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Fur Seal Investigations, 2013-2014

J. W. Testa (editor)

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Fur Seal Investigations, 2013-2014

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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 2013-2014.

Population parameters monitored in 2013 and 2014 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 2014. Harem males increased by 13.3% between 2012 and 2013 and decreased 10.7% between 2013 and 2014. The total estimated number of pups born on St. Paul Island in 2014 was 91,737 (SE = 769); on St. George the estimate was 18,937 (SE = 308). Pup mortality at one month of age was approximately 3% on both islands. Pup production estimates on St. Paul in 2012 and 2014 were similar to that in 2010, with no significant decline over the last three estimates (2010-2014) after ~ 6% annual decline from 1998 to 2010. On St. George, pup estimates have been stable or slightly increasing since 2002 or 2004. In 2014, pups of both sexes were significantly longer and heavier at St. George than at St. Paul. Since 2002, pup production has been below that estimated in 1919, when the population was recovering at 8% annually from a pelagic harvest that ended in the early 20th century. The subadult male harvest on the Pribilof Islands was 379 and 365 in 2013 and 2014, respectively. An inaugural harvest of 214 pups was conducted in autumn 2014 on St. George. Modeling of possible pup harvests on St. Paul projected a mostly minor impact on the population after 25 years, unless the sex ratio of the harvest (expected to be targeted on males) approached 1:1.

From 2007 to 2014, 759 adult and subadult female fur seals were flipper-tagged in the fall at Polovina Cliffs rookery, St. Paul. From 2009 to 2014, 471 were tagged at South Rookery on St. George. Eight hundred and ninety-five female pups were tagged at Polovina Cliffs from 2008 to 2014; 3,010 were tagged from 2010 to 2014 at Zapadni Reef rookery on St. Paul; 8,691 pups of both sexes were tagged from 2009 to 2014 at South Rookery, St. George. Re-sightings were made in July-August every year after the initial tag deployments, and in Sept.-Oct., 2012-2014 for juveniles at South and Zapadni Reef rookeries. Pupping rates at both rookeries 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. Tag loss varied by tag manufacturer (Dalton Superflexitag loss > Monel metal tags > Allflex sheep tags), tag age (1^{st} year > later years), age class (pups > adults), and rookery (South > Polovina Cliffs). Estimated cumulative loss of both tags from an individual were low for adults (0-11% after 3-5 years, depending on tag type), but were as high as 25% (95% confidence interval = 17%-29%) for Dalton tags after 5 years in the first cohort of pups from South rookery. Dalton tags were largely unreadable after 5 years.

At San Miguel Island the index count of territorial bulls at Adams Cove was 166 and 224 in 2013 and 2014, respectively, the latter representing the highest value observed since 1997. In 2013, the total numbers of pups at Adams Cove and Castle Rock were estimated at 2,051 and 1,218, respectively. Only Adams Cove was estimated in 2014, where 2,288 births were estimated, 2% higher than the previous peak in 1997. Pup mortality from birth to 3 months of age in recent years has been high and remained so in 2013 (39%) and 2014 (28%). Pup weights standardized to 1 October were near the long-term average in 2013, but they were more than 2 kg lower in 2014. Counts from aerial photographs of the Farallon Islands, California were presented

for the first time: 401 and 656 pups and 265 and 363 non-pups were counted in 2013 and 2014, respectively.

The total stock size of northern fur seals in the United States, which includes Bogoslof, the Pribilof, and San Miguel Islands was approximately 634,000 fur seals, 83% of which are from the Pribilof Islands.

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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). The smaller

population at nearby St. George declined at a more or less steady rate to less than 30% of the peak, but has stabilized in the last decade. Commercial harvesting of fur seals was discontinued on St. George Island in 1973 and on St. Paul Island in 1984. A small subsistence harvest by Alaska Natives of juvenile males 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 National Marine Mammal Laboratory (NMML) to monitor the status of northern fur seals on U.S. rookeries and to disseminate that information, usually on a biennial basis. This report covers the period 2013-2014, including the most recent biennial estimate of pup production on the Pribilof Islands. In addition, the methods and progress of NMML's recent study of fur seal demographics at three Pribilof rookeries based on longitudinal study of tagged seals is described. Research by the NMML on northern fur seals in 2013-2014 was conducted under Marine Mammal Protection Act Permit No. 782-1708-00.

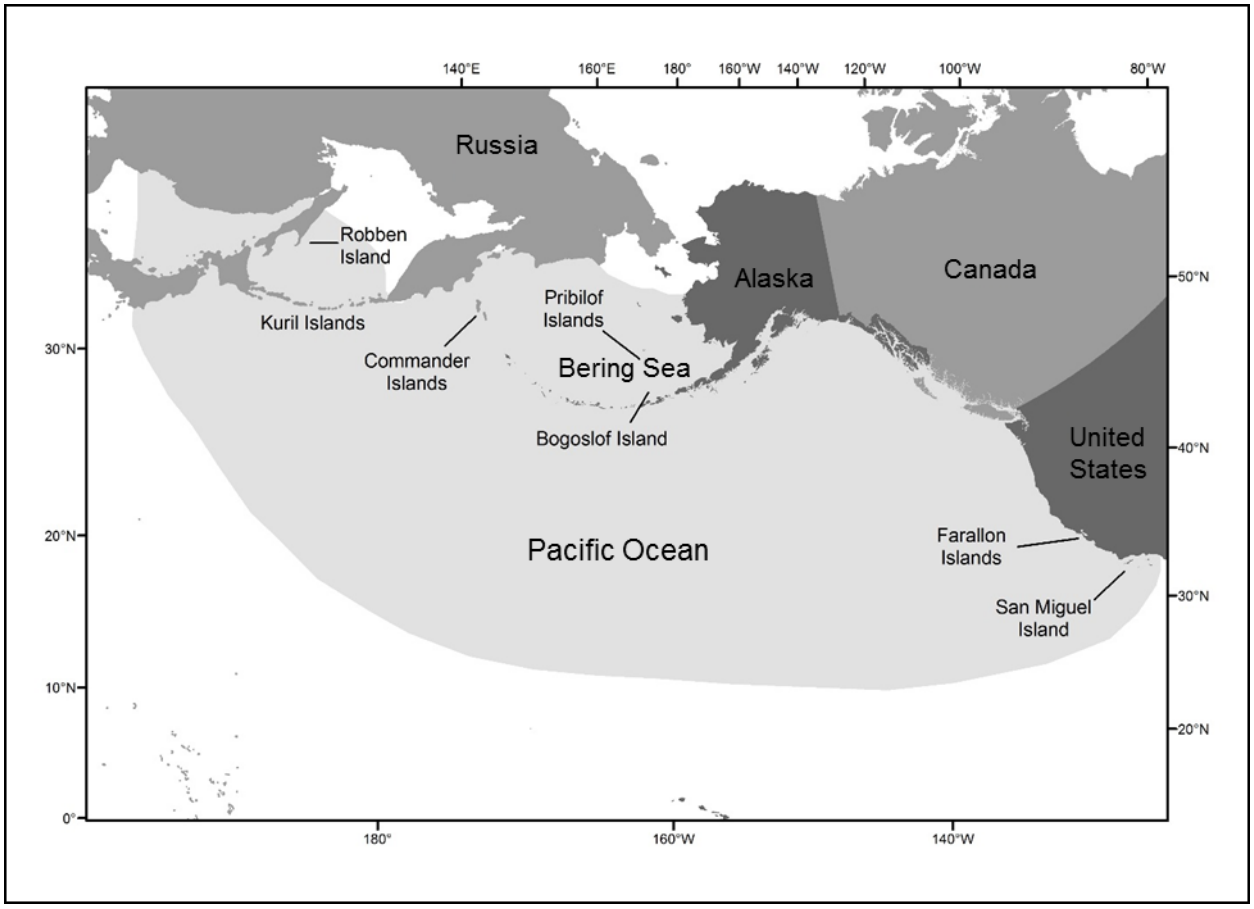

Figure 1. -- Range of northern fur seals and locations of their breeding colonies.

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

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

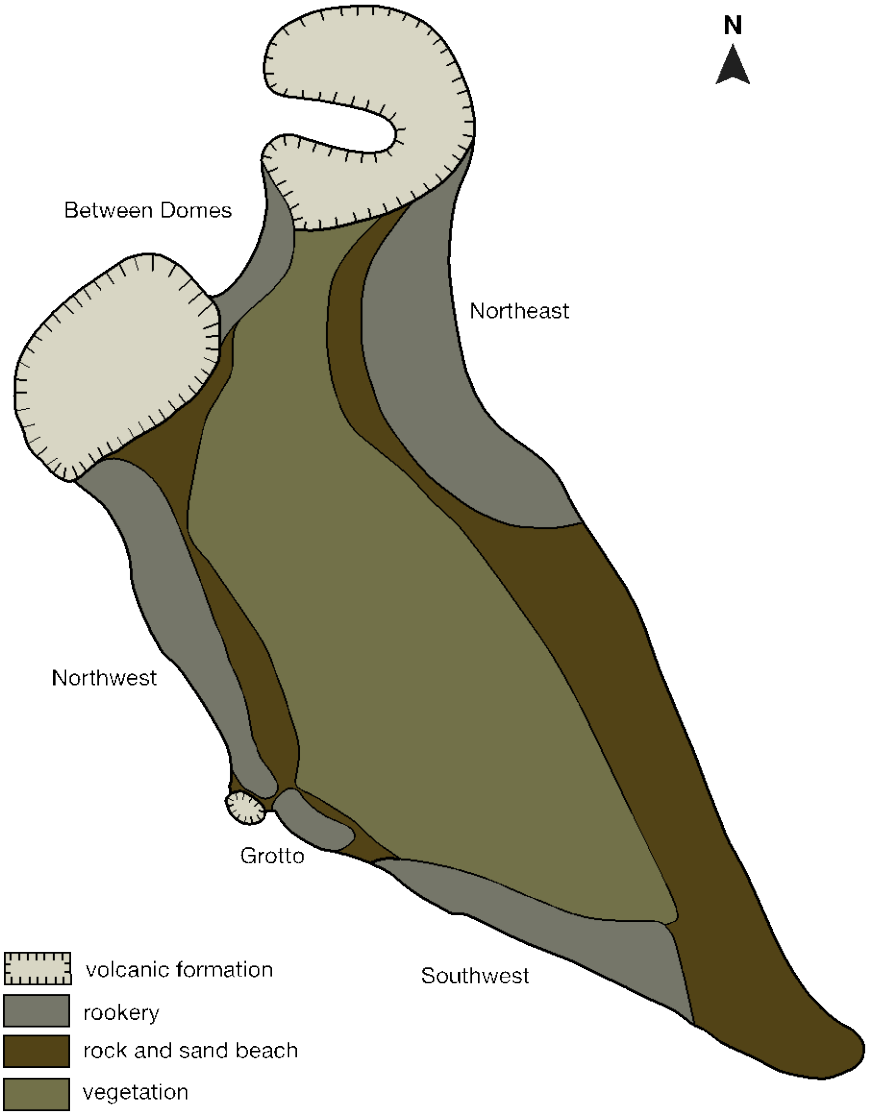

Figure 4. -- Location of northern fur seal rookeries on Bogoslof Island, Alaska.

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

POPULATION ASSESSMENT OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2013 - 2014

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 National Marine Mammal Laboratory (NMML) continues to monitor the status of fur seal populations on the Pribilof Islands. To meet these objectives, data on population size, age and sex composition, and natural mortality are collected annually following the methods described by Antonelis (1992).

METHODS

Population characteristics monitored in 2013 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 2014.

The subsistence harvest was monitored for the number of juvenile males 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. Monitoring on St. Paul Island was conducted and reported by staff from the St. Paul Island Tribal Governments Ecosystem Conservation Office and a board-certified veterinarian, under a grant and contract, respectively,

from the National Marine Fisheries Service (NMFS). The St. George Island Kayumixtax Eco-Office, also under a grant from NMFS, monitors and reports the subsistence harvest of northern fur seals on St. George Island.

Adult male fur seals were visually counted by section for each rookery on St. Paul Island from 10 to 17 July 2013 and 7 to 15 July 2014 (Appendix Tables A-1 and A-2, respectively**)** and on St. George Island from 14 to 16 July 2013 and 9 to 13 July 2014. Counters categorize males as territorial with (Class 3) and without (Class 2) females on the rookeries, and males on hauling grounds (Class 5; Antonelis 1992).

On St. Paul Island, dead fur seal pups were counted on 4 sample rookeries and the numbers of live pups were estimated on 13 rookeries in August 2014 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 and St. George Islands were surveyed for dead fur seals older than pups during surveys for dead pups in August 2014. The total number of pups born was estimated using ratio estimation (Cochran 1977). From 5 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 2012. 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 14 to 26 August. Each observer counted marked and unmarked pups independently to ensure that the entire rookery was well

sampled. Each sampling day was considered an independent replicate; the variance was computed for each rookery based on these replicates (York and Kozloff 1987). Little Polovina rookery was not sampled due to the concern that this small rookery might be more sensitive to disturbance. 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 2014. Dead pups were counted from 16 to 20 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 2014 in the same manner as applied on St. Paul Island. The ratio of marked to unmarked pups on each rookery was determined by two observers from 18 to 20 August and again from 21 to 23 August. Dead pups were counted on three rookeries from 21 to 25 August 2014.

RESULTS AND DISCUSSION

Harvest

A total of 298 and 262 sub-adult male seals were harvested for subsistence on St. Paul Island in 2013 and 2014, respectively (Table 1). On St. George Island, 80 sub-adult male seals were taken in the subsistence harvest in 2013 and 103 were killed in 2014 (Table 2a). Three females were killed in both 2013 and 2014 on St. Paul Island and 1 female was killed on St. George Island in 2014, all females taken were included as part of the subsistence harvest. A total of 54 male northern fur seal pups were harvested for subsistence on St. George Island during November 2014 (Table 2b).

Table 1. -- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvests on St. Paul Island, Alaska, in 2013 and 2014.

2013			2014		
Date	Rookery	Number killed	Date	Rookery	Number killed
July 6	Polovina	16	July 2	Polovina	26
July 13	Zapadni Sands	41	July 18	Zapadni Sands	53
July 20*	Lukanin	26	August 1	Polovina	48
July 27	Morjovi	24	August 4	Lukanin	21
August 3	Polovina	25	August 6***	Zapadni Sands	26
August 5	Zapadni Sands	36	August 7	Morjovi	26
August 6**	Lukanin	51	August 8*	Polovina	66
August 7	Reef	82			
Total		301			266

* Includes 1 female.
** Includes 2 females.
*** Includes 3 females.

Table 2a. -- Date, location, and number of sub-adult male northern fur seals killed in subsistence harvest drives on St. George Island, Alaska, in 2013 and 2014.

2013			2014		
Date	Rookery	Number killed	Date	Rookery	Number killed
July 8	North	10	July 7	North	9
July 10	Zapadni	6	July 9	Zapadni	6
July 15	Zapadni	10	July 11	North	10
July 18	North	10	July 17	Zapadni	11
July 29	Zapadni	11	July 21	North	12
July 31	North	10	July 24	Zapadni	12
August 5	Zapadni	10	August 4*	North	14
August 7	North	13	August 6	Zapadni	12
			August 8	North	18
Total		80			104

* Includes 1 female.

Table 2b. -- Date, location, and number of northern fur seal pups killed in subsistence harvest drives on St. George Island, Alaska, in 2014.

2014		
Date	Rookery	Number killed
November 6	North	12
November 11	East Reef	13
November 17	East Cliffs	9
November 22	North	20
Total		54

Adult Males Counted

The count of territorial males with females (Class 3 or harem males) on St. Paul Island increased 13.7% between 2012 and 2013 and declined 11.4% between 2013 and 2014 (Tables 3 and 4; Appendix Table A-4). The count of harem males on St. George Island increased 11.8% between 2012 and 2013, and decreased 8.1% between 2013 and 2014 (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 13.3% between 2012 and 2013 and decreased 10.7% between 2013 and 2014.

