated with different prey assemblages corresponding to higher abundances of prey with southern affinities and lower abundances of prey with northern affinities (McClathie et al. 2016). Differences in the composition and availability of the prey community may have resulted in nursing females not obtaining enough energy for their pups to grow and ultimately survive. The increase in pup production and pup growth in 2016 indicated that prey were adequate for adult female fur seals to pup and subsequently provide energy for their pups to grow. DeLong and Antonelis (1991) observed that during the 1982-1983 EN, the foraging trips of lactating female northern fur seals were longer than in other years, and weights of 3-month-old pups were 3 to 4 kg below the mean weights of pups in years not affected by an EN event. Their observations indicated adult females were on a low nutritional plane during gestation and after birth. In addition to lactating females feeding at sea for significantly longer durations, they might have returned with less milk and energy to transfer to their pups (DeLong and Antonelis 1991). Distribution (e.g., depth, distance from rookery), abundance, dispersion, and quality (e.g., size, caloric content) of available prey could have influenced the foraging efficiency of these fur seals (Bailey and Incze 1985, Fiedler et al. 1986).

Another factor affecting pup condition and ultimately the population of northern fur seals is disease (e.g., hookworm disease). Hookworm disease was first described in the SMI northern fur seal population during 1996 (Lyons et al. 1997). Northern fur seal pup mortality associated with hookworm disease occurs within the first six weeks of life. 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 19 years at SMI. 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.

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 (e.g., fewer reproductive females in the population) after the 1997-1998 EN may indicate that adult mortality occurred 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 2016.

For both 2015 and 2016, the greatest number of tagged animals re-sighted was of 5-year-olds (of both sexes) from the 2010- and 2011-cohorts, respectively. High numbers of individuals (both males and females) from the 2010-cohort were also re-sighted in 2016, indicating that

apparent survival for that cohort was high. The estimated mean weight of male and female pups in 2010 was higher than the long-term mean, however individuals from the 2011 cohort were slightly lower than the long-term mean, so more research needs to be done to determine how much pup condition factors into long-term survivorship. On the Pribilof Islands, Baker and Fowler (1992) found a positive correlation between pup mass and survival for male fur seals. More "late season" (i.e., August) re-sight effort was exerted during 2012 through 2016, which may account for the higher numbers of 2- and 3-year-olds being re-sighted because they usually return to the colony during the latter part of the season.

Although there may be differences in retention of tags among ages and between sexes, females at SMI have been observed to live up to 20 years of age. They first breed when they are approximately 3 years old and continue to have pups until they are 19 years old. During 2015, mean age of tagged territorial males was 10.2 years (SD = 2.4, Mode = 11). During 2016, the mean age of territorial males was younger (Mean = 8.7 years, SD = 2.4, Mode = 8). However, some of these males might not have been reproductive. Younger, smaller males (esp. 6-year-olds) were only seen occupying territories in August near the end of the breeding season, during a period when most of reproductive females were already bred. Despite the apparent shift in age of reproductive males, it is apparent that male reproduction occurs later in life than in females. Males are sexually mature at age 4, but must attain morphological characteristics (e.g., size) and behavioral experience in order to establish and maintain reproductive territories (Gentry 1998). The oldest tagged males were only 15 and 16 years old during 2015 and 2016, respectively, and were all territorial. These findings imply that males do not live as long as females, and not much (if at all) beyond their reproductively active years. However, tag loss may be greater for males,

as they get much larger than females. Gentry (1998) noted that males on St. George Island, Alaska 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. Of those observed more than once during that study, two males reappeared for eight or more seasons, but all others spent 2-7 years on territory. This finding was consistent with earlier reports that adult males had much higher mortality than females and most held territories for only one year (Johnson 1968).

At the FI, individuals observed during 2015 and 2016 that were tagged came from SMI. Observers did not record reproductive status of individuals. It should be noted that trips to the northern fur seal rookery cannot be made because their peak breeding coincides with peak seabird breeding, and accessing the fur seal colony would cause major disturbances to breeding seabirds. Because the FI is the largest seabird breeding colony in the contiguous United States, the U.S. Fish and Wildlife Service will not grant permission to conduct northern fur seal surveys and observations during the breeding season.

It is evident that some of the northern fur seals at SMI travel to the FI during the same year or in different years. For some individuals, it is not clear which island they preferred, or if they use both islands for different purposes (e.g., breeding versus resting during a foraging trip). However, is apparent that some individuals have not returned to SMI, but rather are permanent residents at FI. This supports the idea that part of the population growth at the FI is due to immigration of individuals from SMI.

Tag-type assessment

Although a quantitative analysis is not presented here, a qualitative assessment and discussion of the tags used on SMI is warranted. Tag loss is a major concern in demographic

studies because the individual can no longer be identified. Subsequently, information about their survival or natality is lost. In 2006, we initiated a study to evaluate different types of tags for northern fur seals. We planned to test different types of tag combinations on 4-year cycles. Pink rototags were attached to one foreflipper and were maintained as the default tag type 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 type are three-fold: 1) fading or wearing of the numbers with time such that alphanumeric digits become 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 rototags. However, monel tags address the shortcomings of the rototags. Monel is a corrosion-resistant alloy 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 may be less likely to come out of the flipper. Therefore, we expect that tag loss should be lower for this tag type and the numbers should be legible throughout the life of the animal, though reading the tag is more difficult relative to larger tags.

Although we started using monel tags in 2006 (through 2013), our comparison of the retention and legibility of monel versus pink rototags was delayed due to low survivorship of individuals in the first few cohorts of this study and because pups from 2010 and 2011 had not returned to the island in large enough numbers to provide sufficient samples sizes for analyses. However, during 2012 through 2014 we did observe a greater number of animals with monel

tags (relative to other years) and the tags were harder to read compared to rototags because of their smaller size, less contrast between the engraved number and rest of tag, and more glare on the tag during sunny conditions. Although it was evident that some monel tags were lost, we have yet to fully evaluate how their loss rate compares to that of pink rototags. In 2012, we began using digital cameras equipped with 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 re-sighted each year. During 2014, we started to tag individuals with a pink Allflex tag on one fore-flipper and pink rototags on the other. We hope to evaluate the reliability and readability of the Allflex tags in the next 2 years when individuals of the 2014 – 2016 cohorts return to SMI.

MASS, LENGTH, AND SEX RATIOS OF NORTHERN FUR SEAL PUPS ON THE PRIBILOF ISLANDS, 2016

by

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

Mass and length measurements of northern fur seal pups on St. Paul and St. George Islands, Alaska, have historically been recorded during late August and serve as an indicator of physical condition. Here we report mean mass, mean length, and sex ratios for male and female pups from Tolstoi, Vostochni, Polovina Cliffs, and Reef rookeries on St. Paul Island and from South, North, and East Reef rookeries on St. George Island in 2016, with comparisons of those variables between islands and among rookeries.

METHODS

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

RESULTS

Pup Mass and Length

Mass of male pups was significantly greater than mass of female pups ($P < 0.01$) on St. Paul Island in 2016 (Fig. 20, Table 17). Mass comparisons among rookeries were analyzed separately for male and female pups because the variance for males was greater than that for females ($P < 0.01$). Rookery effects on mass were significant for males ($P < 0.01$; Table 18) and females ($P < 0.01$; Table 31). The variance for pup lengths did not differ significantly between males and females ($P = 0.30$); therefore, the sexes were analyzed together. Pup lengths were significantly different by sex and rookery on St. Paul Island ($P < 0.01$; Fig. 21, Tables 19 and 20).

On St. George Island, pup mass was also significantly different by sex ($P < 0.01$; Fig. 20, Table 21). Again, male and female pup masses were analyzed separately due to the difference in the variances for each sex. Rookery was not a significant factor in the analysis of mass for females ($P = 0.24$), but was for males ($P = 0.02$; Table 22). The variance in pup lengths was not significantly different between males and females ($P < 0.43$) and ANOVA results indicated significant differences by sex ($P < 0.01$) and rookery ($P < 0.01$, Fig. 21, Tables 23 and 24). Mass and length were compared between islands by sex after testing for unequal variances with an F-statistic assuming normal distributions. There were significant inter-island differences in mass of females (St. Paul = 8.04 kg, St. George = 8.28 kg; $P = 0.02$) but not males (St. Paul = 9.42 kg, St. George = 9.55 kg; $P = 0.27$). Both males (St. Paul = 73.5 cm, St. George = 78.4 cm; $P < 0.01$) and females (St. Paul = 70.1 cm, St. George = 75.1 cm; $P < 0.01$) were significantly longer on St. George Island.