Number of Pups Born on St. Paul Island in 2014

The estimated total number of pups alive on St. Paul Island at the time of marking in 2014 was 89,015 (SE = 725) (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 2,722. The estimated mortality rate for late August was 3.0%. The total number of pups born on St. Paul Island in 2014 was estimated at 91,737 (SE= 769; 95% CI = (90,107 – 93,397)). 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

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 2013 (Appendix A for descriptions).

	Date	Class of adult male			
Rookery	(July)	2	3	5	Total
St. Paul Island					
Lukanin	10	39	107	137	283
Kitovi	10	73	161	132	366
Reef	14	139	443	417	999
Gorbatch	14	103	315	316	734
Ardiguen	14	7	51	14	72
Morjovi	16	92	362	258	712
Vostochni	16	156	723	305	1,184
Polovina	17	25	124	97	246
Little Polovina	17	0	0	99	99
Polovina Cliffs	17	61	374	60	495
Tolstoi	13	141	361	228	730
Zapadni Reef	15	59	162	176	397
Little Zapadni	15	82	228	226	536
Zapadni	15	122	383	478	983
Island total		1,099	3,794	2,943	7,836
St. George Island					
South	15	48	195	84	327
North	16	104	294	203	601
East Reef	16	43	108	78	229
East Cliffs	16	51	220	119	390
Staraya Artil	14	26	43	45	114
Zapadni	15	21	93	93	207
Island total		293	953	622	1,868

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 2014.

Rookery	Date (July)	Class of adult male 2	3	5	Total
St. Paul Island					
Lukanin	7	58	95	81	234
Kitovi	7	90	130	90	310
Reef	10	143	429	263	835
Gorbatch	10/15	99	306	287	692
Ardiguen	10	5	36	6	47
Morjovi	13	96	317	282	695
Vostochni	13	138	631	311	1,080
Polovina	9	23	99	96	218
Little Polovina	9	0	0	68	68
Polovina Cliffs	9	76	265	66	407
Tolstoi	8	140	260	166	566
Zapadni Reef	11/12	69	158	126	353
Little Zapadni	12	86	256	191	533
Zapadni	11/12	135	380	313	828
Island total		1,158	3,362	2,346	6,866
St. George Island					
South	9	55	164	94	313
North	11	102	285	270	657
East Reef	13	50	105	79	234
East Cliffs	12	54	212	165	431
Staraya Artil	12	17	39	64	120
Zapadni	9	29	71	129	229
Island total		307	876	801	1,984

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, 2014.

Rookery	Sheared	E1	E2	Mean	SE
Lukanin	292	3,152	2,798	2,975	177.0
Kitovi	374	3,539	3,433	3,486	53.0
Reef	1,303	11,317	11,300	11,309	8.5
Gorbatch	838	8,332	7,280	7,806	526.0
Ardiguen	81	746	810	778	32.0
Morjovi	964	9,443	8,875	9,159	284.0
Vostochni	1,539	15,036	14,964	15,000	36.0
Polovina	286	2,838	3,265	3,052	213.5
Little Polovina*					
Polovina Cliffs	912	7,605	7,454	7,530	75.5
Tolstoi	951	8,888	8,781	8,835	53.5
Zapadni Reef	459	3,801	4,000	3,901	99.5
Little Zapadni	736	6,031	5,749	5,890	141.0
Zapadni	1,049	9,514	9,074	9,294	220.0
Sea Lion Rock	459	5,387	4,801	5,094	293.0

* 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, 2014.

Rookery	Pups alive at marking	Total pups born	Harem males	Ratio pups/males
Lukanin	2,975	3,066	95	32.27
Kitovi	3,486	3,593	130	27.64
Reef	11,309	11,655	429	27.17
Gorbatch	7,806	8,045	306	26.29
Ardiguen	778	802	36	22.28
Morjovi	9,159	9,439	317	29.78
Vostochni	15,000	15,459	631	24.50
Polovina	3,052	3,145	99	31.77
Little Polovina			0	
Polovina Cliffs	7,530	7,760	265	29.28
Tolstoi	8,835	9,105	260	35.02
Zapadni Reef	3,901	4,020	158	25.44
Little Zapadni	5,890	6,070	256	23.71
Zapadni	9,294	9,578	380	25.21
St. Paul Total	89,015	91,737	3,362	27.29
Sea Lion Rock	5,094	5,250		
Total	94,109	96,987		

CI due to the ratio estimation of the total pups born. The above total does not include the pups born on Sea Lion Rock in 2014.

A total of 459 pups were sheared on Sea Lion Rock on 5 August, 2014. A single sampling of marked to unmarked pups occurred on 19 August, 2014. Estimated number of pups alive on Sea Lion Rock at the time of marking was 5,094 (SE = 293.0) and total number of pups born was estimated to be 5,250.

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. 7). The slope of the regression line without an estimated intercept (P = 0.18) was 26.61 (SE = 0.82, P < 0.01), representing an estimate of the ratio of pups to breeding males.

Number of Pups Born on St. George Island in 2014

Estimated total number of pups alive on St. George Island at the time of marking was 18,435 (SE = 298, Tables 7 and 8). The total number of dead pups was estimated to be 502 (Appendix Table A-7) and the estimated mortality rate was 2.6% (Table 8). The total number of pups born on St. George Island was 18,937 (SE = 308, 95% CI = (18,198 – 19,705)).

The 2014 estimate of pups born on St. George Island was significantly different than the estimate of pups born in 2012 (P < 0.01) and was significantly different than the estimate of pups born in 2010 (P = 0.03). The number of pups born and the number of harem males on St. George Island rookeries were highly correlated (r^2 = 0.99; Fig. 7). The intercept of the regression line was not significantly different from zero (P = 0.18) and was not included in the regression equation. The slope of the regression line was 21.07 (SE = 0.67) representing an estimate of the ratio of pups born to breeding males.

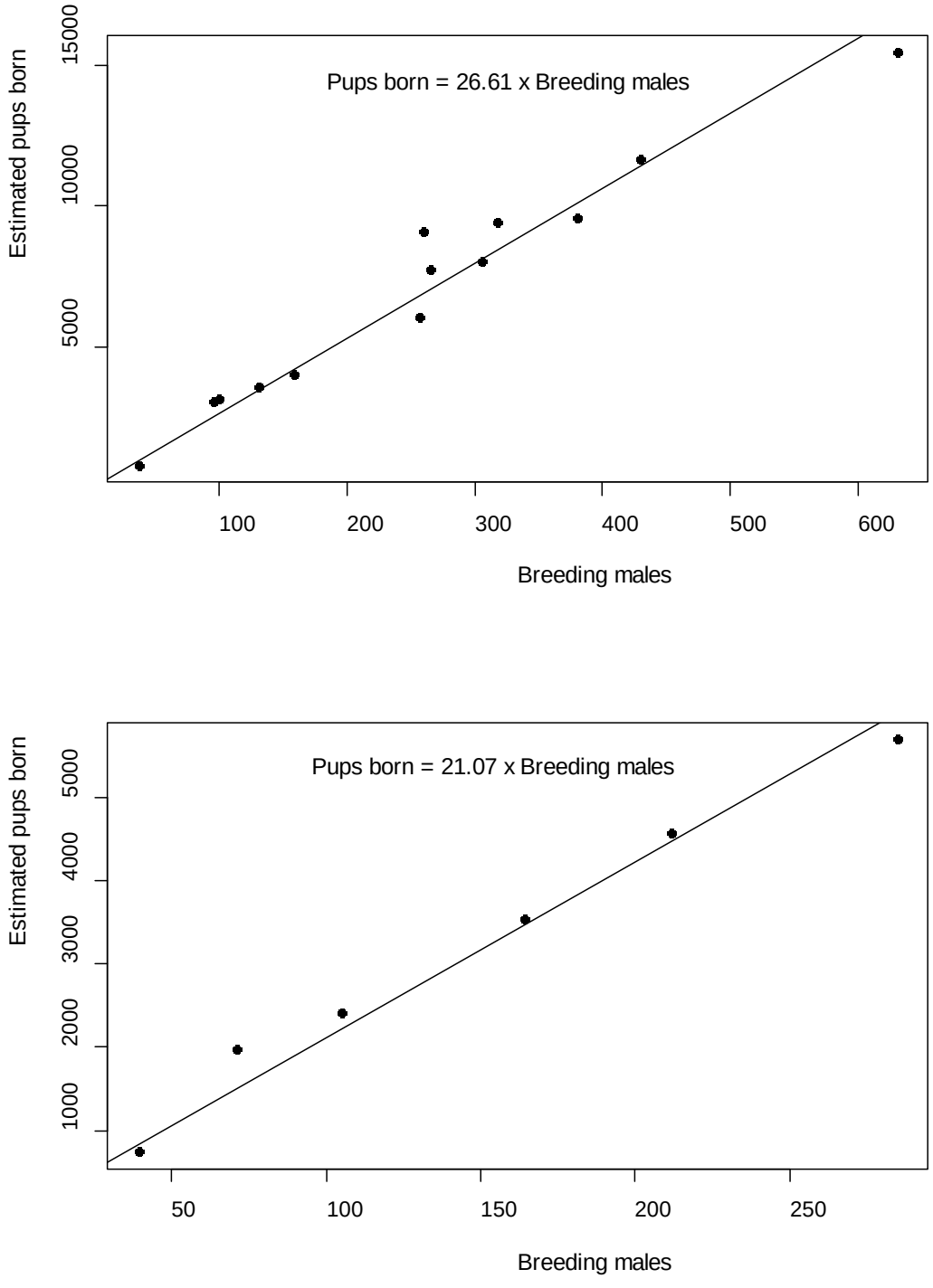

Figure 7. -- Pups born versus number of breeding males on St. Paul Island (top) and St. George Island (bottom), Alaska, 2014. Solid regression lines are shown for both locations.

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, 2014.

Rookery	Sheared	E1	E2	Mean	SE
South	378	3,360	3,542	3,451	91.0
North	502	5,715	5,376	5,546	169.5
East Reef	173	2,502	2,210	2,356	146.0
East Cliffs	410	4,403	4,480	4,442	38.5
Staraya Artil	85	648	792	720	72.0
Zapadni	190	2,074	1,765	1,920	154.5

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, 2014.

Rookery	Pups alive at marking	Total pups born	Harem males	Ratio pups/males
South	3,451	3,545	164	21.62
North	5,546	5,697	285	19.99
East Reef	2,356	2,420	105	23.05
East Cliffs	4,442	4,563	212	21.52
Staraya Artil	720	740	39	18.97
Zapadni	1,920	1,972	71	27.77
Total	18,435	18,937	876	21.62

Trends in Numbers of Pups

The total estimated number of pups born on St. Paul Island in 2014 (not including Sea Lion Rock) was 5.3% less than in 2012 (Fig. 8; $P < 0.01$), which was 2.5% greater than in 2010 (Appendix Table A-4). On St. George Island there was a 17.0% increase between 2012 and 2014, following a 10.0% decrease between 2010 and 2012. Pup production has been declining since 1998 at an average annual rate of 4.25% (SE = 0.48%, $P < 0.01$) on St. Paul Island and 1.42% (SE = 0.54%, $P = 0.04$) on St. George Island. The overall rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 3.71% (SE = 0.48%, $P < 0.01$) annually from 1998 to 2014. However, there is no significant trend in the last 3 estimates on St. Paul (2010-2014), or since 2004 on St. George (Fig. 8). Since 2002, pup production has been lower than was estimated in 1919 on St. Paul Island and in 1917 on St. George Island, when the populations were recovering at 8% annually from a pelagic harvest that ended in the early 20th century.

Estimate of Total Stock 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 stock for the Pribilof Islands population in 2014 (Table 9) was about 528,000 fur seals. The total stock size for the United States, which includes the Pribilof, Bogoslof, and San Miguel Islands was approximately 634,000 fur seals.

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

Sixty dead adult fur seals were counted on rookeries sampled for dead pups (54 on St. Paul Island and 6 on St. George Island; Table 10) and tooth samples were collected from 54. Appendix Table A-8 summarizes the number of dead male and female fur seals from which teeth were collected from 1978 to 2014.

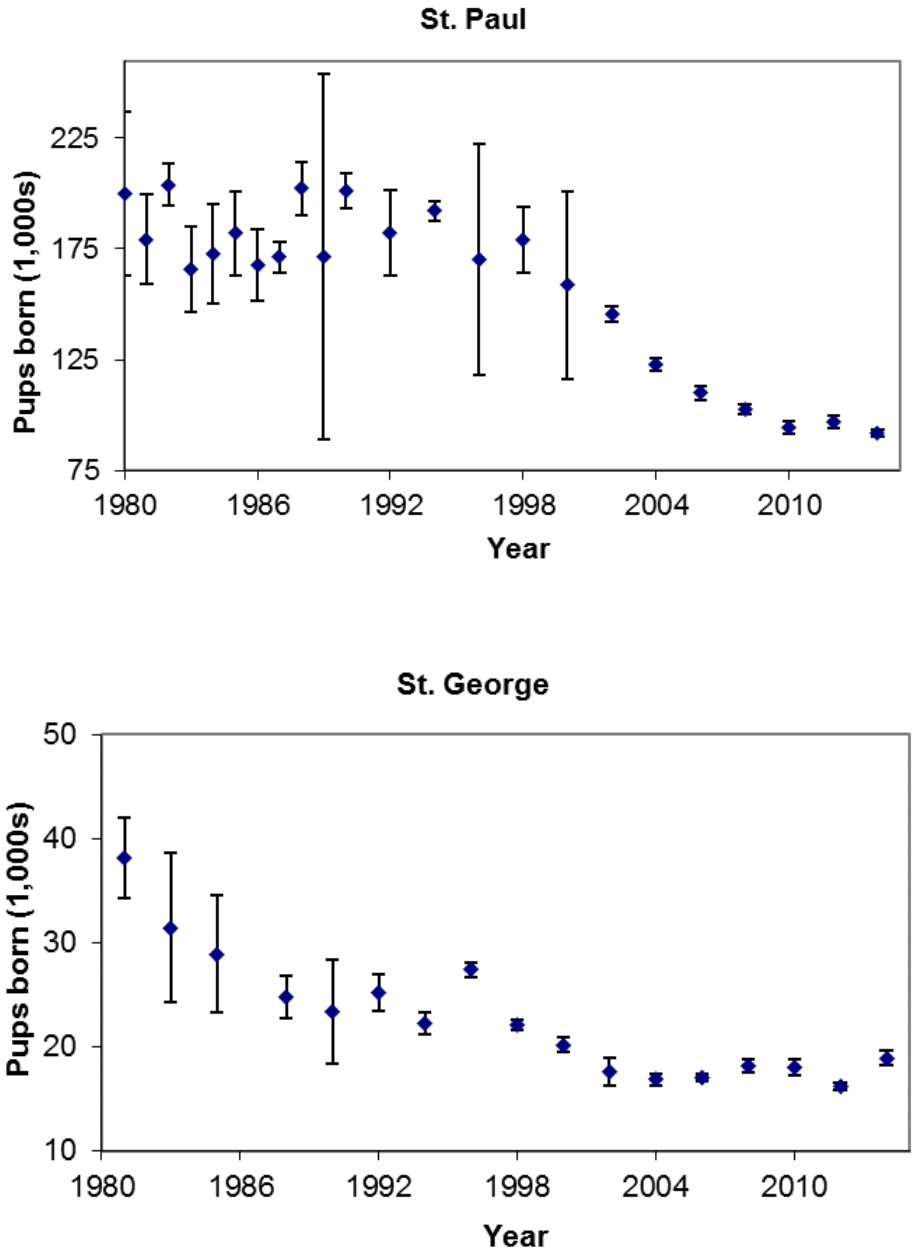

Figure 8. -- Estimated number of pups born (± 95% confidence intervals) on St. Paul and St. George Islands, Alaska, 1980 to 2014.

Table 9. -- Details of the computation of stock size estimates of fur seals in U.S. rookeries in 2014. 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 2010, 2012, 2014	118,050	23,637	Pups
(Pups) × 0.5	59,025	11,818	Yearlings
(Yearlings) × 0.8	47,220	9,455	Age 2 year
(2-year-old females) × 0.86 / 2	20,305	4,066	Females age 3 year
(2-year-old males) × 0.8 / 2	18,888	3,782	Males age 3 year
(Pups) / 0.6	196,750	39,395	Females 3+ years
(3-year-old males) × 3.6	67,997	13,615	Males 4+ years
Total	528,235	105,768	

[1] The mean of the 2008 and 2014 estimates for Sea Lion Rock was added to the St. Paul estimates of pup production for all years because they were the most current.

[2] The 2011-2013 estimates for Castle Rock and 2012-2014 estimates for Adams Cove, both on San Miguel Island and the 2007 and 2011 estimates for Bogoslof Island were used.

Table 10. -- Number of animals older than pups found dead and from which teeth were collected during August 2014 on the Pribilof Islands.

Rookery	Male	Female	Unknown	Total
St. Paul				
Kitovi	2	5	0	7
Gorbatch[1]	3	14	0	17
Vostochni[2]	5	18	0	23
Zapadni Reef	1	6	0	7
Total St. Paul	11	43	0	54
St. George				
South	1	2	0	3
East Cliffs	1	2	0	3
Zapadni	0	0	0	0
Total St. George	2	4	0	6
Total Both Islands	13	47	0	60

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

DEMOGRAPHIC STUDIES OF NORTHERN FUR SEALS ON THE PRIBILOF ISLANDS, ALASKA, 2007-2014

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, pup production was stable from 1980 to 1998 before entering a second period of decline of ~6% annually (Towell et al. 2006) that appears to be slowing and may have stopped since 2010 (Fig. 8). For the smaller population at St. George, the initial decline was continuous to about 1990 with a lesser decline beginning about the same time as on St. Paul, but pup production has been relative stable since 2004 (Fig. 8). In response to the most recent decline, the National Marine Mammal Laboratory convened a panel of experts to evaluate the feasibility and likely success of a long-term tagging program to address demographic questions about the decline given the life history of northern fur seals and past tagging programs (Melin et al. 2006). In 2007, a long-term demographics research program was begun on St. Paul, and in 2009 on St. George, based primarily on tagging and re-sighting of fur seals at a few rookeries where it was deemed feasible. The objectives were to estimate age-specific survival and reproductive rates of female northern fur seals in order to determine which life-history stage or stages, in comparison with historic age-specific rates, were driving the decline. In doing so, it is hoped that critical ecological or anthropogenic causal mechanisms for the decline might be either excluded or identified for further research and mitigation. The purpose of this report is to describe the study sites, captures, tag deployments and re-sighting efforts from 2007 to 2014 at three study sites on

St. Paul and St. George, with preliminary estimates of reproductive rates and evaluation of tags. Unbiased survival estimates are dependent on further study of emigration and tag loss rates, so they will not be presented here.

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, and that the terrain be favorable for re-sighting and identification of tagged fur seals by means of high-powered optics and cameras without significant disturbance to the seals. On St. Paul, nearly all rookeries either lack natural overlooks or have major obstructions (e.g., large rocks). However, the northernmost end (section 7) of Polovina Cliffs rookery has low (5-15 m) overlooking banks with few obstructions (Fig. 9). That section (57° 10’ 11”N, 170° 9’ 54”W to 57° 10’, 19”N, 170° 9’ 43”W), which had ~1,800 pups born in 2006, was selected for studies beginning in 2007. South rookery (Fig. 2, 56° 32’ 40” N, 169° 40’ 32” W to 56° 32’ 4” N, 169° 38’ 43”W, Fig. 10) on the south side of St. George has excellent viewing cliffs ~20 m in height along most of its length, though the beach is wider than at Polovina Cliffs and has larger rocks that can obstruct visibility. Approximately 3,800 pups were born at South rookery in 2008 and demographic studies began with tagging there in 2009. It is known that foraging areas and diet of fur seals differ on St. Paul and St. George by rookery (Robson et al. 2004, Zeppelin and Ream 2006), with fur seals generally foraging in waters matching the direction faced by their rookery shore. Zapadni Reef rookery (57° 9’, 14”N, 170° 18’ 15”W to 57° 9’, 13”N, 170° 18’ 29”W), with ~4,900 pups born in 2008, lies at the head of English Bay on the west side of St. Paul Island. Surrounded by larger rookeries, it was selected in 2010 to represent the large breeding population in English Bay where many of the fur seals are

known to forage westward, both on and off the continental shelf, in contrast to Polovina Cliffs where most foraging by fur seals occurs eastward on the Bering Sea Shelf. Zapadni Reef has no natural vantages for tag viewing (Fig. 11), but the beach is narrow with few large rocks that would block viewing, provided some elevated structures could be built there. Tagging of female pups began there in 2010; dedicated re-sighting effort directed primarily at those tagged fur seals returning as juveniles and newly mature adults began in 2013 using elevated blinds (Fig. 11).

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

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

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

METHODS

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

In their review of fur seal marking methods, Melin et al. (2006) concluded that livestock tags applied to the flippers remain the most viable means of identifying northern fur seals for longitudinal study of their demography. However, little was known about the effectiveness of

contemporary tags for long-term studies in northern fur seals. Earlier studies relied primarily on Monel steel tags that were either not well-retained or were difficult to read without recapturing the seals (Scheffer 1950, York 2006). While several studies have examined the issue of tag retention in other pinnipeds (e.g., Testa and Rothery 1993, Bradshaw et al. 2000, McMahon and White 2009), we were concerned here with the retention and readability of tags over periods that might encompass a long absence for juvenile seals between tagging as pups and possible first return 5-8 years later, and a study duration greater than a fur seal lifespan (Melin et al. 2006). Tag visibility (for detection), readability from distances of 5-80 m, resistance to breakage, wear and fading of printed characters, as well as resistance to tears or necrosis of the foreflippers where tags are applied were all unresolved issues that could bias or invalidate mark-recapture analyses of fur seal re-sighting data. Therefore, several different tag types were used and evaluated in this study. We focused on tags with a history of good performance with other pinnipeds: Allfex large and Allflex sheep tags (Allflex USA, Dallas, TX, USA), Dalton Superflexitags (Dalton ID Systems Ltd., Oxfordshire, United Kingdom), and Monel self-piercing round-post tags (National Band and Tag Company, Newport, KY, USA) (Fig. 12). These were sometimes paired with VHF radio-tags applied for other purposes, but the radio-tags were not considered a reliable means of visual identification.

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

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

Re-sighting and identification of tagged seals was accomplished visually with the aid of binoculars, spotting scopes and digital telephoto photography from late June or early July to the end of August (2008-2011) or 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 (Tables 11 and 12). In all years since 2010 on section 7 of Polovina Cliffs rookery and since 2011 on section 1 of South rookery, daily counts were taken of pups, adult females, and adult territorial and harem bulls.

Observers assigned an arbitrary "seal number", unique for the seal and day, to each tagged seal detected. This seal number was used to link multiple observations that might occur. Time of recording, sighting conditions (1-3, from excellent to poor), section of the rookery, foreflipper side (Left, Right or Both) observed, tag type, tag number, tag color, and associations with possible offspring (0 = unknown, 1 = apparently alone, 2 = passive association with a single pup without behavioral interaction, 3 = active association with non-aggressive maternal

Table 11. -- Periods of re-sighting effort, number of observers and tagged northern fur seals seen at Polovina Cliffs section 7 and Zapadni Reef rookeries, St. Paul Island, Alaska, from 2008 to 2014.

Year	Early season	Min. staff	Max. staff	Tagged seals	Late season	Seals added
2008	6/30-8/31	2	3	205		
2009	7/1-8/25	3	3	218		
2010	7/1-8/31	2	3	271		
2011	6/28-8/31	3	4	196		
2012	6/29-8/7	2	3	196		
2013	6/30-8/31	2	3	253, 37*	9/1-9/26	38, 76*
2014	6/26-8/5	1	3	190, 75*	9/1-10/15	32, 260*

* Polovina Cliffs and Zapadni Reef, respectively

Table 12. -- Periods of re-sighting effort, number of observers and tagged northern fur seals seen at South rookery, St. George Island, Alaska, from 2008 to 2014.

Year	Early season	Min. staff	Max. staff	Tagged seals	Late season	Seals added
2010	7/8-8/1	1	1	56		
2011	6/28-9/1	2	2	233	9/26-10/2	36
2012	7/4-8/12	2	3	320	8/13-9/1, 10/2-10/18	160, 87
2013	7/1-8/31	1	2	691	9/1-9/24	125
2014	6/27-8/14	2	3	272	8/26-10/16	232

behavioral, 4 = nursing, 5 = parturition, 6 = association with dead pup). Parturition was attributed to a female for pup association codes 3-5, but in the initial year (2008) the distinction between codes 2 and 3 was not yet explicit, and observers recorded only when they were "confident" of a maternal bond based on the behavior observed. In practice, most mother-pup associations during a season (> 90%) are made on the basis of observed suckling or parturition. Beginning in 2009, a second visual confirmation of each recorded tag was also recorded. In 2012, a confirmation field was added for tag side, which was occasionally mis-identified. Suspect records are rare, but can be excluded from analyses if confirmation was not obtained. Photographs that verified the tag were also noted and archived. Absence of a tag on the flipper opposite a recorded tag was also recorded by codes for open tears or "slots", holes (usually also commented upon for their size as allowing for tags to fall out or so small as for the tag to be absent only by breakage), closed scars, or no evidence of tagging. Protocol also called for distinguishing whether the flipper was seen sufficiently to positively determine if there was no tag, had the tag been missing. This was done as a filter for assessing tag loss, as it is easier to spot a tag than it is to positively determine its absence, and this can create bias in estimating tag loss rates. A small number of re-sightings came from other fur seal monitoring activities (bull counts, harvests), occasional search of other rookeries or haulouts, and a few roundups of juvenile males on haulouts.

Tagging and re-sighting effort are reported for our primary study rookeries in terms of the numbers of tags deployed and the numbers re-sighted. All analyses are considered preliminary. Tag loss estimates were based on the assumption that tag loss from opposite flippers was independent (Testa and Rothery 1993). Pupping rates were estimated as the proportion of adult female seals seen each year that were positively associated with a pup. That sample excluded

non-pups the year after they were tagged if they were categorized as a juvenile (< 25 kg or with dark vibrissae). Seals tagged as pups were included in this sample beginning in the year following primiparity.

RESULTS

Tags Deployed

At section 7 of Polovina Cliffs rookery on St. Paul, 759 adult female fur seals were tagged from 2005 to 2014 (Table 13). Female pups were targeted beginning in 2008 (Table 14), but numbers obtainable in section 7 of Polovina Cliffs (908 over 7 years; maximum of 457 in 2009) were insufficient to meet our objectives for precision of pup survival estimates. From 2010 to 2014, 3,010 female pups were tagged at Zapadni Reef rookery (Table 15). At St. George Island, 471 adult females and 8,691 pups of both sexes were tagged at South rookery from 2009 to 2014 (Tables 16 and 17).

Re-sightings

Dates of systematic re-sighting effort, staffing, and number of individually identified fur seals are summarized in Table 11 for Polovina Cliffs and Zapadni Reef rookery on St. Paul and in Table 12 for South rookery on St. George. The number of observers increased from mid-July to early August, when the number of adult females on the rookeries was highest (Fig. 13). The timing of peak counts and the cumulative proportions of uniquely tagged adult fur seals identified (Fig. 14) suggest a slightly earlier (~ 3 days) median date of arrival at South rookery.

Re-sighting effort for seals tagged as pups and the availability of ages 2-4 were greatest in 2014 at South Rookery, resulting in a well-illustrated seasonal pattern of returns (Fig. 15). In general, older seals return earlier in the season, and males return earlier than females of the same

Table 13. -- Adult (non-pup) female northern fur seals tagged at Polovina Cliffs rookery on St. Paul Island, 2005-2014. Tag types refer to Allflex narrow sheep tags (AN), Allflex large tags (AL), Monel steel tags (M), Dalton Superflexitags (DS) and VHF transmitter tags (TX). Tags in combination are separated by "/"; all others were tagged with the same tag type on both foreflippers.

Year	Adult females	New	Retags	Tooth collected	Tag type	Sequence
2005	5	5	0	0	AN	0136-0141 White
2006	24	24	0	0	AL	1769-1793 Blue
2007	230	230	0	0	AN/M AL/TX	P301-P443 Pink/SP0251-SP0385 X001-X096 White, 95 w/TX
2008	94	92	2	51	DS/TX	P001-P050 Yellow, P000-P009, P022-P028 Orange, 37 w/TX
2009	155	131	24	107	DS	P051-P160 Yellow, P043-P087 Orange
2010	31	25	6	0	DS/TX	P104-P110 Orange/TX
2011	94	84	10	0	AN/TX	001P-087P Green, 10 w/TX
2012	44	41	3	0	AN/TX	001A-002A Yellow, 089P-131P Green, 10 w/TX
2013	40	32	8	0	AN	003A-004A Yellow, 137P-164P Green, 0226K White
2014	42	36	6	0	AN	169P-206P Green, 23 with TX
Total	759	700	59	158		

Table 14. -- Pups tagged at Polovina Cliffs rookery on St. Paul Island, 2006-2014. Tag types refer to Allflex narrow sheep tags (AN), Monel steel tags (M), and Dalton Superflexitags (DS). Tags in combination are separated by "/"; all others were tagged with the same tag type on both foreflippers.

Year	Pups	Male	Female	Tag type	Sequence
2006	12	6	6	AN/M	P036-P047 Pink/SP0036-SP0047
2007	0	0	0		
2008	18	0	18	DS/M	P 1-P 18 White/SP0386-405
2009	480	2	478	DS	P 26-P508 White
2010	138	0	138	AN	P1377-P1578 Pink
2011	58	1	57	AN	0001K-0058K White
2012	39	0	38	AN	0059K-0097K White
2013	164	2	162	AN	0098K-0261K White
2014	19	0	19	AN	0262K-0280K White
Total	908	12	895		

Table 15. -- Pups tagged at Zapadni Reef rookery on St. Paul Island, 2010-2014. Tag type "AN" refers to Allflex narrow sheep tags (AN) applied on both foreflippers.

Year	Pups	Male	Female	Tag type	Sequence
2010	656	3	653	AN	P429-P1376, P1579-1954 Pink
2011	703	3	700	AN	0001Z-0707Z White
2012	562	0	562	AN	0001X-0573X White
2013	577	2	575	AN	0574X-1150X White
2014	521	1	520	AN	1151X-1671X, White
Total	3019	9	3010		

Table 16. -- Adult (non-pup) females tagged at South rookery on St. George Island, 2009-2014. Tag types refer to Allflex narrow sheep tags (AN) and Dalton Superflexitags (DS). Seals were tagged with the same tag type on both foreflippers.

Year	Adult females	New	Retags	Tooth collected	Tag type	Sequence
2009	92	92	0	85	DS	G001-G085 Yellow, G001-G008 Orange
2010	171	162	9	155	DS AN	G009-G019 Orange G086-G249 Yellow
2011	199	191	8	0	AN	002H-190H Green
2012	0	0	0	0		
2013	4	1	3	0	AN	001R-003R Yellow, 2982E White
2014	5	0	5	0	AN	004R-005R Yellow 4653E, 4780E, 4949E White
Total	471	446	25	240		

Table 17. -- Pups tagged at South rookery on St. George Island, 2009-2012. Tag types refer to Allflex narrow sheep tags (AN) and Dalton Superflexitags (DS) applied to both foreflippers.