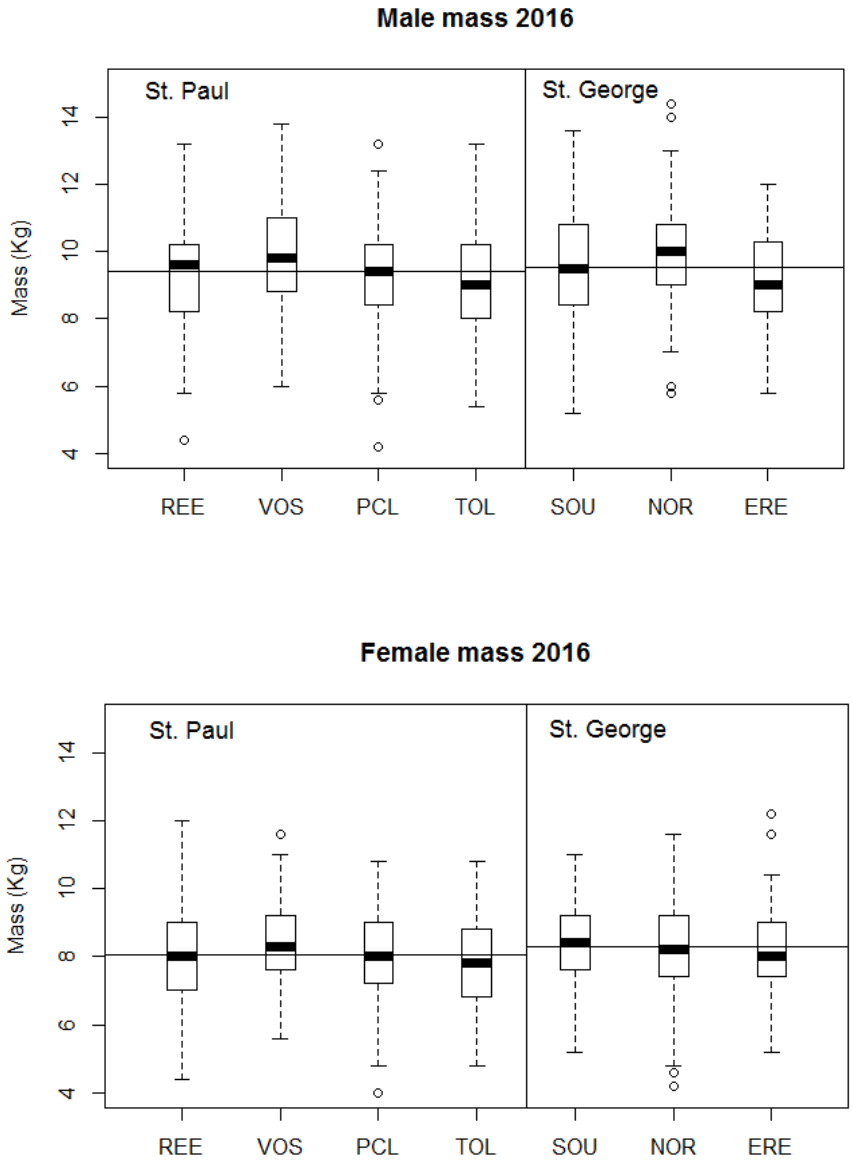

Figure 20. -- Boxplots of the mass (kg) of northern fur seal pups on St. Paul and St. George Islands, Alaska, August 2016: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL), Tolstoi (TOL), South (SOU), North (NOR), and East Reef (ERE). Whiskers represent 1.5 × the interquartile range; open circles are outliers.

Table 17. -- Mean mass (kg), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups weighed at four rookeries on St. Paul Island, Alaska, 22-24 August 2016.

Rookery		Females	Males	Combined
Reef	kg	7.97	9.39	8.69
23 August	SD	1.37	1.54	1.62
	n	151	155	306
Vostochni	kg	8.36	9.81	9.09
24 August	SD	1.25	1.46	1.54
	n	132	135	267
Pol. Cliffs	kg	8.06	9.38	8.66
24 August	SD	1.27	1.45	1.50
	n	131	110	241
Tolstoi	kg	7.74	9.13	8.53
22 August	SD	1.31	1.53	1.59
	n	112	150	262
Combined	kg	8.04	9.42	8.75
	SD	1.32	1.51	1.58
	n	526	550	1076

Table 18. -- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. Paul Island, Alaska, August 2016.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	3	24.7	8.2	886	522	4.85	<0.01
Males							
Rookery	3	33.5	11.2	1,225	546	4.98	<0.01

*MSS = SS divided by df

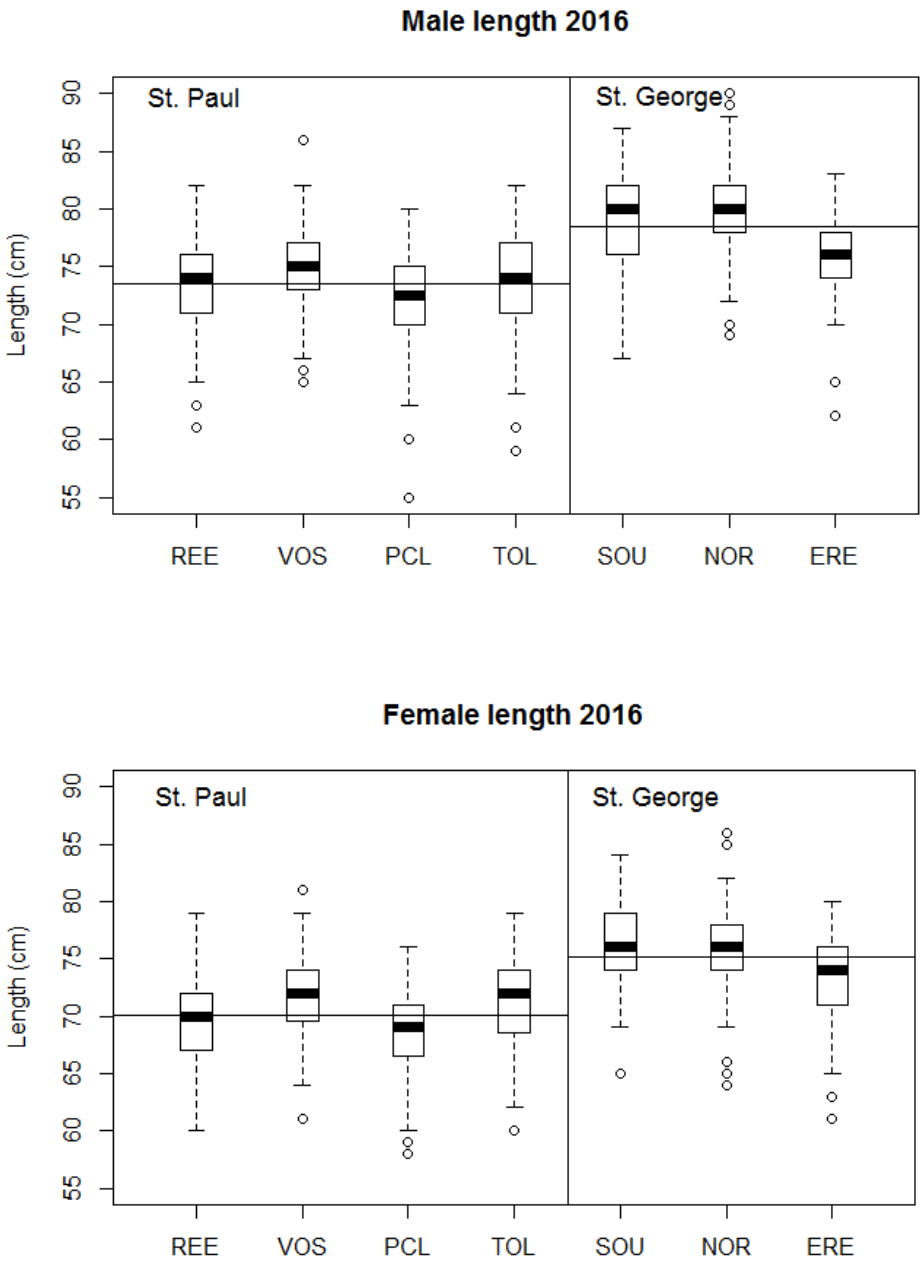

Figure 21. -- Boxplots of the length (cm) of northern fur seals on St. Paul and St. George islands, Alaska, August 2016: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL),Tolstoi (TOL), South (SOU), North (NOR), and East Reef (ERE). Whiskers represent 1.5 × the interquartile range; open circles are outliers.