Year	Pups	Male	Female	Tag type	Sequence
2009	1963	979	984	DS	G0001-G1978 White
2010	1763	917	846	DS DS AN	G1979-G2500 White E001-E979 White/H001-979 White G501-G1000 Yellow
2011	1840	950	890	AN	0001E-1901E White
2012	1039	567	471	AN	1902E-2941E White
2013	1159	594	562	AN	2942E-4111E White
2014	927	467	460	AN	4112E-5049E White
Total	8691	4474	4213		

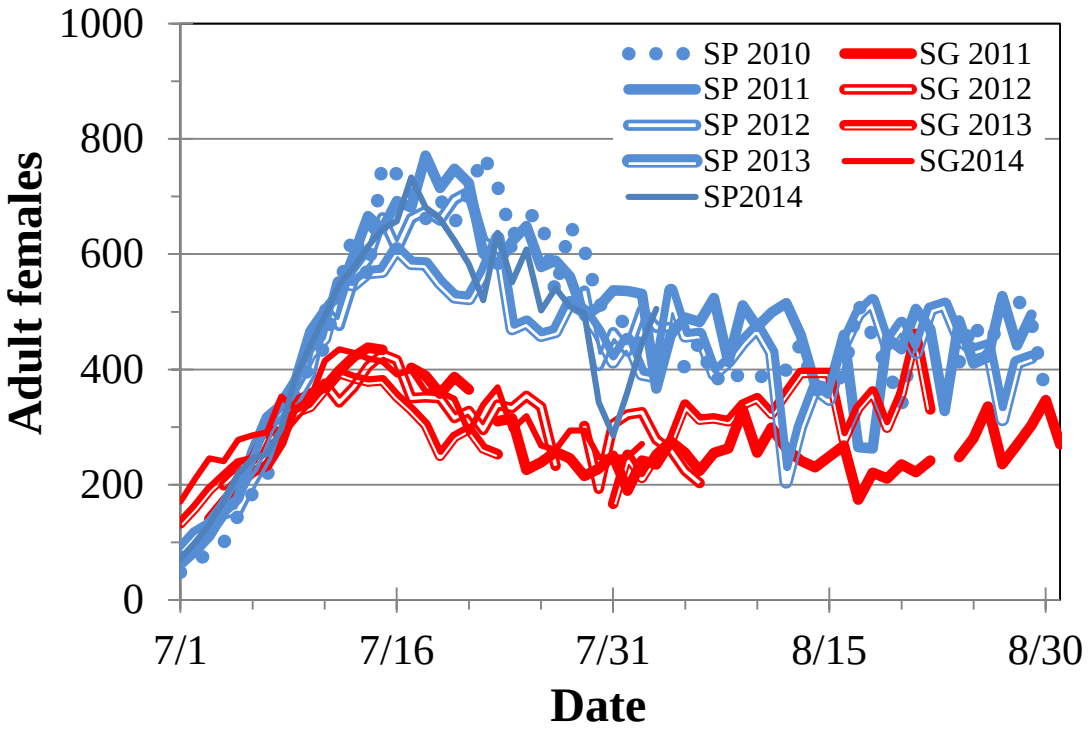

Figure 13. -- Daily counts of adult females at section 7 of Polovina Cliffs rookery, St. Paul Island (SP), and section 1 of South rookery, St. George Island (SG)

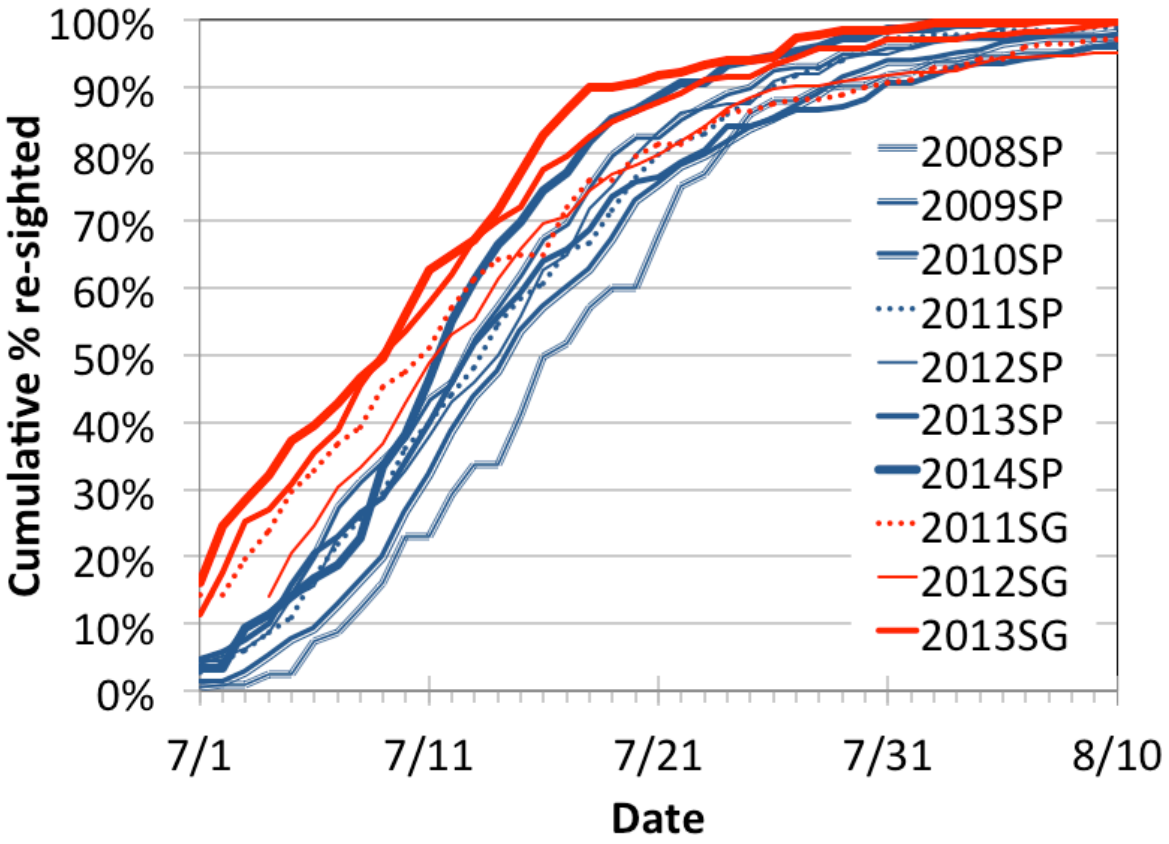

Figure 14. -- Cumulative re-sights in the years shown of female fur seals tagged as adults on Polovina Cliffs rookery, St. Paul Island (SP) and at South rookery, St. George Island (SG) as a percentage of total re-sights to the end of August (Tables 14 and 15). In 2010, re-sighting ended on 9 August at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

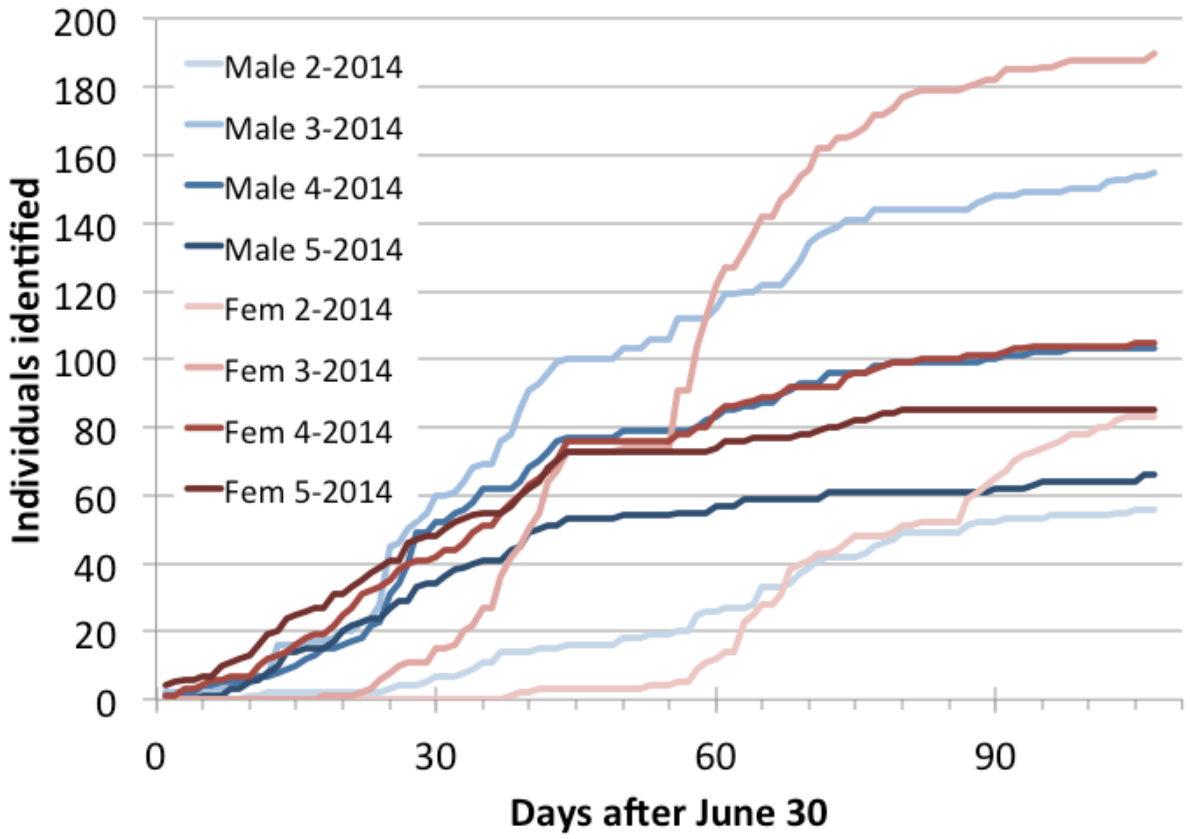

Figure 15. -- Cumulative numbers of re-sighted male (Male) and female (Fem) fur seals that were tagged as pups at South rookery, St. George Island, and re-sighted in 2014, with their age in years and the year of re-sighting shown in the legend. Re-sighting effort was either absent or very low 12-24 August (days 43-55 after June 30).

age. Re-sighting effort at South was adequate to produce near-asymptotic discovery curves for all ages ≥ 2 years by the middle of October when re-sighting effort ended (Fig. 15).

Pupping Rates

In 2014, the proportion of Dalton tags seen that were unreadable due to faded lettering began to increase from an average under 5% in the first 3 years, and reached 44% in 2014 at St. Paul, 5-6 years after their initial deployment. Parturient females are typically associated with a pup only 10-20% of the times they are seen, so this decline in readability creates negative bias in our reproductive estimates that was controlled by excluding all adult seals with Dalton tags > 4 years old from our estimates of annual reproductive rate. Estimated pupping rates at Polovina Cliffs rookery ranged from 0.80 to 0.90) from 2008 to 2014 (Table 18), with a significant downward trend ($P < 0.01$). At South rookery, rates from 2010 to 2014 ranged from 0.80 to 0.88 (Table 19) with no significant trend ($P = 0.42$).

Tag Loss

AL tags were not evaluated because they offered little advantage in readability or likely retention over AN tags, and they were only paired with radiotransmitters, which were not considered a reliable visual identifier. Assuming independent loss from opposite sides, rates of tag loss in adult females were generally low, with an estimated probability of losing both tags (hence, becoming indistinguishable from mortality) ≤ 0.01 even after 3-5 years at Polovina Cliffs. DS tags (Table 20) were lost at a higher rate than AN or M tags (Table 21) at the same site, and appear to accumulate in the first 2 years after application, but not from year 2 to 3. In contrast, estimated rate of loss for M tags increased each year after application, but the rates were lower (Table 21). Loss of AN tags was evident at Polovina Cliffs from only a single seal in year 3, which implies a double tag loss in the AN+M tag cohort of only 0.0085 by year 5.

Table 18. -- Annual sample sizes (n) and apparent pupping rates of adult females at Polovina Cliffs rookery, St. Paul Island, from 2008 to 2014.

Year	n	Rate	SE
2008	196	0.87	0.024
2009	204	0.90	0.021
2010	217	0.88	0.022
2011	161	0.84	0.029
2012	157	0.82	0.031
2013	142	0.84	0.031
2014	104	0.80	0.039

Table 19. -- Annual sample sizes (n) and apparent pupping rates of adult females at South rookery, St. George Island, from 2010 to 2014.

Year	n	Rate	SE
2010	56	0.86	0.047
2011	161	0.88	0.025
2012	255	0.80	0.025
2013	212	0.83	0.026
2014	187	0.84	0.027

Table 20. -- Numbers of adult female fur seals observed 1-4 years after tagging that retained 1 (n_1) and both (n_2) Dalton Superflexitags (DS) at Polovina Cliffs rookery, with estimated single and double-tag loss rates (95% bootstrap confidence interval) under assumption that probability of loss on opposite flippers is independent.

Tag	Tags retained		Single tag	Double tag
age	n_1	n_2	loss rate	loss rate
1	9	102	0.04 (0.02-0.07)	0.002 (0.000-0.005)
2	12	63	0.09 (0.04-0.15)	0.008 (0.002-0.022)
3	9	43	0.10 (0.04-0.16)	0.009 (0.002-0.025)
4	10	41	0.11 (0.05-0.19)	0.012 (0.002-0.036)

Table 21. -- Numbers of adult female fur seals observed 1-5 years after tagging in 2007 that retained single Allflex Narrow (AN), single Monel metal (M), and both tags in combination at Polovina Cliffs rookery, with estimated single and double-tag loss rates (95% bootstrap confidence interval) under assumption that probability of loss on opposite flippers is independent.

Tag	Tags retained			Estimated rates of loss		
age	n_M	n_{AN}	n_{Both}	Loss-M	Loss-AN	Loss-both
1	0	5	100	0.05 (0.01-0.10)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
2	0	3	83	0.04 (0.00-0.08)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
3	1	3	59	0.05 (0.00-0.11)	0.02 (0.00-0.05)	0.001 (0.000-0.003)
4	1	4	51	0.07 (0.02-0.15)	0.02 (0.00-0.06)	0.001 (0.000-0.006)
5	1	2	39	0.05 (0.00-0.12)	0.02 (0.00-0.08)	0.001 (0.000-0.006)

Table 22. -- Numbers of adult female fur seals observed 1-5 years after tagging that retained a single Dalton Superflexitag (DS) on the left (n_{Left}), right (n_{Right}) or both (n_{Both}) flippers at South rookery, with bootstrap median single and double-tag loss rates (bootstrap 95% confidence interval).

Tag	Tags retained			Estimated rates of loss			
age	n_{Left}	n_{Right}	n_{Both}	Right	Left	Both	P(R≥L)
1	4	10	43	0.08 (0.02-0.18)	0.19 (0.09-0.31)	0.02 (0.00-0.04)	0.07
2	5	17	30	0.14 (0.03-0.27)	0.35 (0.21-0.50)	0.05 (0.01-0.11)	0
3	5	14	26	0.16 (0.03-0.31)	0.33 (0.21-0.53)	0.06 (0.01-0.12)	0.017
4	4	12	16	0.19 (0.05-0.41)	0.43 (0.25-0.60)	0.08 (0.01-0.21)	0.018
5	5	8	12	0.29 (0.08-0.53)	0.40 (0.20-0.63)	0.11 (0.03-0.28)	0.006

Bootstrap estimates of DS loss at South rookery showed higher loss rates from the left side and losses that continued to accumulate over time (Table 22). Loss of AN tags by adults at South was very low, being confined to just eight individuals that lost their tags from either side in 634 seal-years observed (Table 23). Loss of DS tags in the 2009 and 2010 pup cohorts was much higher than in adults (Table 24) and evidence for a bias to left or right side was equivocal. Pup cohorts with AN tags had higher loss rates than in adults, but estimated probability of losing both tags remained low (Table 25).

DISCUSSION

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

Apparent pupping rates among tagged females at both study sites have been high and comparable to the highest historic estimates (Lander 1981, Towell 2007). The estimated rates presented here 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 > 0.90, allowing for only a small amount of bias even if none of the missing females pupped elsewhere, which is not certain. Considered with the high pregnancy rates reported by Testa et al. (2010), it appears unlikely that reduced adult reproduction has contributed to the recent population decline.

Table 23. -- Numbers of adult female fur seals after 1-4 years that retained a single Allflex narrow sheep tag (AN) on one (n_1) or both (n_2) flippers at South rookery, with estimated single and double-tag loss rates (95% bootstrap confidence interval) under the assumption that loss on opposite flippers is independent.

Tag	Tags retained		Single tag	Double tag
age	n_1	n_2	loss rate	loss rate
1	2	237	0.004 (0.000-0.011)	0.000 (0.000-0.000)
2	6	201	0.015 (0.005-0.030)	0.000 (0.000-0.001)
3	4	154	0.013 (0.003-0.026)	0.000 (0.000-0.001)
4	1	58	0.009 (0.000-0.027)	0.000 (0.000-0.001)

Table 24. -- Numbers of northern fur seal pups after 2-5 years that retained a single Dalton Superflexitag (DS) on one (n_1) or both (n_2) flippers at South rookery, with single and double-tag loss rates (95% confidence interval).

Tag	Tags retained		Single tag	Double tag
age	n_1	n_2	loss rate	loss rate
2	80	87	0.31 (0.24-0.38)	0.10 (0.07-0.13)
3	141	147	0.32 (0.27-0.37)	0.11 (0.08-0.13)
4	173	149	0.37 (0.32-0.42)	0.14 (0.11-0.16)
5	90	48	0.48 (0.40-0.57)	0.23 (0.17-0.29)

Table 25. -- Numbers of northern fur seal pups that retained one (n_1) or both (n_2) Allflex Narrow (AN) tags after 2 and 3 years at South Rookery, with single and double-tag loss rates (bootstrap 95% confidence interval).

Tag	Tags retained		Single tag	Double tag
age	n_1	n_2	loss rate	loss rate
2	22	312	0.03 (0.02-0.05)	0.001 (0.000-0.002)
3	39	308	0.06 (0.04-0.08)	0.004 (0.002-0.006)

Our expectation, based on the history of harvesting young males on hauling grounds, was that juvenile males would be available for re-sighting at younger ages than females, and allow for earlier conclusions about juvenile survival. In 2014, the year with the greatest extended re-sighting effort, this clearly was not the case, with juvenile females of the same ages appearing in equal or greater proportions than males, only delayed by a month or more. In comparison to

previous years (Testa et al. 2013), expanding the period of re-sighting into September and October greatly improved the probability of sighting 2- and 3-year-old females.

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

Loss of DS tags calculated for adults at Polovina Cliffs appears stable after 2 years, indicating that most loss occurs in the first year after tagging at that site. In contrast, DS loss

among adults at South rookery was higher, and concentrated on the left side. Bradshaw et al. (2000) noted that substrate and the height of the tag profile on the underside of the flipper were likely the factors leading to higher tag loss in New Zealand fur seal pups, and we concur based on those same features of tags and rookeries here. Greater loss on one side at South might also indicate a behavioral component, and we speculate that this could be the result of females favoring a 'head uphill and back to the prevailing winds' orientation at this site. Loss of DS tags among pups was much higher, giving rise to concerns that non-independence of opposing tags could lead to greater bias in pups. Notwithstanding this concern, deterioration of DS tags is likely to taint estimates of pup survival, as our ability to identify DS-tagged cohorts may be compromised before their full recruitment into our study population as adults. These problems were identified early in the study, so the shift to AN tags as the primary mark should alleviate much of the bias to be expected from tag loss, though we will continue to evaluate and estimate bias on a tag, age class, and site-specific basis. Future estimates of survival depend on accurate assessment of this bias, and on improving our understanding of permanent emigration from the original tagging sites.

STATUS OF THE CALIFORNIA STOCK OF NORTHERN FUR SEALS, 2013 – 2014

by

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

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 fur seals from the Pribilof (Alaska) and Russian Islands during the late 1950s or early 1960s (DeLong 1982). The FI were recolonized in 1996 (Pyle et al. 2001) and the population includes tagged animals from SMI.

During the breeding season, the majority of northern fur seals in the United States are found on the Pribilof Islands (St. George and St. Paul), which are located in the cool, subarctic waters of the Bering Sea (Fig. 1). 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 that adversely affect abundance and availability of prey species of northern fur seals. These prey generally

move to more productive areas farther north and deeper in the water column (Arntz et al. 1991) and thereby become less accessible for 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 along the California coast 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 disease has decreased pup survival for the past 16 years and is also a major factor affecting the population dynamics of this species at its southernmost rookery (Lyons et al. 2001).

After the discovery of the FI colony in 1996, annual ground surveys were conducted in early fall to document population trends of the colony (Tietz 2012). Starting in 2013, aerial surveys have been conducted (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 2013 and 2014 northern fur seal population monitoring studies at SMI and summarized FI census information. We discuss the importance of environmental influences and disease on the SMI population trends during the past 18 years (1997-2014), and summarize data from a long-term study that began in 1975 examining the condition of northern fur seal pups.

METHODS

Census

Fur seal censuses were conducted at two rookeries of SMI (34.03° 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 only once on 29 July 2013, to conduct a census of pups. Weather prevented a pup count in 2014. Daily censuses were conducted at ACV between 30 May and 20 July 2013, and 28 May and 27 July 2014. For the long-term comparisons, territorial bull counts were used as an index of the maximum number of breeding males, and the cumulative live pup count was used to determine the date of the first birth and median pupping date for each year. In 2001 and 2007, daily censuses were terminated too early in the season to determine a median pupping date.

Counts of live and dead pups were used to index of the number of pups born (i.e., production) at the CR and ACV rookeries. Total births each year was the sum of the number of live pups counted at the census and the cumulative number of dead pups counted up to the time of the live-pup census. Date of the census was determined by the frequency of births observed during daily surveys in ACV. When no births were documented over three consecutive days, pupping was considered complete and the live-pup census was conducted. The live-pup census was conducted on 29 July at CR and on 31 July at ACV during 2013. During 2014, a live-pup census was only conducted at ACV (28 July). 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 moving through the colony. The observers defined section boundaries while counting in each area to ensure that they were counting the same groups of animals. Counts were not compared until the end of the census to ensure independence between observer counts. At ACV,

the substrate is sandy and there are no markers to delineate counting areas. However, observers arbitrarily demarcated sections and independently counted the number of pups within each section. The number of pups for the colony was estimated from the mean of both observers' total counts.

In ACV, fur seal pup mortality surveys were conducted between July and September. Each dead pup was counted, removed from the territory, and then stacked away from the survey area to minimize the possibility of recounting the same pup during subsequent surveys. Because pups died and disappeared between surveys, the observed count was an underestimate of the total mortality. We estimated total mortality (up to 3 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. 2010). We have not estimated a species-specific mortality correction factor for northern fur seal pups at SMI because we do not have access to the territories early in the season (before 4 July) due to breeding CSLs. The environmental conditions contributing to disappearance of dead pups (e.g., surf, sand, flooding) for the two species are similar except that a greater proportion of dead northern fur seal pups are more likely to be washed out to sea relative to CSLs because fur seal territories are located along or below the beachcrest. Additionally, fur seals are smaller than CSLs, so they are likely to disappear faster. Therefore, the correction factor is a minimal approximation of the disappearance rate of dead northern fur seal pups.

At CR, pup mortality during 2013 was estimated from one survey conducted at the time of the live pup count (29 July). No estimate is provided for 2014. 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 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), aerial surveys were started in 2013 to determine northern fur seal abundance. The fur seals were counted from aerial photographs taken on 6 August 2013 and 5 August 2014. They were identified to an age-sex category based on morphological and behavioral characteristics by Berger et al. (2013). Age-sex categories included: adult male, subadult male, adult female and juveniles combined, and pup. 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 are difficult to differentiate by size unless a pup is associated with the adult female. Pups were determined by their relatively small size.

Pup Condition

Pups were sexed, tagged, measured (length), and weighed in September (n_{2013} = 170; n_{2014} = 201) in ACV to continue survival and condition studies that began in 1975. We used pup weight at the time of tagging as an index of pup condition. To account for differences in mean pup weight due to different sampling dates among years, we developed a predictive linear mixed-effects model with normal errors to adjust the observed mean mass to 1 October for each year between 1975 and 2014 (Laake, unpublished data). 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.

Sightings of Marked Individuals

Northern fur seals were tagged as pups and the number marked varied (range = 97 – 287) by how many pups could be collected during a particular year (Table 26). Surveys of tagged individuals were conducted from a mobile blind in ACV during 2013 (6 July – 14 August; n = 16) and 2014 (5 July – 13 August; n = 19). 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. Identification of tagged animals was also recorded opportunistically when observers were engaged in other activities from May through October.

Surveys of tagged individuals at the FI were done by hiking to various places on the survey route. During 2013, surveys were conducted on 8 and 13 September, and 7 October. During 2014, re-sight efforts were made approximately every other week from 7 September to 28 November (n = 6 days).

Tag-loss Assessment

Because tag loss is a problem with northern fur seals, we began a study in 2006 to evaluate different types of tags for retention and readability. From 2006 to 2013, we tagged pups at ACV with a Dalton jumbo pink Rototag on one foreflipper and a silver Monel tag on the other foreflipper. During 2014, we started assessing the effectiveness of pink Allflex narrow sheep tags. Pups were tagged at ACV with a jumbo pink Rototag on one foreflipper and a pink Allflex tag on the other (Fig. 16). The side assigned for a particular tag type varied throughout the study period, however pink Rototags were placed on the left flipper a majority of the time except during 2006, 2012, and 2014 (Table 27).

Table 26. -- Number of northern fur seal pups tagged at Adams Cove on San Miguel Island, 1997-2014.

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

Figure 16. -- Northern fur seal tagged with pink Roto (left flipper) and silver Monel (right flipper) tags.

Table 27. -- Flipper side (L = left, R = right) that different types of tags were applied to northern fur seal pups at San Miguel Island, CA, during 2006 – 2014. Different types of tags were used to evaluate their retention and readability.

Year	Pink Roto		Silver Monel		White Allflex		Pink Allflex		#
	L	R	L	R	L	R	L	R	pups
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

RESULTS

Census

The maximum number of territorial bulls counted in ACV was 166 in 2013, representing a 7% decrease from 2012 (Fig. 17). During 2014, territorial males increased 35% from 2013 to 224, which represents the second highest count on record (Fig. 17). The largest number of territorial bulls was observed in 1997 (n = 253; Fig. 17).

The first pup born at ACV was observed on 2 June in 2013 and 7 June in 2014. The median pupping date was 3 July in 2013 and 8 July in 2014. The mean of median pupping dates between 1998 and 2014 was 5 July (SE = 1.0). During 2013, the mean number of live pups was 1,261 (SE = 83.0) at ACV and 1,242 (SE = 5.0) at CR (Table 28). During 2014, the mean number of live pups was 1,658 (SE = 15.0) at ACV, which represents a 31.5% increase from 2013. At ACV, 790 dead pups were estimated in 2014, the highest recorded from 1997 to 2014. During 2014, the number of dead pups decreased 20.2% to 630. At CR, the observed number of dead pups decreased 28.7% in 2013 from 2012 levels.

During 2013, total births at ACV (2,051) were 8.5% below the record high estimated in 1997, and 4.5% lower than in 2012 (Table 28; Fig. 18). During 2014, total births (n = 2,288) exceeded the previous record high counted in 1997 by 2.0%. At CR during 2013, total production (n = 1,281) was 5.2% higher than the previous peak in 2012. No counts were conducted at CR in 2014 so total production at SMI was not estimated. Since 2010 (not including 2014), total production at SMI (i.e., ACV + CR) has surpassed the previous high set in 1997 3 out of 4 years (2011 being the exception; Table 28).

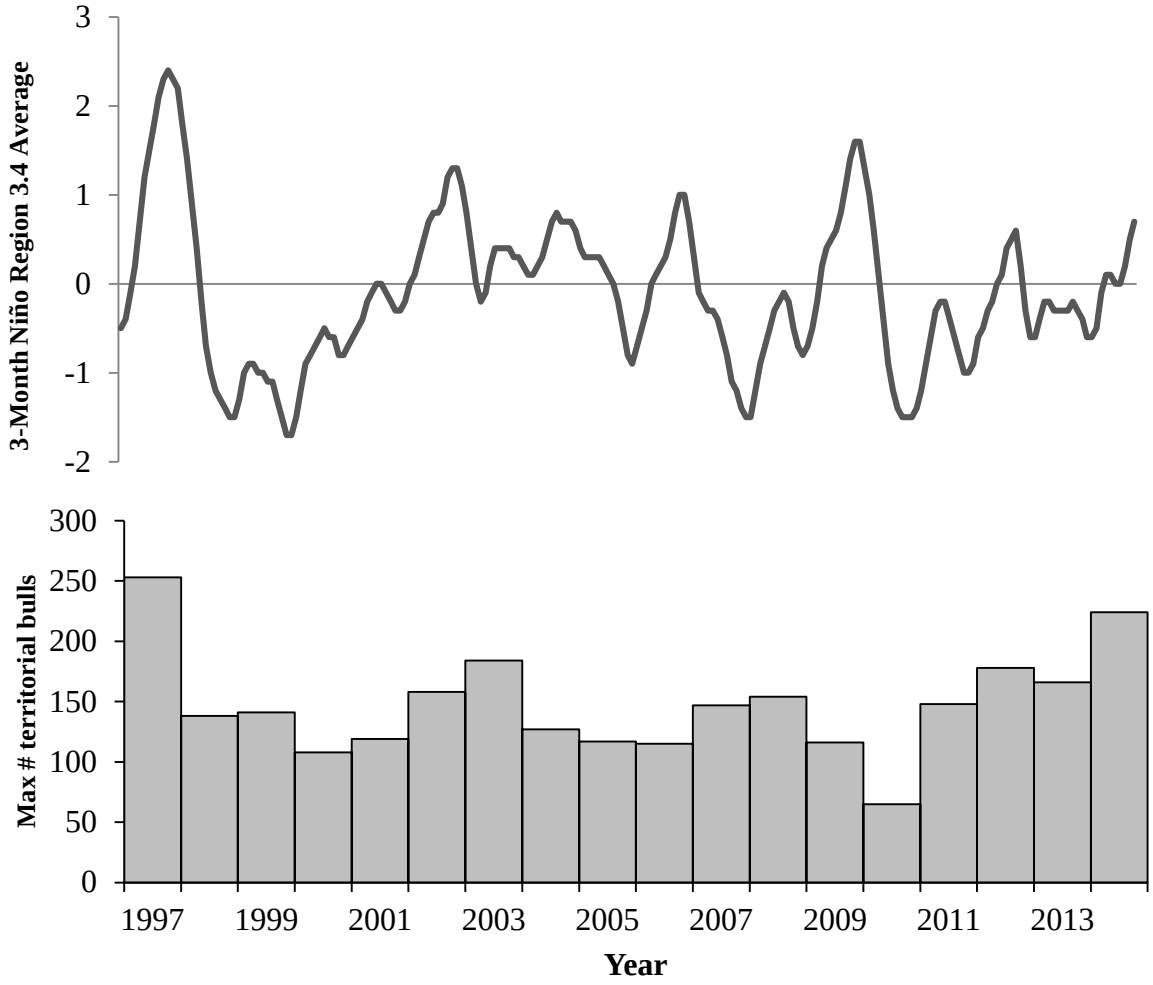

Figure 17. -- Maximum number of territorial northern fur seal bulls at Adams Cove on San Miguel Island, California, 1997-2014 (bottom bar graph) with the Oceanic Niño Index (ONI; line graph), a running 3-month mean sea-surface temperature (SST) anomaly for the Niño 3.4 region (i.e., 5°N-5°S, 120°-170°W) that is used to identify El Niño (warm; positive values) and La Niña (cool; negative values) events in the tropical Pacific.

Table 28. -- 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, CA), 1997-2014.

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
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
2006	634	16	650
2007	758	---	758*

Table 28. -- Continued.