Table 19. -- Mean length (cm), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups measured at four rookeries on St. Paul Island, Alaska, 22-24 August 2016.

Rookery		Females	Males	Combined
Reef	cm	69.6	73.4	71.5
23 August	SD	3.92	3.65	4.22
	n	151	155	306
Vostochni	cm	71.6	74.6	73.1
24 August	SD	3.40	3.54	3.80
	n	132	135	267
Pol. Cliffs	cm	68.5	72.1	70.2
24 August	SD	3.39	4.08	4.12
	n	131	110	241
Tolstoi	cm	70.8	73.7	72.5
22 August	SD	3.96	4.41	4.46
	n	112	150	262
Combined	cm	70.1	73.5	71.8
	SD	3.84	4.01	4.29
	n	526	550	1076

Table 20. -- Analyses of variance of length of male and female northern fur seal pups on St. Paul Island, Alaska, August 2016.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Sex	1	3,227	3,227	16,568	1,074	222.82	< 0.01
Rookery	3	1,059	353	15,510	1,071	24.37	< 0.01

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

Table 21. -- Mean mass (kg), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups weighed on St. George Island, Alaska, 22-24 August 2016.

Rookery	Mass	Females	Males	Combined
South	kg	8.46	9.58	8.94
23 August	SD	1.12	1.83	1.56
	n	88	66	154
North	kg	8.15	9.89	9.09
24 August	SD	1.48	1.59	1.77
	n	74	86	160
East Reef	kg	8.17	9.20	8.76
22 August	SD	1.26	1.47	1.47
	n	64	87	151
Combined	kg	8.28	9.55	8.93
	SD	1.29	1.64	1.61
	n	226	239	465

Table 22. -- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2016.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	2	4.8	2.4	371	223	1.45	0.24
Males							
Rookery	2	20.8	10.4	618	236	3.97	0.02

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

Table 23. -- Mean length (cm), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups measured on St. George Island, Alaska, 22-24 August 2016.

Rookery		Females	Males	Combined
South	cm	76.3	78.8	77.4
23 August	SD	3.26	4.59	4.06
	n	88	66	154
North	cm	75.7	80.2	78.1
24 August	SD	4.34	3.75	4.61
	n	74	86	160
East Reef	cm	72.9	76.2	74.8
22 August	SD	4.14	3.82	4.28
	n	64	87	151
Combined	cm	75.1	78.4	76.8
	SD	4.14	4.36	4.54
	n	226	239	465

Table 24. -- Analyses of variance of length of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2016.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Sex	1	1203	1203	8,380	463	76.1	< 0.01
Rookery	2	1094	547	7,285	461	34.6	< 0.01

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

Sex Ratios

The fractions of female pups by rookery were significantly different from 0.5 only on Tolstoi rookery (0.43, P = 0.02) on St. Paul in 2016 (Table 25). Across the sampled rookeries, the fraction of females was not significantly different from 0.5 on St. Paul Island (0.49, P = 0.48), St. George Island (0.49, P = 0.57) or islands combined (0.49, P < 0.36). Sex ratios between islands did not differ significantly (P = 0.92).

DISCUSSION

Consistent with earlier evaluations of pup size (York and Antonelis 1990, York and Towell 1993, Towell et al. 1996, and Towell et al. 1997), the strongest pattern was that male pups were heavier and longer than female pups. After controlling for sex, both male and female pups in 2016 were significantly longer on St. George Island than those on St. Paul Island. Male mass did not differ between islands in 2016 (P = 0.26). The fraction of females was significantly different than 50% only on Tolstoi rookery in 2016, consistent with differences seen across the past two decades (Table 26). Differences in mass and length may reflect the influence of environmental variability on the condition of pups and their mothers. Undetected biases in sampling techniques may also be responsible for the differences detected in this study.

Table 25. -- Numbers of northern fur seal female pups, total number of pups, and fraction (that are female) of pups sampled during pup weighing on St. Paul and St. George Islands, Alaska, August 2016. The fraction of females is significantly less than 50% ($P \leq 0.05$) for bold items.

Rookery	Females	Total	Fraction
St. Paul			
Reef	151	306	0.493
Vostochni	132	267	0.494
Polovina Cliffs	131	241	0.543
Tolstoi	**112**	**262**	**0.427**
Total	526	1,076	0.489
St. George			
South	88	154	0.571
North	74	160	0.463
East Reef	64	151	0.424
Total	226	465	0.486

Table 26.-- Numbers of female pups, total number of pups, and fraction (that are female) of live northern fur seals pups captured during weighing operations on St. Paul and St. George Islands, Alaska, for the years 1996-2016. Bold numbers indicate the fraction of females significantly different than 50%.

	St. Paul			St. George		
Year	Females	Total	Fraction	Females	Total	Fraction
1996	**520**	**1149**	**0.453**	**331**	**749**	**0.442**
1997	495	1020	0.485	311	639	0.487
1998	**506**	**1100**	**0.460**	**344**	**745**	**0.462**
1999	**462**	**1081**	**0.427**	--	--	--
2000	543	1079	0.503	**292**	**640**	**0.456**
2001	**510**	**1095**	**0.466**	--	--	--
2002	**424**	**1016**	**0.417**	300	627	0.478
2004	**489**	**1,067**	**0.458**	**279**	**619**	**0.451**
2006	**446**	**983**	**0.454**	304	640	0.475
2008	500	1,029	0.486	298	627	0.475
2010	**472**	**1,016**	**0.465**	303	652	0.465
2014	**462**	**1,026**	**0.450**	**212**	**470**	**0.451**
2016	526	1,076	0.489	226	465	0.486

DEMOGRAPHIC STUDIES OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2007-2016

by

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

From 1958 to 1980, the population of northern fur seals on the Pribilof Islands (St. Paul and St. George Islands), as indexed by pup production estimates, declined by over 60% (Towell 2007). On St. Paul Island, pup production was stable from 1980 to around 2000 before entering a second period of decline of ~6% annually (Towell et al. 2006), and a subsequent hiatus from 2010-2014 (Fig. 8). For the smaller population at St. George Island, the initial decline ended around 1990 with a second decline beginning about the same time as on St. Paul Island, but pup production has been relative stable or increasing on St. George Island since 2004 (Fig. 8). In response to the most recent decline, the 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 demographic research program began on St. Paul Island, and in 2009 on St. George Island. The objectives were to estimate age-specific survival and reproductive rates of tagged female northern fur seals in order to determine which life-history stage or stages, in comparison with historic age-specific rates, were driving the population decline. From this, we hoped that critical ecological or anthropogenic causal mechanisms for the decline might be either excluded or identified for further research and mitigation. Here, we describe the tagging and re-sighting efforts of northern fur seals from 2007

to 2016 at three study sites on the Pribilof Islands, building on earlier reports (Testa et al. 2013, 2016), with preliminary estimates of reproductive and survival 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 the terrain be favorable for re-sighting and identifying tagged fur seals, using high-powered optics and cameras, without significant disturbance to the seals. The study sites chosen, as described in more detail by Testa et al. (2013, 2016), are at the northernmost end of Polovina Cliffs (Section 7) and at Zapadni Reef on St. Paul Island (Fig. 2), and at South rookery on St. George Island (Fig. 3).