2008	1076	---	1076*
2009	800	138	938
2010	1144	23	1167
2011	1150	19	1169
2012	1163	55	1218
2013	1242	39	1281
2014	---	---	---

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

[*]Number based on the number of live pups only.

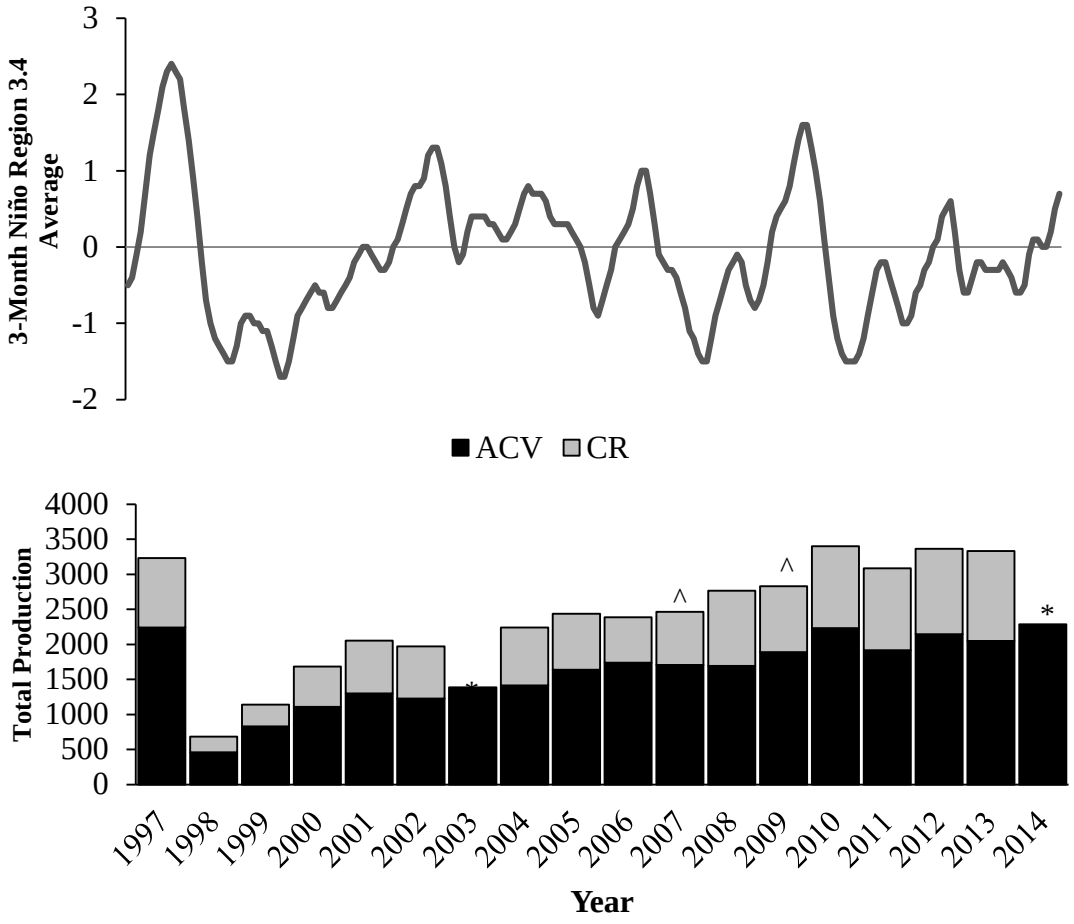

Figure 18. -- Total number of northern fur seal births (i.e., number of live pups + number of dead pups) at Adam's Cove (ACV) and Castle Rock (CR) rookeries during 1997 – 2014. Asterisk (*) indicates no counts at CR. Caret (^) indicates live-pup counts only (i.e., dead pups were not counted). Included is the Oceanic Niño Index (ONI; line graph), a running 3-month mean sea-surface temperature (SST) anomaly for the Niño 3.4 region (i.e., 5°N-5°S, 120°-170°W) that is used to identify El Niño (warm; positive values) and La Niña (cool; negative values) events in the tropical Pacific.

At the FI, there was an increase of individuals in each age class except subadult males from 2013 (n = 666) to 2014 (n = 1,019; Table 29). The total number of animals increased 53.0% between the two years including a 63.6% increase in the number of pups.

Pup Condition

During 2013, estimated mean (± standard error) weight of female pups (10.8 kg ± 0.1) was 9.1% higher than in 2012 and 6.9% higher than the long-term average of 10.1 kg. Mean weight of male pups (12.0 kg ± 0.1) was 7.1% higher than in 2012 and 6.2% higher than the long-term average of 11.3 kg (Fig. 19). During 2014, mean weight of female pups (7.8 kg ± 0.2) was 27.8% lower than in 2013 and 22.8% lower than the long-term average of 10.1 kg. Mean weight of male pups (9.1 kg ± 0.2) was 24.1% lower than in 2013 and 20.2% lower than the long-term average of 11.4 kg (Fig. 19).

Sightings of Marked Individuals

Northern fur seals that were tagged as pups (316 females, 136 males) were re-sighted in ACV during the 2013 breeding season (Fig. 20). Tagged females ranged in age from 2 to 19 years old (Fig. 20). Females sighted with pups were 4 to 12 years of age (Fig. 21). Tagged males ranged in age from 2 to 13 years old (Fig. 20). Territorial males were between 6 and 12 years old (Fig. 21). Twelve-year-old males had the highest number of territories among tagged bulls (Fig. 21). Only a small proportion (8%) of tagged females and no (0%) tagged males were seen older than 14 years of age. There were no tagged individuals from the 1997 (16-year-olds) EN cohorts seen during 2013 (Fig. 20).

A total of 466 uniquely tagged northern fur seals (324 females, 142 males) were observed during 2014 (Fig. 20). Tagged females were between 1 and 19 years old, and tagged males were between 1 and 14 years old (Fig. 20). Females observed with pups were between 4 and 19 years

Table 29. -- Number of northern fur seals counted from aerial photographs taken during surveys at the South Farallon Islands on 6 August 2013 and 5 August 2014.

Year	Adult male	Subadult male	Adult female/ juvenile	Pup	Total
2013	24	34	207	401	666
2014	27	19	317	656	1019

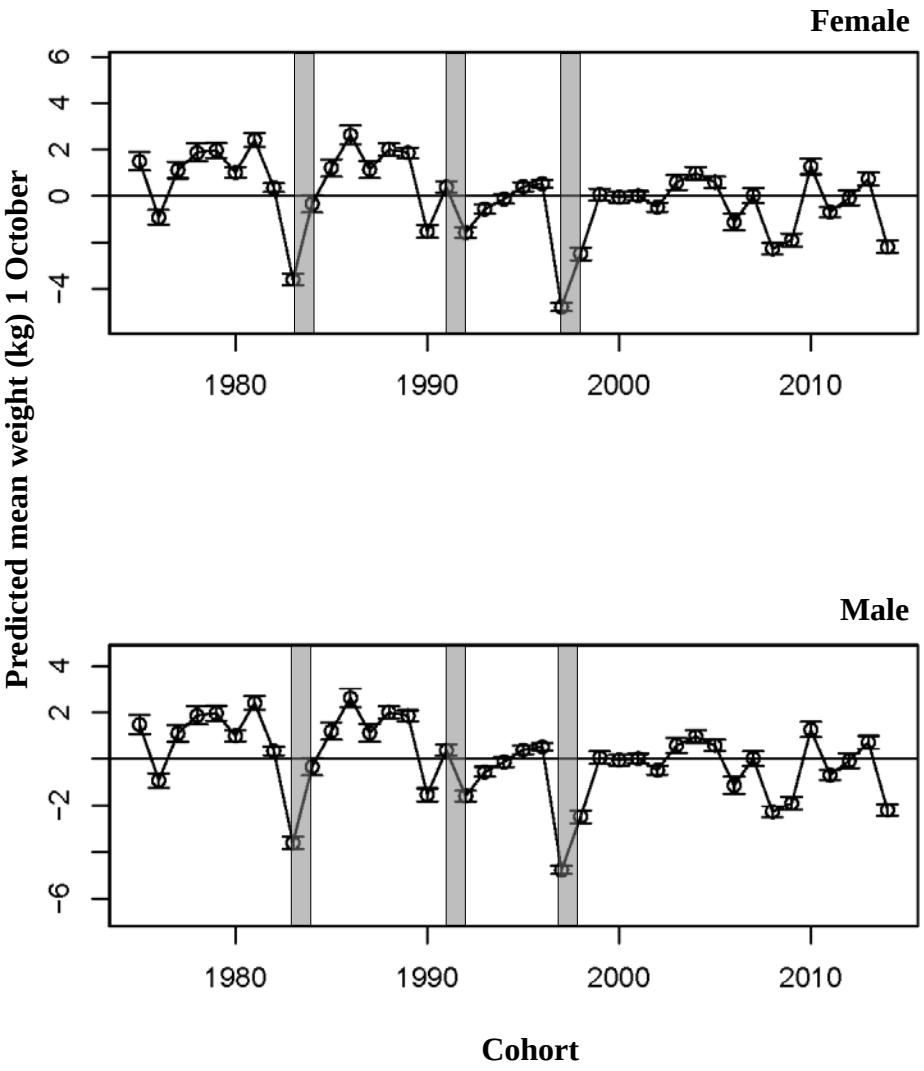

Figure 19. -- Predicted mean weights (kg) of northern fur seal pups at 3 months of age at San Miguel Island, California during 1975-2014, expressed as anomalies from the long-term mean (indicated by the horizontal line). Weights were adjusted to a standardized weighing date of 1 October of each year 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).

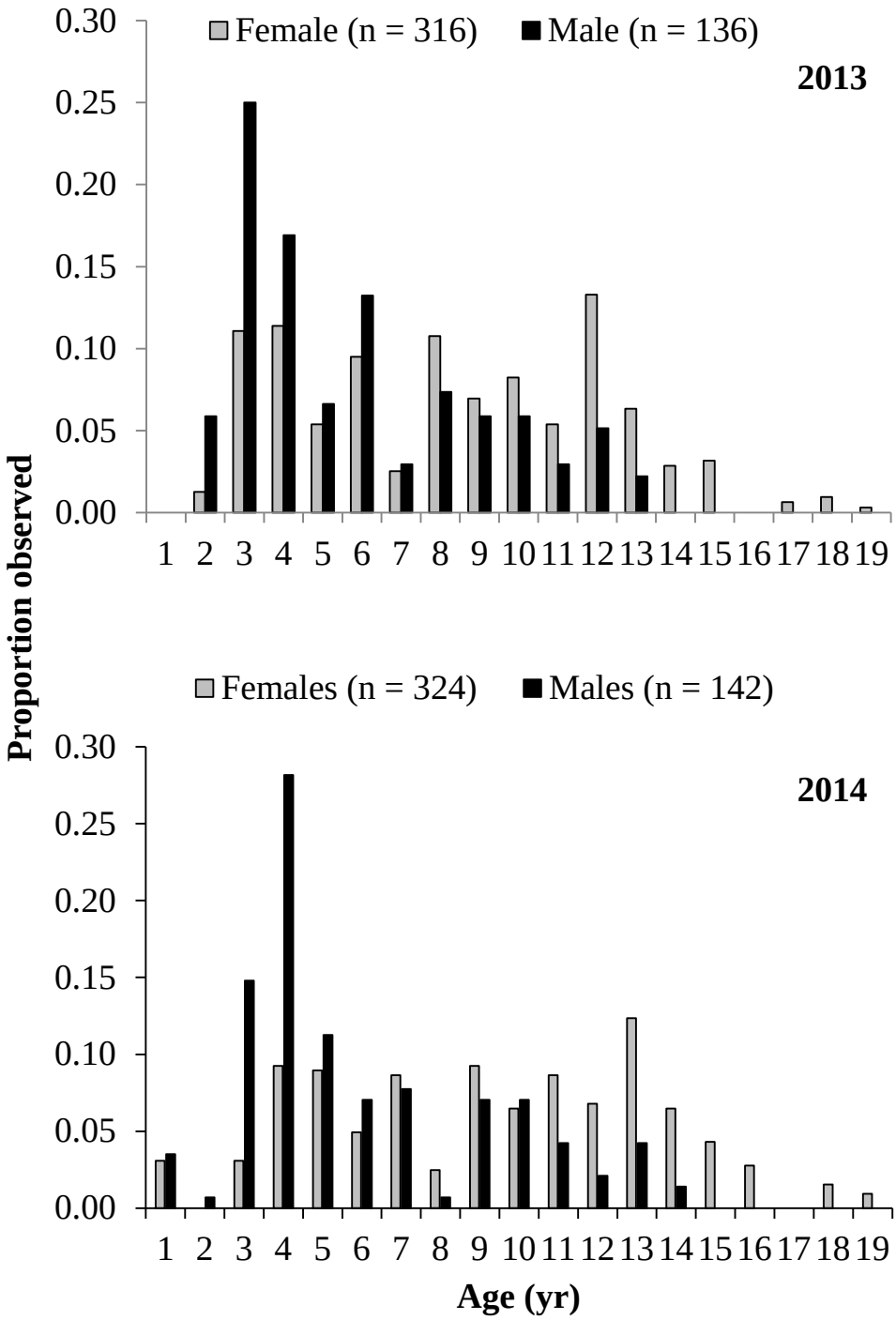

Figure 20. -- Age distribution of female and male northern fur seals that were tagged as pups and re-sighted at San Miguel Island, California during the reproductive season in 2013 (top) and 2014 (bottom).

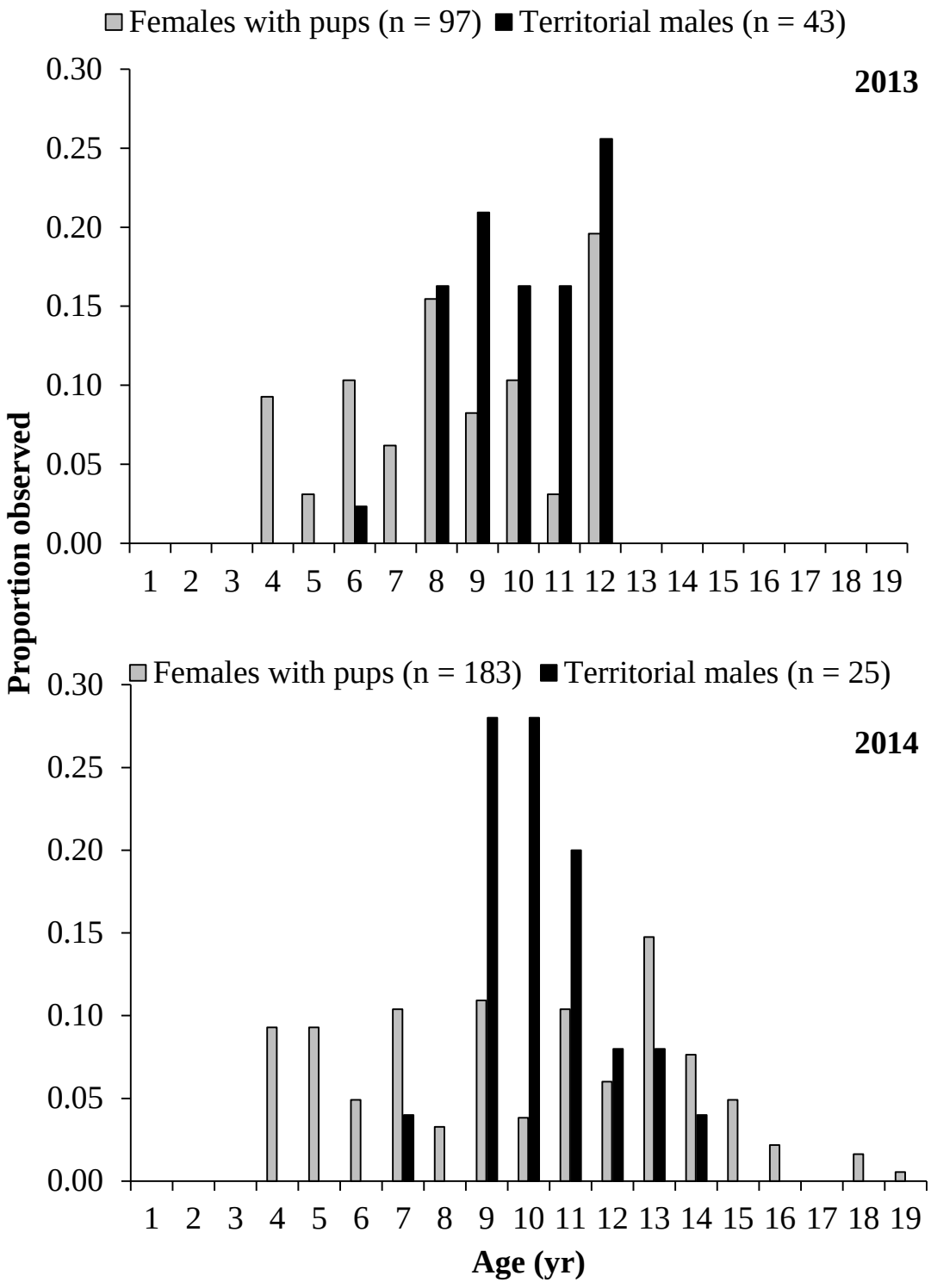

Figure 21. -- Age distribution of tagged adult female and male northern fur seals observed as reproductive at San Miguel Island, California during 2013 (top) and 2014 (bottom).

old and territorial males were between 7 and 14 years old (Fig. 21). Nine and 10-year-old males had the highest number of territories among tagged bulls. The number of individuals that were over 14 years of age increased in 2014 compared to 2013; however, they remained a small proportion of the total population (16% of females, 1% of males). As in 2013, there were no tagged individuals from the 1997 (17-year-olds) EN cohorts seen during 2014 (Fig. 20).