METHODS

Adult female fur seals were captured by noose-pole and restrained with a neoprene vest and wooden stock restraining board (Gentry and Holt 1982), usually in late September and early October, though captures in 2007 and 2008 were conducted from late October to mid-November at Polovina Cliffs (Testa et al. 2010). Animals were weighed on the restraining board using a digital scale and tags were applied to the trailing edge of both foreflippers near the hairline (Gentry and Holt 1982, Antonellis 1992; Fig. 22). The color of vibrissae (dark, mixed, or white) was noted as an index to age (Scheffer 1962). A range of other procedures were performed and samples collected for related studies, as described earlier (Adams et al. 2007, Testa et al. 2013). Pups were captured and restrained by hand, tagged in both foreflippers, and weighed in a large bucket from a suspended scale (Antonelis 1992).

Several different tag types (Fig. 22) were used and evaluated (Testa et al. 2013, 2016): Allfex large (AL) cattle tags and Allflex narrow (AN) sheep tags (Allflex USA, Dallas, TX, USA), Dalton Superflexitags (DS; Dalton ID Systems Ltd., Oxfordshire, United Kingdom), and Monel (M) self-piercing round-post tags (National Band and Tag Company, Newport, KY, USA). One of these tag types were sometimes paired with VHF radio-tags (applied for other purposes), but the radio-tags were not considered a reliable means of visual identification. By 2010 it was clear that Allflex sheep tags were superior in retention and durability to the others (Testa et al. 2013, 2016), and were used exclusively in remaining years, with the exception for VHF tags mentioned above.

Re-sighting and identification of tagged seals was accomplished with the aid of binoculars, spotting scopes, and digital telephoto photography from late June or early July to the

Figure 22. -- 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).

end of August (2008-2011) or early August (2012). Beginning in 2012, the period of re-sighting effort was extended into the fall to obtain more observations of juveniles tagged as pups. Field protocols for data collection are described by Testa et al. (2013, 2016) and resulted in daily

records for each tagged seal seen, the number and condition of its tags, and whether it was associated with a pup on that day. A small number of re-sightings came from other fur seal monitoring activities (e.g., bull counts, harvests), occasional search of other rookeries or haulouts, and a few roundups of juvenile males on haulouts.

A small number of tagged seals have only been detected at rookeries other than where they were tagged, demonstrating a small, but unknown level of permanent emigration that biases survival estimates downward. Some of these adult seals could also have been captured in the fall while only visiting that rookery (i.e., actually a permanent resident from a neighboring rookery or section). For these reasons, conservative filters were imposed on our sample of adult females in order to minimize this known bias to survival estimates (though unknown biases might be introduced with such filters if seals retained in the analysis are not representative of survival probabilities): only females seen on the rookery with a pup after the year of tagging were assumed to be resident and therefore unlikely to emigrate. The re-sighting season each year was confined to 1 July-5 Aug to standardize the length of the survival intervals, with all sightings for that season reduced to a single annual sighting observation. Only re-sightings at the rookery of original tag deployment were included in the analysis.

Previous tag loss estimates (Testa et al. 2013) were based on the assumption that tag loss from opposite flippers was independent (Testa and Rothery 1993). Those rates were significantly higher for DS than for AN tags, and the assumption of independence is questionable in pinnipeds (Bradshaw et al. 2000, McMahon and White 2009) but believed to be less of a factor when estimates of tag loss are low (Oosthuizen et al. 2010). Estimated loss rates of single AN tags were extremely low (~0.01 the first year, and less over time), and we have treated seals with one or two AN tags as the primary group for survival estimation in order to minimize bias from tag

loss (Testa et al. 2016). The proportion of Dalton tags seen on any given day that were unread began to increase from an average under 5% in the first three years to 44% in 2014 at St. Paul Island, 5-6 years after the tags were initially applied (Testa et al. 2016). The increase was primarily due to faded lettering. Whereas many of these faded tags might have been read under ideal conditions during the season, the degradation contributed to a lower probability of sighting, and in lower apparent survival of DS-tagged seals as if the tags had been lost. Also, parturient females are typically associated with a pup only ~25% of the times they are seen, so this decline in readability creates negative bias in our reproductive estimates. Both of these effects were controlled by excluding all adult seals with Dalton tags ≥ 4-years-old that were tagged as adults from our reproductive analyses, and incorporating DS tags ≥ 4-years-old as a covariate in the survival analyses to isolate and quantify that effect. Among DS tags applied to pups, those at South showed the same degradation as the tags on adults, but at Polovina Cliffs tags deployed on pups (in 2008 and 2009) were much more readable up to age 6.

All tagging studies of large mammal demographics carry inherent problems of representation. Even if one can safely assume to have tagged a representative sample of the population, the tag cohorts age and die while the larger population balances that process with recruitment of young animals. Where there is senescence in survival or reproduction, as has been established for northern fur seals (Lander 1981), one may expect estimated survival and reproduction of tagged cohorts to decline over time as older animals become over-represented in the tagged sample. We included a covariate for years since first tagged to model this effect in both survival and reproduction without knowing the true age of the individuals.

Adult female survival was estimated in program ‘marked’ (Laake et al. 2013) in the R statistical software package (R Core Team 2012). Models incorporating constant and time-

varying survival (Phi) and probability of sighting (p), as well as covariates for tag type and tag age were compared using Akeike's Information Criteria (AIC) to select the best model or models (Burnham and Anderson 2002). Only females bearing AN, DS and AL tags, and seen once on the study site with a pup in a year after their first tagging occasion were analyzed, considering the year of re-sighting as the beginning of their history. DS tags 4-years-old and older were modeled as a covariate on survival, and as a covariate on probability of sighting at age 5 and older due to the degradation of the tags. Survival estimates are reported for the best-retained tag type (AN), given the known effect of tag loss for the other tag types (Testa et al. 2016).

Female pup survival was also estimated in 'marked' for three cohorts that survived to age 5 years: South (2011) and Zapadni Reef (2010 and 2011). The first re-sighting occasion (as yearlings) was excluded due to the very low number of tagged yearlings seen. Only AN-tagged pups were analyzed. Polovina Cliffs rookery was excluded from analysis due to the low sample size. Models were completely general (i.e., fully age-specific probabilities of survival and re-sighting, and survivorship (cumulative survival to age) with confidence intervals were estimated by Markov Chain Monte Carlo (MCMC) sampling of annual survival estimates to produce a cumulative product estimate for survival to each age (Laake et al. 2013).

Pupping rates were estimated using generalized linear models (logit link; R Core Team 2012), pooling all sightings of an individual each year and counting any positive behavioral association with a pup as evidence of parturition (Testa et al. 2013, 2016). Females tagged as non-pups could include immature seals, so for analysis of known-adult females we included only those that had been associated with a pup in a previous year (i.e., "known-parous"). Testa et al. (2016) suggested an effect of cohort aging on reproductive rates, and the years since first tagging was included as a covariate, along with year as a trend variable and as individual factors. Age-

specific rates of pupping and parity (pupped in a given year or previously) were pooled across all pup cohorts that were at least 4-years-old by 2016 and are presented graphically for comparison to previous estimates of age of first reproduction (York 1983).

RESULTS

Tagging and Resighting Effort

From 2007 to 2017, 13,979 pups and 1,301 non-pup northern fur seals were tagged at the 3 sites, with numbers of animals re-sighted at least once each year ranging from 56 to 1,053 (Table 27). The temporal distribution of re-sighting effort varied by site and year (Fig. 23). South rookery on St. George Island has good vantages with little opportunity for disturbance, so can be easily surveyed at all times. Polovina Cliffs becomes increasingly difficult to approach after July without significant disturbance, so few visits were made after August. Zapadni Reef was primarily used to address survival of tagged pup cohorts, and re-sighting effort in September to October was prioritized there due to the later arrival of 2- and 3-year-olds (Testa et al. 2016).

Adult Female Survival

For adult females at Polovina Cliffs, the AIC identified the model controlling for constant effects of tag type on survival, and DS tag age ≥ 5 years on probability of sighting, which was favored over its nearest competing model by ΔAIC of 9.57. Adult females with AN tags had an annual apparent survival of 0.80 (95% CI = 0.76-0.83), whereas DS (< 4-years-old) and AL tags had an estimated survival of 0.69 (95% CI = 0.64-0.74) and 0.73 (95% CI = 0.67-0.78), respectively. Annual probability of sighting was 0.94 (95% CI = 0.92-0.96), except for old DS tags (0.58, 95% CI = 0.36-0.76). Despite the clear difference in AIC values, alternative models had nearly identical estimates of survival of AN-tagged adults.

Table 27. -- Numbers of northern fur seals tagged and re-sighted as adults (non-pups) annually at three study rookeries on St. Paul (SP) and St. George (SG) Islands, Alaska.

	Tagged Adults (non-pups)			Tagged Pups			Re-sighted Adults		
Rookery:	Polovina Cliffs (SP)	Zapadni Reef (SP)	South (SG)	Polovina Cliffs (SP)	Zapadni Reef (SP)	South (SG)	Polovina Cliffs (SP)	Zapadni Reef (SP)	South (SG)
2007	230								
2008	92			18			205		
2009	131		92	480		1963	218		
2010	8		162	138	656	1763	271		56
2011	84		191	58	703	1840	196		270
2012	41		0	39	562	1039	196		567
2013	32		1	164	577	1158	291	113	816
2014	36		0	19	521	928	222	335	504
2015	81		11	239	624	406	232	449	1053
2016	38	26	45	101	377	876	212	534	972
Total	**773**	**26**	**502**	**1268**	**4020**	**8691**			

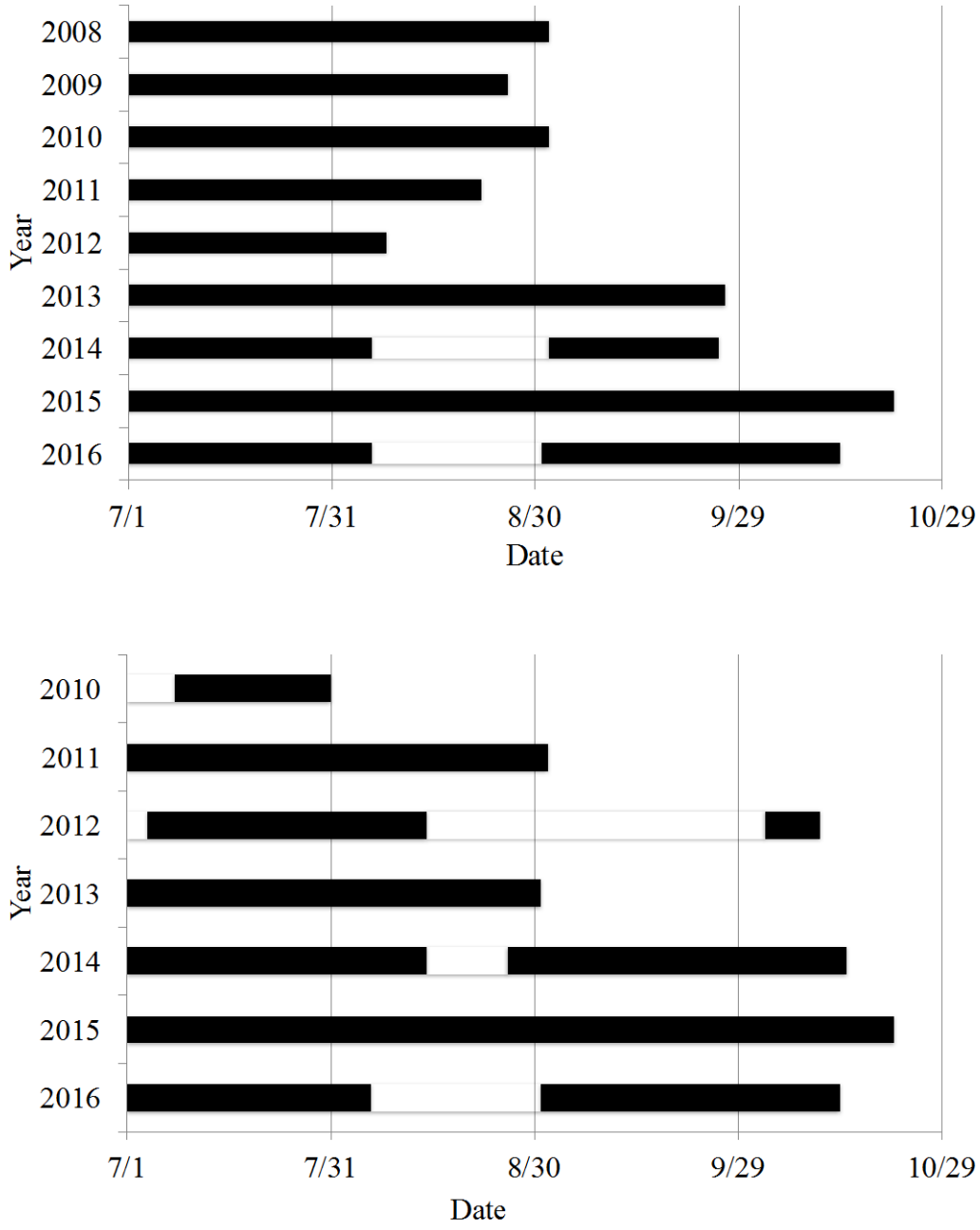

Figure 23. -- Seasonal distribution of tag re-sighting effort on St. Paul Island (top, Polovina Cliffs in all years, and Zapadni Reef 2013-2016) and St. George Island (South rookery, bottom). At St. Paul Island most observations in July and August were from Polovina Cliffs, and most observations from Zapadni Reef were from September and October.

At South rookery, a single model of survival was chosen by AIC criteria (DS tags ≥4-years-old, tag type and years since first tagged; Fig. 24), with three nearly identical models for probability of sighting (constant, tag type, and DS tags ≥ 5-years-old) that had high estimates (>0.98 all tags except old DS) and did not affect survival estimates. A constant survival model derived solely from AN tags, which appear to have negligible double-tag loss, estimated the annual survival of 0.81 (95% CI = 0.78-0.84) and p = 0.99 (95% CI = 0.98-1.00).

Pup Survival

The three pup cohorts with AN tags that were followed into their 5th year of life (South 2011, Zapadni Reef 2010 and 2011) had high rates of re-sighting at ages 4 and 5 (Table 28), suggesting recruitment to the breeding rookery had been obtained at both sites by that age. Estimates of survivorship at every age were overlapping among the three cohorts, with the point estimate at South slightly higher than those at Zapadni Reef (Table 28).

Adult Pupping Rates

Controlling for years since first tagged, and excluding DS-tagged seals >4-years-old, adult reproductive rates on both islands were generally high. At Polovina Cliffs there was some support (P = 0.06) for a higher (0.92, 95% CI = 0.89-0.96) reproductive rate in 2009 than in the remaining years (0.89, 95% CI = 0.84-0.92). At South, the pupping rate was similarly high (0.88, 95% CI = 0.85-0.90), except for a lower rate (0.76, 95% CI = 0.72-0.81) in 2016.

Age of First Reproduction

Among female seals that were tagged as pups and seen at ages 3-6, age-specific pupping rates were similar at all three study sites when only seals seen at each age were included (Fig. 25a), or when assuming those not seen at a given age but seen subsequently (known to be