At the FI, all of the tagged individuals seen were originally tagged at SMI. Fifteen uniquely tagged northern fur seals (female = 8, male = 7) were observed during 2013 (Fig. 22). Tagged females were between 2 and 9 years of age, and tagged males were between 2 and 6 years old. Modal age for both sexes was 3 years (Fig. 22). During 2014, 40 uniquely tagged northern fur seals (female = 27, male = 13) were observed (Fig. 22). Tagged females were between 1 and 24 years old, and tagged males were between 2 and 9 years old. Most tagged individuals were between 2 and 4 years of age. As in 2013, modal age for both sexes was 3 years (Fig. 22).

Tag-type Assessment

To date, a quantitative assessment of tag type (i.e., pink Roto vs. silver Monel; Fig. 16) has not been conducted. We hope to have results in the forthcoming issue of the Fur Seal Investigations, as well as preliminary results of comparisons between Allflex and Roto tags.

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

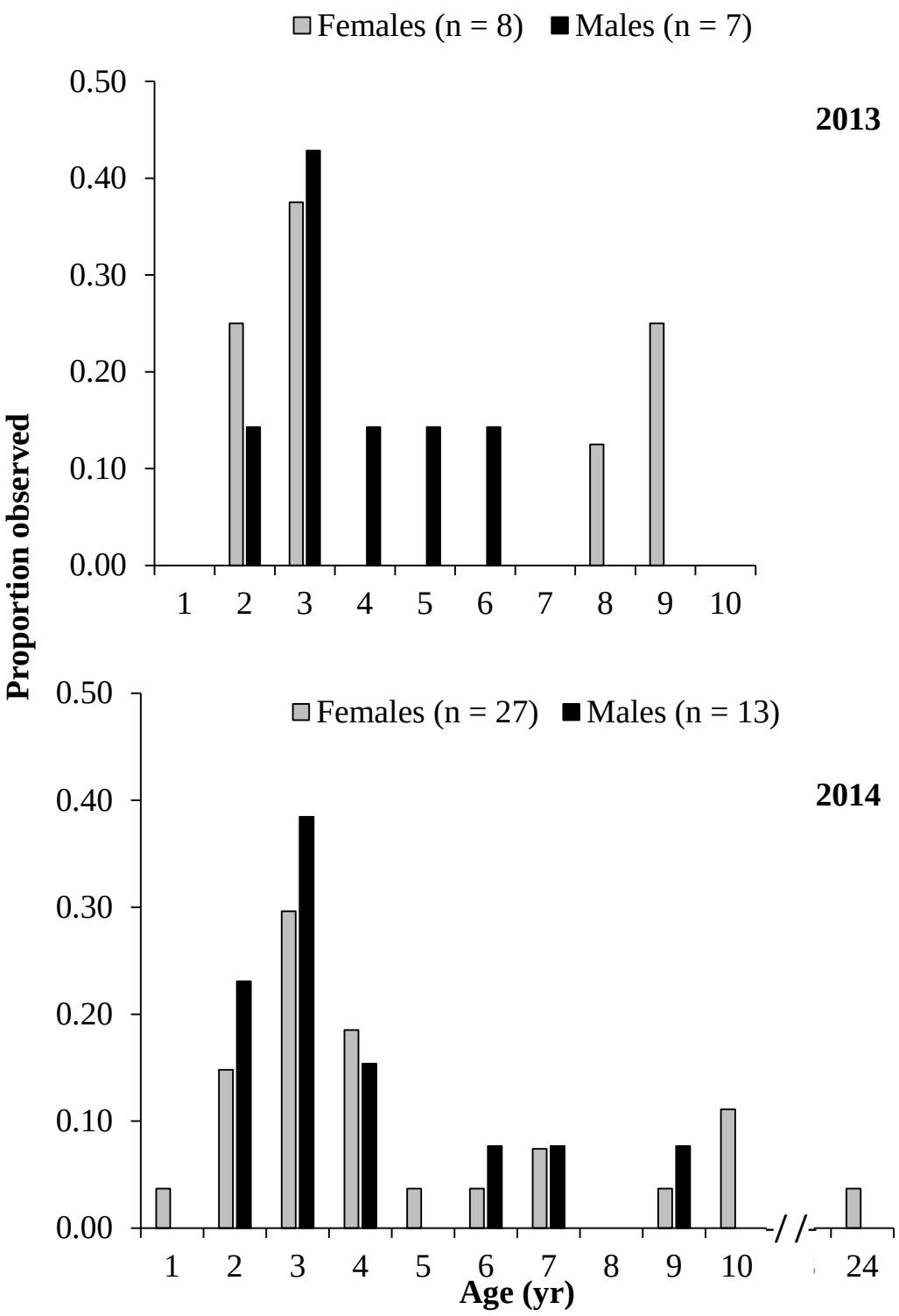

Figure 22. -- Age distribution of tagged female and male northern fur seals observed at the Farallon Islands, California, during 2014.

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. La Niña 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. EN events appear to negatively affect the return of territorial bulls to SMI but reasons are unclear.

Pup production in ACV during 2013 was only 8.5% below the record high in 1997, and a new record high was set in 2014. At CR, a record-setting number of pups was counted during 2013, surpassing the pup production of 1997 and the previous high set in 2012. This contributed to the second highest recorded number of pup births at SMI since the colony (i.e., both rookeries combined) was discovered in 1968 (the highest number was set in 2012). No counts were conducted at CR during 2014, but if trends were consistent with those at ACV, 2014 could have set a new mark for the population at SMI. The pup population increased significantly (> 60% from 2013 levels) at the FI as well.

The population at the FI has grown over 50% during the last 2 years. It is difficult for the observers to differentiate between adult females and juveniles, but it appears that each age-sex class increased except subadult males. The FI currently are viable re-established rookeries of northern fur seals; however, it appears that immigrants from SMI continue to contribute to the increase in population at those islands.

Pup Condition

The mean weights of pups decreased dramatically in 2014 from 2013 levels and the long-term mean. However, 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 remains uncertain. We

speculated that the warmer oceanographic conditions during summer 2014 (e.g., high sea-surface temperatures influenced the foraging behaviors of their mothers and subsequently affected pup growth). 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 that the lactating 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 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).

Whereas EN events represent an external, periodic, density-independent factor affecting the population, hookworm disease is generally considered a density-dependent factor (Spraker and Lander 2010, Lyons et al. 2003). Lyons et al. (2000) noted that the drastic decline in hookworm prevalence corresponded to the decrease in numbers of northern fur seals on St. Paul Island. 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 6 weeks of life. In 2000, 95% of the dead pups less than 1-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 18 years. We speculate that the high pup mortality will continue until the population mounts an immune response to the parasite (or the prevalence of the parasite is reduced), perhaps several generations

into the future. Therefore, in addition to environmental perturbations (e.g., EN events), disease has an influential role in the population dynamics of the northern fur seals at SMI.

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 2014. For both 2013 and 2014, the highest number of tagged animals re-sighted was from the 2001 cohort for females and the 2010 cohort for males, indicating that apparent survival for these cohorts was high. The mean weight of male pups in 2010 was higher than the long-term mean; however, mean weight of females from the 2001 cohort was approximately the same as the long-term mean, so it is unclear how much pup condition factors into long-term survivorship. On the Pribilof Islands, Baker and Fowler (1991) found a positive correlation between pup mass and

survival for male fur seals. However, it was unclear how pup mass factored into long-term survival for female fur seals. More “late season” (i.e., August) re-sight effort was exerted during 2012 - 2014, 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 19 years of age, first breed when they are approximately 3 years old, and continue to have pups until they are 14 years old. During 2013 and 2014, the predominant ages of territorial males were 8 – 12 years. This is indicative that males must survive longer than females before breeding, attain particular morphological characteristics, and display a number of behavioral and physiological factors in order to mate at all (Gentry 1998). The oldest tagged males were only 13 and 14 years old during 2013 and 2014, respectively. Males as old as 12 and 14 years in 2013 and 2014, respectively, defended territories. These findings imply that males do not live as long as females, and not much 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 spent a relatively small amount of their lives attempting to breed; most (75%) were seen on rookeries for only one season before they disappeared permanently. In that study, two males reappeared for 8 or more seasons, but all others spent 2-7 years on territory; the mean for all males was 1.45 years of breeding.

At the FI, individuals that were tagged came from SMI. Observers did not record reproductive status of individuals; however, most animals were juveniles. Of special note is the observation of a tagged 24-year-old adult female. This is of special significance because the

animal is the oldest tagged individual observed, and because the tag has remained readable and attached to the animal for so long.

Tag-loss Assessment

Although a quantitative analysis is not presented here, some 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 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 3-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. The tags are made of corrosion-resistant metal and the tag numbers are engraved so that the numbers do not fade or wear over time, the metal does not break or crack, the puncture hole is small, and the tag is bent and crimped back onto itself into a loop so it 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 are 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. Whereas it evident that some Monel tags were lost, we have yet to fully evaluate whether the loss rate of Monel tags is greater than that of pink Rototags. In 2012, we began using digital-SLR 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 foreflipper and pink Rototags on the other. We hope to evaluate the reliability and readability of the Allflex tags in 2016 when individuals of the 2014 cohort start to return to SMI.

MASS, LENGTH, AND SEX RATIOS OF NORTHERN FUR SEAL PUPS ON THE PRIBILOF ISLANDS, 2014

by

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

Mass and length measurements of northern fur seal pups on St. Paul and St. George Islands, Alaska, have historically been recorded in 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 2014, with comparisons of those variables between islands and 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 of pup mass and length by island, sex, and rookery variables. Significant differences in mass and length by sex between islands were compared using a two-sample t-test for samples with variances not significantly different from one another, or a Welch-modified two-sample t-test (Snedecor and Cochran, 1980) for samples with significantly different variances. We used an exact binomial test to determine if the proportion of female pups at different islands and rookeries was significantly different from 50%.

RESULTS

Pup Mass and Length

Pup mass varied significantly by sex ($P < 0.01$) on St. Paul Island in 2014 (Fig. 23, Table 30). Mass of male and female pups was analyzed separately because the variance for males was greater than that for females ($P < 0.01$). Rookery effects on mass were significant for males ($P < 0.01$; Table 31) but not for females ($P = 0.23$; Table 31). The variance in pup lengths was not significantly different between males and females ($P = 0.06$); therefore, the sexes were analyzed together. Pup lengths were significantly different by sex and rookery on St. Paul Island ($P < 0.01$; Fig. 24, Tables 32 and 33).

On St. George Island, pup mass was also significantly different by sex ($P < 0.01$; Fig. 23, Table 34). 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 ($P = 0.60$) or males ($P = 0.25$; Table 35). The variance in pup lengths was significantly different between males and females ($P < 0.01$). The analysis of variance for lengths did not indicate significant differences by rookery for either females ($P = 0.08$) or males ($P = 0.62$; Fig. 24, Tables 36 and 37).

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 males (St. Paul = 9.14 kg, St. George = 9.89 kg; $P < 0.01$) and females (St. Paul = 8.01 kg, St. George = 8.50 kg; $P < 0.01$). Both males (St. Paul = 73.8 cm, St. George = 77.9 cm; $P < 0.01$) and females (St. Paul = 70.7 cm, St. George = 74.5 cm; $P < 0.01$) were significantly longer on St. George Island.

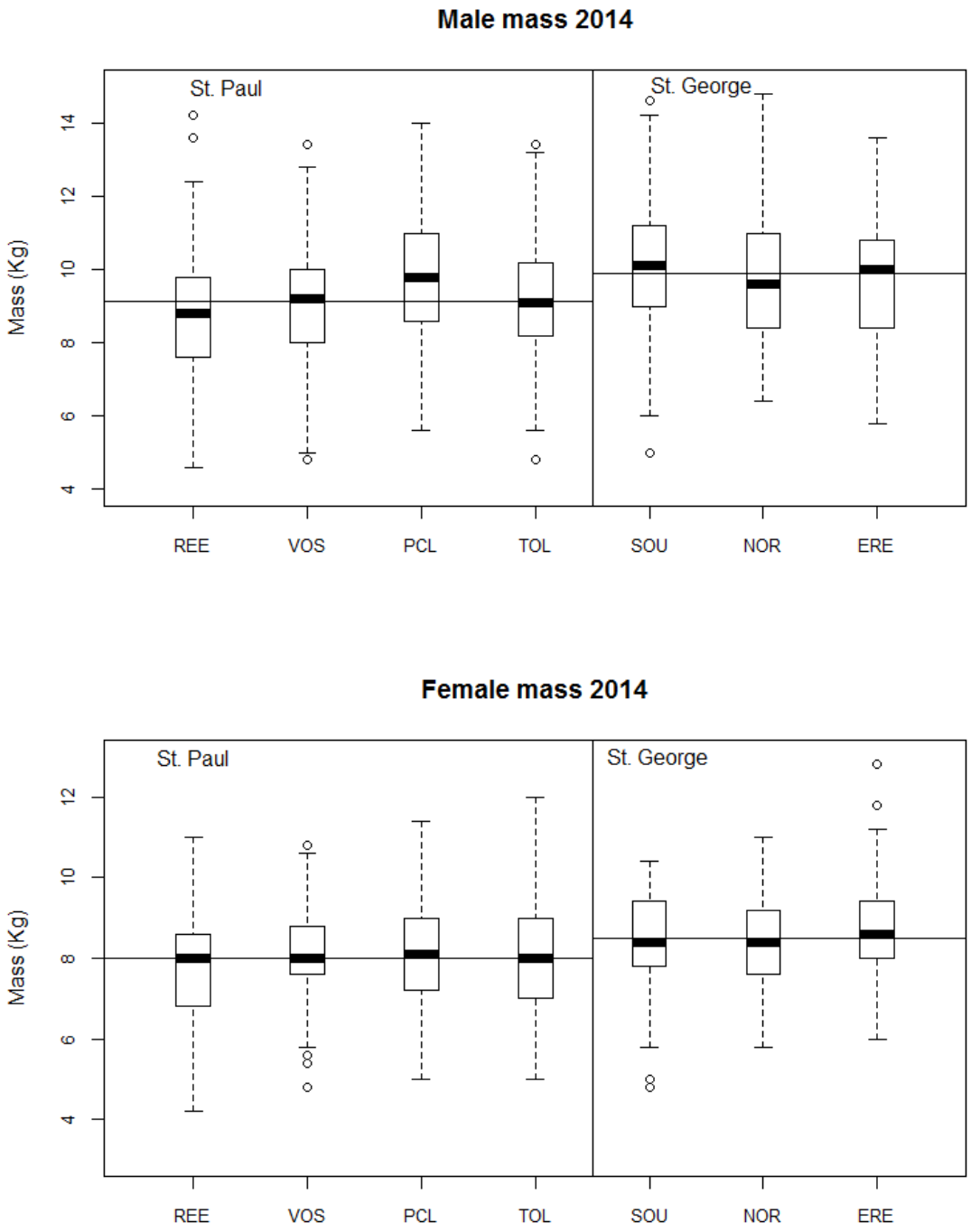

Figure 23. -- Boxplots of the mass (kg) of northern fur seal pups on St. Paul and St. George Islands, Alaska, August 2014: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL), Tolstoi (TOL), South (SOU), North (NOR), and East Reef (ERE). Whiskers represent 1.5 x the interquartile range; open circles are outliers.