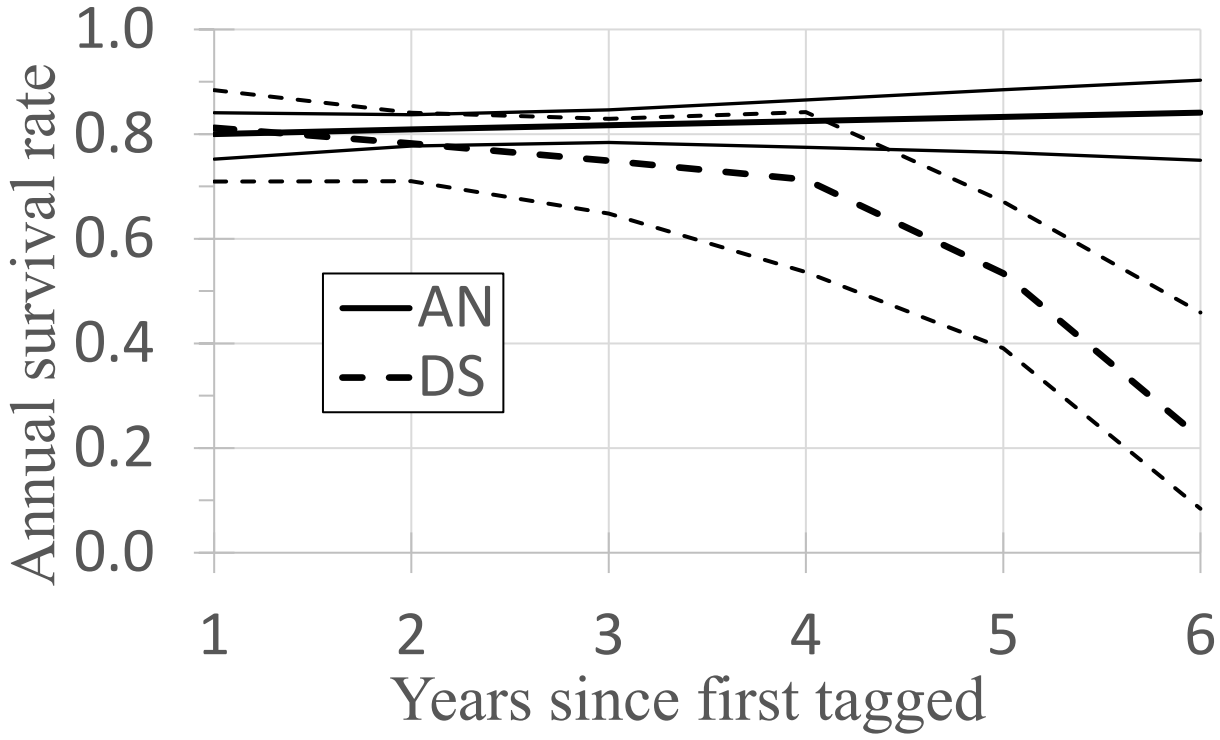

Figure 24. -- Estimated annual survival rates and 95% confidence intervals of adult female fur seals at South rookery modeled as a function of tag type, Allflex narrow (AN) sheep tags or Dalton Superflexitags (DS), and years since first tagged. Decline in apparent survival of Dalton tags is a result of tag loss and deterioration of tag lettering.

Table 28. -- Age-specific survivorship and probabilities of resighting of female northern fur seal cohorts tagged with AN tags at South rookery (St. George Island) in 2011, and Zapadni Reef rookery (St. Paul Island) in 2010 and 2011. No estimates were made at age 1 due to the very low return of seals at age 1, nor at age 2 for the Zapadni Reef cohort of 2010 due to lack of re-sighting effort there in 2012.

	Age-specific survivorship (95% CI) to age (years)			
Rookery (year)	2	3	4	5
Zapadni Reef (2010)		0.24 (0.20-0.28)	0.18 (0.15-0.21)	0.14 (0.11-0.17)
Zapadni Reef (2011)	0.29 (0.24-0.36)	0.23 (0.20-0.26)	0.18 (0.15-0.21)	0.14 (0.11-0.17)
South (2011)	0.30 (0.27-0.34)	0.26 (0.23-0.29)	0.21 (0.18-0.24)	0.17 (0.14-0.20)

	Probabilities of sighting at age (in years)			
	2	3	4	5
Zapadni Reef (2010)		0.45 (0.38-0.55)	0.95 (0.89-0.98)	0.97 (0.91-1.00)
Zapadni Reef (2011)	0.19 (0.14-0.26)	0.78 (0.71-0.84)	0.94 (0.87-0.98)	0.99 (0.83-1.00)
South (2011)	0.37 (0.31-0.43)	0.82 (0.77-0.87)	0.89 (0.83-0.94	0.90 (0.82-1.00)

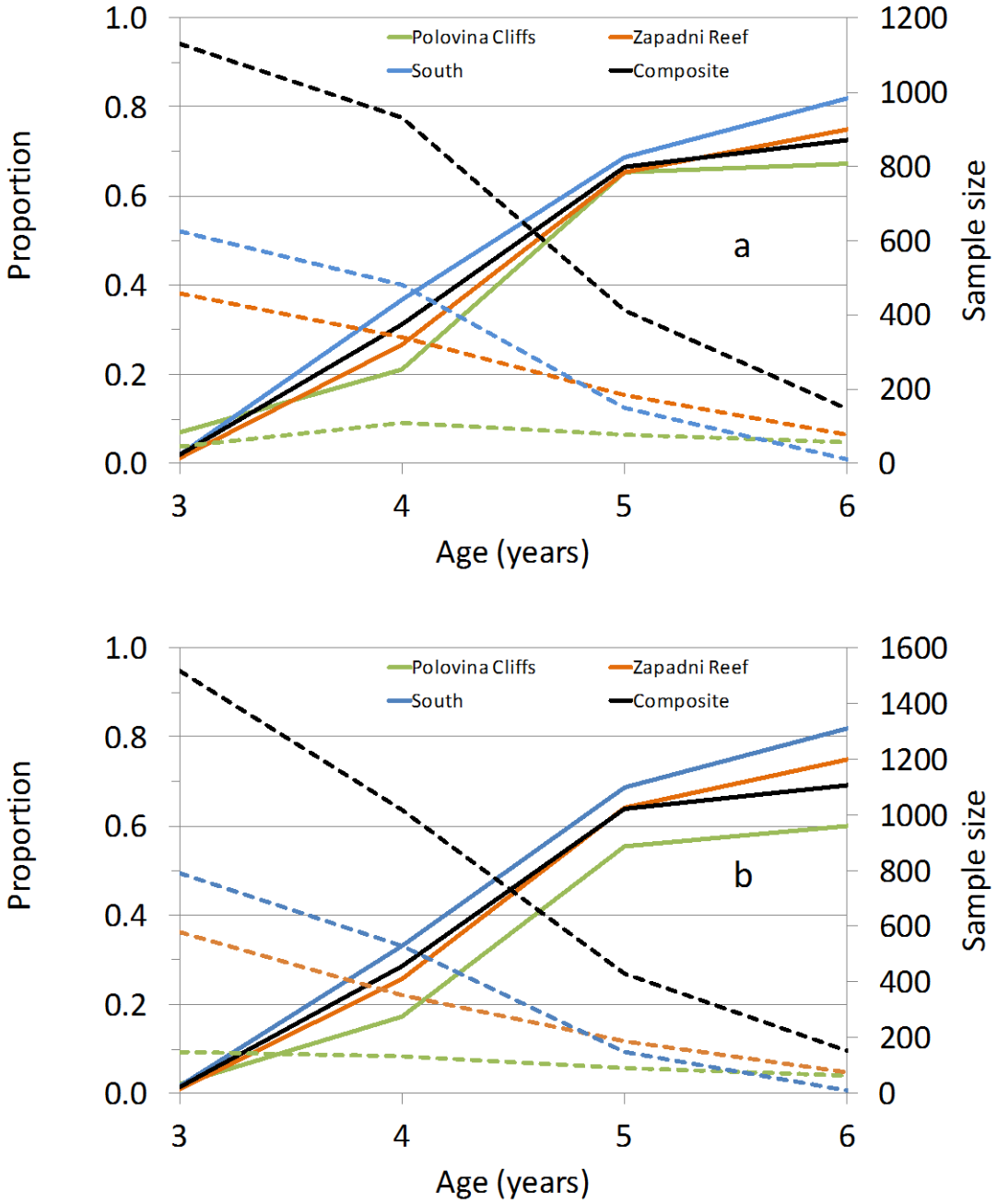

Figure 25. -- Age-specific sample sizes (dashed) and proportions (solid) of northern fur seals seen with pups among cohorts originally tagged as pups at South, Zapadni Reef and Polovina Cliffs rookeries, and all rookeries pooled. Top figure (a) includes only those seals seen at the given age, whereas the bottom (b) includes seals if they were seen in that year or later (i.e., known to be alive at age, but assumed non-parturient if not seen).

alive) did not have a pup (Fig. 25b). Both methods indicated pupping rates > 65% by age 5 (Fig. 25).

When considered as an age-specific rate of parity and using all females known to be alive at each age, over 60% of those seen were parous by age 5, and over 80% were parous by age 6 (Fig. 26). Age specific rates of parity were lowest at Polovina Cliffs and highest at South rookery, but this is probably a result of different behavior and sighting probabilities; re-sighting rates of juveniles is higher at South than at Polovina Cliffs, where seals may be present a short distance from the small rookery section under study and not be observed. Zapadni Reef has intermediate sightability, with effort coming primarily later in the summer and under more difficult re-sighting conditions.

DISCUSSION

Apparent pupping rates among tagged females at these study sites have been high and comparable to the highest historic estimates (Lander 1981, Towell 2007). Models of adult reproduction here were controlled for years past first tagging as a proxy for age, so impose some correction for the aging of the tagged population. The estimated rates excluded possible nulliparous juveniles and females whose tags had deteriorated to the point where their re-sighting rates were low and the likelihood of associating them with their pup had declined, but did not account for females that were not seen in a given year and may have skipped pupping. In the latter case, the degree of potential negative bias must be small, given that re-sighting rates at both rookeries are > 0.94, allowing for only a small amount of bias even if none of the missing females pupped elsewhere, which is not certain. Lander's (1981) estimates of age-specific

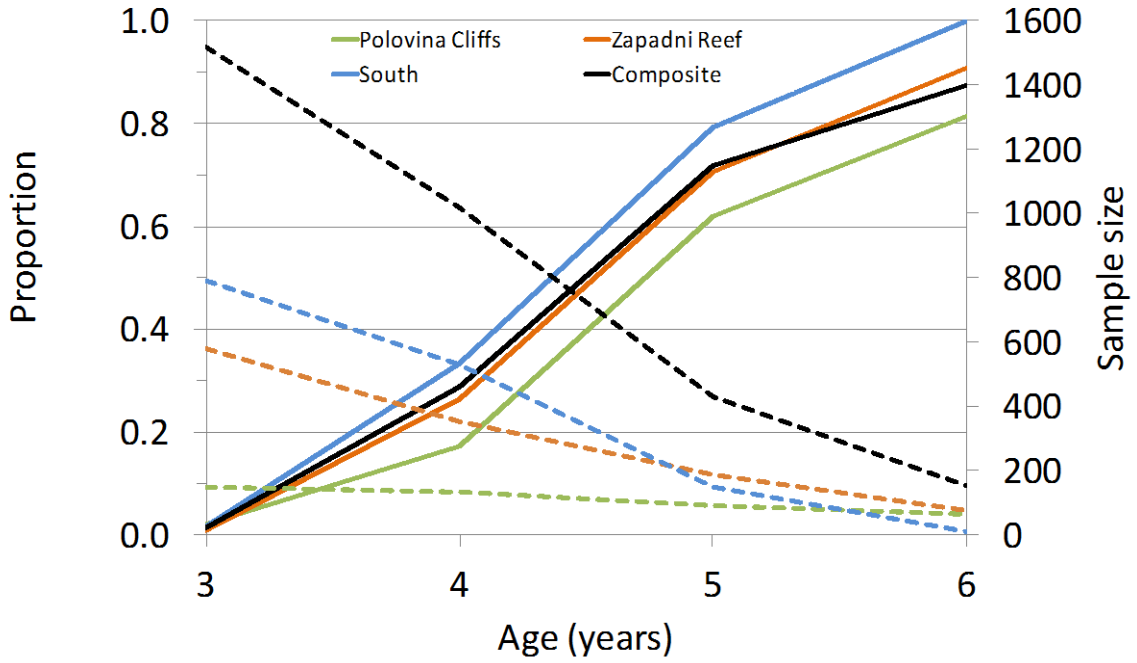

Figure 26. -- Age-specific sample sizes (dashed) and proportions (solid) of northern fur seals that were known parous (had pup at that age or younger) among cohorts originally tagged as pups at South, Zapadni Reef and Polovina Cliffs rookeries, and all rookeries pooled. Seals were included if they were seen in that year or later (i.e., known to be alive at age, but assumed non-parturient if not seen).

pregnancy rate, when adjusted by a stable age structure yield an average adult pregnancy rate of around 0.83, suggesting that the current reproductive rate is at least as high as during the period of pelagic collections (1958-1974), and is probably higher (Testa et al. 2010). Considered with the high pregnancy rates determined by ultrasonography in 2007 and 2008 (Testa et al. 2010, Shero et al. 2017), it appears unlikely that reduced adult reproduction has contributed to the recent population decline.

Similarly, AFR from longitudinal studies has some potential biases that are different from the collection data York (1983) used to estimate AFR due to the missing observations of young seals not seen, but potentially without pups at early ages (i.e., 4 and 5). However, the high rates of re-sighting and the effects of conservative assumptions about missing animals do not appear to affect the conclusion that AFR in recent years was roughly a year younger than determined from the pelagic collections of 1958-1974.

Lander's (1981) life table, derived from pelagic collections from 1958-1974, produced a stable finite population growth rate ($\lambda = 1.0$). Those age-specific survival rates weighted by a stable-age distribution produces averages that can be compared to the juvenile and adult classes we estimated (Table 29). In general, recent reproductive parameters are higher and survival estimates are lower than those of Lander (1981). However, the current rates still imply a rate of population growth that is more negative than observed in the years of this study. Using the simplified Lotka equation derived by Eberhardt and Siniff (1979), the finite rate of growth implied by the ranges shown in Table 29 is $\lambda = 0.91 \pm 0.03$, which substantially exceeds the annual rate of decline in pup production in the period of this study. This implies significant unexplained bias in our survival rates. The apparent rates of tag loss for our best-retained tags, on which the survival rates are based, is too small to account for such a large difference (Testa et al. 2016).

The largest remaining factor that has not been accounted for is permanent emigration, which is the subject of ongoing research.

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 will be revised.

Table 29. -- Comparison of vital rates derived from Lander's (1981) life table for fur seals and a stationary age structure, and the range of values estimated in this study.

Vital rates	Lander(1981)	This study
Age at >50% pupping	6 years	5 years
Adult pupping rate	0.84	0.84-0.92
Survival(0-4 years)	0.31	0.15-0.24
Annual adult survival	0.89	0.76-0.84

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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.

Page

Appendix 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, 9-14 July 2015. 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	18	9													27
3	83	30													113
5	45	10													55
Kitovi [b]															
2	(3) 6	2	6	14	7										38
3	(12) 17	33	40	42	37										181
5	(31)1	8	11	13	75										139
Reef															
2	22	33	11	12	11	15	7	14	3	6	4				138
3	41	59	38	43	31	58	0	57	34	28	3				392
5	12	30	21	26	78	14	32	12	35	48	42				350
Gorbatch															
2	20	8	16	16	12	11									83
3	60	32	51	20	48	53									264
5	208	13	17	42	14	12									306
Ardiguin															
2	6														6
3	51														51
5	7														7
Morjovi[c]															
2	(17) 11	14	17	6	11	9									85
3	(39) 41	38	40	21	73	36									288
5	(11) 139	19	19	12	30	47									277
Vostochni															
2	13	6	6	12	10	18	10	4	8	4	5	9	13	16	134
3	38	23	31	45	35	69	33	39	33	24	21	57	155	83	686
5	39	20	7	16	27	35	15	7	13	10	7	17	43	44	300
Little Polovina															
2	0														0
3	0														0
5	98														98
Polovina															
2	16	10													26
3	72	41													113
5	113	68													181
Polovina Cliffs															
2	10	4	2	6	10	11	19								62
3	36	30	23	42	36	53	37								257
5	12	4	3	2	1	9	6								37
Tolstoi															
2	12	6	4	4	12	22	28	40							128
3	19	21	26	35	35	37	53	51							277
5	2	2	2	3	6	19	17	181							232
Zapadni Reef															
2	41	25													66
3	125	35													160
5	42	80													122
Little Zapadni															
2	2	11	18	20	17	13									81
3	19	31	39	33	39	53									214
5	9	26	14	11	19	121									200
Zapadni															
2	9	9	15	13	17	26	16	21							126
3	19	41	40	49	48	56	51	56							360
5	102	10	18	14	24	25	24	153							370

[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.

Appendix Table A-2. – Number of adult male northern fur seals counted (rounded average of two counts), by class[a] and rookery section, St. Paul Island, Alaska, 10-19 July 2016. 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	21	5													26
3	73	32													105
5	40	7													47
Kitovi[b]															
2	(2) 6	3	13	15	9										48
3	(10) 13	22	31	34	26										136
5	(13) 4	10	6	7	55										95
Reef															
2	4	30	7	11	20	18	2	15	13	5	1				126
3	43	76	42	45	35	67	1	62	42	46	5				464
5	15	39	21	20	23	13	17	15	15	11	23				212
Gorbatch															
2	13	10	14	4	5	19									65
3	56	35	64	26	58	60									299
5	133	7	31	31	8	3									213
Ardiguin															
2	4														4
3	30														30
5	7														7
Moriovi[c]															
2	(15) 17	5	13	2	16	7									75
3	(50) 43	42	48	24	51	34									292
5	(35) 97	3	14	9	11	25									194
Vostochni															
2	4	7	6	12	9	14	3	3	4	3	3	6	11	11	96
3	37	16	28	54	39	67	30	34	33	18	25	53	133	82	649
5	9	6	11	13	14	20	6	12	9	6	1	17	35	34	193
Little Polovina															
2	0														0
3	0														0
5	83														83
Polovina															
2	12	15													27
3	55	45													100
5	137	13													150
Polovina Cliffs															
2	9	6	3	4	14	16	5								57
3	32	22	20	35	31	51	45								236
5	7	2	3	2	6	2	4								26
Tolstoi															
2	3	10	6	7	7	13	13	19							78
3	23	23	27	42	40	52	53	61							321
5	6	2	4	3	8	11	12	82							128
Zapadni Reef															
2	36	13													49
3	111	32													143
5	68	54													122
Little Zapadni															
2	2	6	12	17	12	17									66
3	23	34	43	41	36	65									242
5	10	7	13	12	15	64									121
Zapadni															
2	6	7	6	12	15	11	21	15							93
3	22	36	46	52	41	57	64	51							369
5	73	1	5	8	8	16	17	114							242

[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

Appendix Table A-3. -- Number of northern fur seal pups sheared on each sampled rookery of St. Paul Island, Alaska, 2016.

	Section															
Rookery	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Lukanin		224	94													318
Kitovi[a]	21	40	60	85	91	66										363
Reef[b,c]		108	211	114	106	84		162	174	72	78	6				1115
Gorbatch		153	98	168	70	156	151									796
Ardiguen		75														75
Morjovi[a]	108	146	144	154	89	175	115									931
Vostochni[c]		88	44	67	128	99	155	97	79	88	24	68	94	321	194	1546
Polovina		178	143													321
Little Polovina																
Polovina Cliffs		106	62	55	103	81	131	120								658
Tolstoi		60	53	68	144	107	148	156	175							911
Zapadni Reef		320	91													411
Little Zapadni		55	85	110	105	95	158									608
Zapadni		51	111	113	144	96	152	131	108							906
Total																8,959

[a] Section 0 corresponds to 2nd Point South on Morjovi and Kitovi Amphitheater.
[b] Section 7 was combined with Section 6.
[c] One pup died during shearing include here but not included in the estimation of pups born.

Appendix Table A-4. -- Number of harem and idle males, pups born, number of rookeries sampled, standard deviation (SD) of the number of pups born, and the number of dead pups on the Pribilof Islands, Alaska, 1990-2016. 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
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[a]	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[a]	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[a]	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[b]	720	650	17,072	143	6	712[b]
2007	3,568	5,270	--	--	--	--	744	559	--	--	--	--
2008	4,119[c]	5,050	102,674	1,084	13	5,503[b]	805	638	18,160	288	6	986[b]
2009	4,121	5,226	--	--	--	--	873	824	--	--	--	--
2010	3.974	4.840	94.502	1.120	13	5.284[b]	830	1.030	17.973	323	6	959[b]
2011	3.829	5.139	--	--	--	--	842	1.112	--	--	--	--
2012	3,336	3,657	96,828	1,260	13	3,624[b]	852	1,055	16,184	155	6	497[b]
2013	3,794	4,042	--	--	--	--	953	915	--	--	--	--
2014	3.362	3.504	91.737	769	13	2722[b]	876	1.108	18.937	308	6	502[b]
2015	3.356	3.674	--	--	--	--	989	688	--	--	--	--
2016	3,386	2,643	80,641	717	13	2,181	898	588	20,490	460	6	229

[a] Dead pups for the entire Island are estimated from the mortality rate on sampled rookeries.
[b] Total dead pups are estimated from dead pup counts on sample rookeries, different protocol than [a].
[c] Error in bull counts, see Appendix Table B-1 (FSI 2008-09) for details on Vostochni, section 14.

Appendix Table A-5. -- Number of dead northern fur seal pups counted by section on the sampled rookeries of St. Paul Island, Alaska, 2016.

		Section														
Rookery	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	necropsies	Total
Lukanin	8/16	64	39														103
Reef	8/17	25	35	17	22	20	6	27	39	27	9	1					228
Morjovi[a]	8/18	(33) 24	28	25	14	37	13										174
Zapadni Reef[b]	8/16	34	118														152
Polovina Cliffs[b]	8/19							21									

[a] Number in parentheses are number of dead pups counted in Second Point South of Sea Lion Neck, Morjovi.
[b] Dead pups were counted and piled on Zapadni Reef rookery and section 7 of Polivina Cliffs for vital rates studies

Appendix Table A-6. -- Number of northern fur seal pups sheared on each rookery of St. George Island, Alaska, 2016.

Rookery	Section					Total
	1	2	3	4	5	
South	98	129	128			355
North	108	166	176	111	61	622
East Reef	246					246
East Cliffs	304	146				450
Staraya Artil	64	12				76
Zapadni	150		57			207
Total						1,956

Appendix Table A-7. -- Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 2016.

Rookery	Date	Section					Total
		1	2	3	4	5	
South	8/19	7	20	14			41
North	8/21	22	26	15	9	9	81
East Reef	8/18	25					25

Appendix Table A-8. -- Number of dead northern fur seals counted that were older than pup, Pribilof Islands, Alaska, 1979-2016. 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
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
2014[n]	11	43	2	4	13	47
2016	3	19	3	5	6	24

[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 taken from 2 males and 2 females on Reef, or from 1 female and 2 males on Little Zapadni and 1 male on Morjovi.
[n] Teeth were not taken from 1 male and 2 females on Gorbatch, or from 3 females on Vostochni.

APPENDIX B

Scientific staff engaged in northern fur seal
field research in 2013-2014

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

Employees and Volunteers	Affiliation
Jason Baker	NMML
John Bengtson	NMML
Robert DeLong	NMML
Tom Gelatt	NMML
Jeff Harris	NMML
Harriet Huber	NMML
Devin Johnson	NMML
Carey Kuhn	NMML
Jeff Laake	NMML
Katie Luxa	NMML
Sharon Melin	NMML
Anthony Orr	NMML
Rolf Ream	NMML
Jeremy Sterling	NMML
Katie Sweeny	NMML
Ward Testa	NMML
Jim Thomason	NMML
Rod Towell	NMML
Kristin Wilkinson	NMML

Research Associates and Cooperators	
Roxanne Beltran	UAA
Ryan Berger	PBCS
Sean Bogle	OAI
Russell Bradley	PBCS
Laurel Ann Curry	PBCS
Jacob Drucker	PBCS
Garrett Duncan	PBCS
John Edwards	OAI
Eva Gruber	PBCS
Sophie Guarasci	MMC
Mark Hoover	ABL
Oliver James	PBCS
Greg Larsen	OAI

Serge Lekanof	SGTC
Pamela Lestenkof	TGSP
Captain Lestenkof	SGTC
Curtis Lestenkof	SGTC
Kyle Marsh	PBCG
Paul Melovidov	TGSP
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Affiliation Codes

ABL – Auke Bay Laboratory, Alaska Fisheries Science Center, Juneau, AK
MMC – Marine Mammal Center, Sausalito, CA
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.
ODFW – Oregon Department of Fish and Wildlife, Astoria, OR
OEPA – Ohio Environmental Protection Agency
PBCS – Point Blue Conservation Group
SGTC – St. George Traditional Council
TGSP – Tribal Government of St. Paul, AK
UAA – University of Alaska Anchorage

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AFSC-

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