Table 30. -- Mean mass (kg), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups weighed on St. Paul Island, Alaska, 22-23 August 2014.

Rookery		Females	Males	Combined
Reef	kg	7.81	8.64	8.26
22 August	SD	1.38	1.73	1.63
	n	129	152	281
Vostochni	kg	8.04	9.03	8.61
23 August	SD	1.21	1.62	1.54
	n	110	146	256
Pol. Cliffs	kg	8.15	9.80	9.02
23 August	SD	1.29	1.65	1.70
	n	114	128	242
Tolstoi	kg	8.05	9.18	8.68
22 August	SD	1.39	1.61	1.61
	n	109	138	247
Combined	kg	8.01	9.14	8.63
	SD	1.32	1.70	1.64
	n	462	564	1,026

Table 31. -- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. Paul Island, Alaska, August 2014.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	3	7.5	2.5	797	458	1.44	0.23
Males							
Rookery	3	95.0	31.7	1,529	560	11.60	<0.01

*MSS = SS divided by df

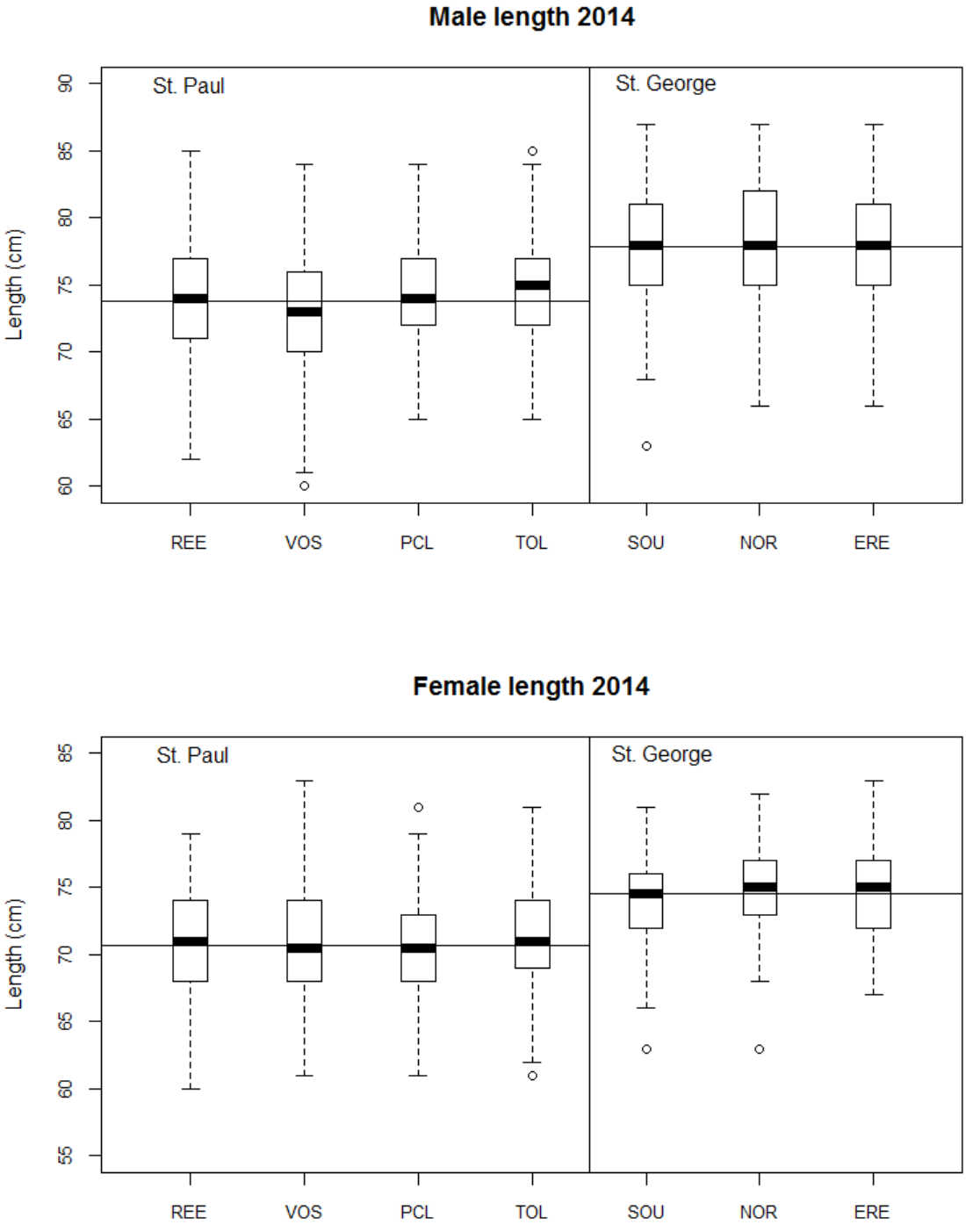

Figure 24. -- Boxplots of the length (cm) of northern fur seals on St. Paul and St. George Islands, Alaska, August 2014: Reef (REE), Vostochni (VOS), Polovina Cliffs (PCL),Tolstoi (TOL), South (SOU), North (NOR), and East Reef (ERE). Whiskers represent 1.5 × the interquartile range; open circles are outliers.

Table 32. -- Mean length (cm), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups measured on St. Paul Island, Alaska, 22-23 August 2014.

Rookery		Females	Males	Combined
Reef	cm	70.6	73.8	72.4
22 August	SD	4.18	4.65	4.70
	n	129	152	281
Vostochni	cm	70.6	72.7	71.8
23 August	SD	4.01	4.40	4.36
	n	110	146	256
Pol. Cliffs	cm	70.3	74.4	72.4
23 August	SD	3.86	3.83	4.35
	N	114	128	242
Tolstoi	cm	71.4	74.4	73.0
22 August	SD	3.94	4.26	4.38
	n	109	138	247
Combined	cm	70.7	73.8	72.4
	SD	4.01	4.35	4.47
	n	462	564	1,026

Table 33. -- Analyses of variance of length of male and female northern fur seal pups on St. Paul Island, Alaska, August 2014.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Sex	1	2,429	2,429	18,089	1,024	138.74	< 0.01
Rookery	3	211	70	17,878	1,021	4.02	< 0.01

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

Table 34. -- Mean mass (kg), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups weighed on St. George Island, Alaska, 24-25 August 2014.

Rookery		Females	Males	Combined
South	kg	8.42	10.13	9.40
25 August	SD	1.30	1.84	1.84
	n	64	86	150
North	kg	8.44	9.78	9.23
24 August	SD	1.09	1.71	1.62
	n	63	89	152
East Reef	kg	8.60	9.74	9.17
24 August	SD	1.28	1.49	1.50
	n	85	83	168
Combined	kg	8.50	9.89	9.26
	SD	1.23	1.69	1.65
	n	212	258	470

Table 35. -- Analyses of variance of mass of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2014.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	2	1.5	0.8	317	209	0.51	0.60
Males							
Rookery	2	8.0	4.0	730	255	1.40	0.25

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

Table 36. -- Mean length (cm), standard deviation (SD), and sample sizes (n) of male and female northern fur seal pups measured on St. George Island, Alaska, 24-25 August 2014.

Rookery		Females	Males	Combined
South	cm	73.7	77.7	76.0
25 August	SD	3.71	4.39	4.56
	n	64	86	150
North	cm	75.0	78.3	76.9
24 August	SD	3.31	4.40	4.29
	n	63	89	152
East Reef	cm	74.8	77.7	76.2
24 August	SD	3.49	4.03	4.04
	n	85	83	168
Combined	cm	74.5	77.9	76.4
	SD	3.53	4.28	4.30
	n	212	258	470

Table 37. -- Analyses of variance of length of male and female northern fur seal pups across rookeries on St. George Island, Alaska, August 2014.

Factor	df	SS due to factor	MSS*	Residual	df	F	P
Females							
Rookery	2	61.8	30.9	2,569	209	2.51	0.08
Males							
Rookery	2	17.5	8.8	4,681	255	0.47	0.62

*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 Vostochni rookery on St. Paul (0.43, $P = 0.03$), and on North rookery on St. George (0.41, $P = 0.04$) in 2014 (Table 38). Across the sampled rookeries, the fraction of females was significantly different from 0.5 on St. Paul Island (0.45, $P < 0.01$) and St. George Island (0.45, $P = 0.04$) and for both islands combined (0.45, $P < 0.01$). Comparison of the sex ratios between islands showed no significant difference ($P = 0.98$).

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 2014 were significantly heavier and longer on St. George Island than those on St. Paul Island. The fraction of females was significantly different than 50% on both islands in 2014, consistent with differences seen across the past two decades (Table 39). 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 38. -- Numbers of female pups, total number of pups, and fraction (that are female) of northern fur seal pups sampled during pup weighing on St. Paul and St. George Islands, Alaska, August 2014. The fraction of females is significantly less than 50% ($P \leq 0.05$) for bold items.

Rookery	Females	Total	Fraction
St. Paul			
Reef	129	281	0.459
Vostochni	**110**	**256**	**0.430**
Polovina Cliffs	114	242	0.471
Tolstoi	109	247	0.441
Total	**462**	**1,026**	**0.450**
St. George			
South	64	150	0.427
North	**63**	**152**	**0.414**
East Reef	85	168	0.506
Total	**212**	**470**	**0.451**

Table 39. -- 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 1995-2014. Bold numbers indicate the fraction of females significantly different than 50%.

	St. Paul			St. George		
Year	Females	Total	Fraction	Females	Total	Fraction
1995	**939**	**2040**	**0.460**	**294**	**653**	**0.450**
1996	**520**	**1149**	**0.453**	**331**	**749**	**0.442**
1997	495	1020	0.485	311	639	0.487
1998	**506**	**1100**	**0.460**	**344**	**745**	**0.462**
1999	**462**	**1081**	**0.427**	--	--	--
2000	543	1079	0.503	**292**	**640**	**0.456**
2001	**510**	**1095**	**0.466**	--	--	--
2002	**424**	**1016**	**0.417**	300	627	0.478
2004	**489**	**1,067**	**0.458**	**279**	**619**	**0.451**
2006	**446**	**983**	**0.454**	304	640	0.475
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**

MODELING THE POPULATION EFFECTS OF A NORTHERN FUR SEAL PUP HARVEST ON THE PRIBILOF ISLANDS, ALASKA

by

Rodney G. Towell and Michael Williams

Northern fur seal pups historically were a traditional food source for Native Alaskans on the Pribilof Islands, Alaska. The harvest of northern fur seal pups was prohibited in 1891. The St. George Island Traditional Council petitioned the National Marine Fisheries Service (NMFS) in September 2006 to change the northern fur seal harvest regulations to authorize a harvest of 150 male pups. The Alaska Region requested the National Marine Mammal Laboratory to analyze the potential impacts of harvesting 150 male pups on St. George Island. The National Environmental Policy Act (NEPA) requires that all federal agencies must analyze a reasonable range of alternatives to the proposed action of authorizing the petitioned harvest of pups. Because there are more animals at ages 0 and 1 year, typically with lower survival than juveniles aged 2 to 6 years, there is less of an impact on the population if the youngest animals are killed (DeMaster 1981).

NMFS promulgated new subsistence harvest regulations on 30 October 2014, authorizing the subsistence harvest of 150 male pups on St. George Island based on four harvest alternatives analyzed in an Environmental Impact Statement. The four alternatives included: 1) 500 males between 2 and 4 years old, hereafter “subadult”, killed annually (no action alternative); 2) 150 pups and 350 subadult males killed annually (preferred alternative); 3) 500 pups killed annually; and 4) 50 pups and 450 subadult males killed annually. Analyses of model results examined the loss of adult seals among the alternative male harvest scenarios and estimated accidental female mortality.

The Aleut Community of St. Paul Island (ASCPI) petitioned NMFS to change the regulations governing the subsistence harvest of northern fur seals on St. Paul Island in 2007. NMFS' current understanding of ASCPI's petition is for the harvest of 2,000 pup and juvenile male fur seals on St. Paul Island. ACSPI defined juvenile males as those too young to mate or have pups (i.e., up to 7 years old). ACSPI also requested an accidental female harvest limit of 20 individuals. No alternatives have been developed through the NEPA process for St. Paul Island, however, the currently petitioned harvest scenario and the no action alternative can be modeled for comparison to St. George. Similar analytical methods were applied to both islands.

METHODS

To assess the impacts of harvest, island-, age-, and sex-specific population projections were modeled for each of the four alternatives. Population impact was quantified by removing pups and subadult / juvenile males under various harvest alternatives. Whereas the subsistence harvest was directed at males, harvesters occasionally misidentified young females and they were accidentally killed. Several assumptions went into the models, including:

- sex ratio of pups born was 1:1;
- survival, fecundity and pup production were time invariant over the projection period;
- the proportion of adult males counted during the annual July counts was time invariant;
- and harvest and the age distribution of the harvest were constant.

Lander's (1981) and Towell's (2007) age- and sex-specific survival estimates were used to project the population size and composition into the future, and to compare the harvest alternatives. Lander's (1981) models used predominately commercial male harvest age data for

age classes 2-5 years, assumed a survival rate for males age 6-10, and estimated ages greater than 10 from Johnson's (1968) data. Towell (2007) used more current data in more complex models to estimate survival parameters. Lander's (1981) survival estimates for males were adjusted upwards to remove the effect of commercial harvest mortality in his original estimates. The final time period of Towell's (2007) survival estimates were also applied to the simulations. Both estimates were used because they resulted in very different population sizes due to different population trends after Lander's (1981) analysis and more data available to inform the Towell (2007) models and survival estimates.

Lander's (1981) estimates of fecundity were used with both survival curves when modeling accidental female mortality scenarios. Models were initiated using the pup production estimate for 2012 (Towell et al., 2013). Survival and fecundity schedules were applied to each year for 25 years allowing the population to equilibrate and to assess the impacts for harvest alternatives.

Given a harvest alternative, the population was projected for 25 years into the future to quantify the impact of removing northern fur seals according to the alternatives. The projection runs assume that pup production, number harvested from the age group, fecundity and survival were the same each year for 25 years. The population prediction in year 25 of the projection of each harvest alternative was compared to the population projection without harvest for assessing the probable range of impact. Age 7 and older males were those available to breed in the population, so comparisons were also made of this class between harvest alternatives.

Similar models were applied to assess the impact of accidental female mortality (i.e., 10% of the total pup harvest) and a random pup harvest (i.e., 50% of the total pup harvest) for St. George Island. St. Paul Island's proposal includes an accidental harvest of up to 20 females (i.e., 1% of 2,000) total killed across their entire harvest season. Whereas only a 1% female harvest

was included in the proposal (similar to St. George Island), 10% and 50% female harvests were also modeled. For the comparison of lost pup production, only the result of the last year was compared (i.e., pup production in year 25 with no harvest compared to the pup production in year 25 with a harvest).

RESULTS

The NMFS regulations in 2013 allowed up to 500 subadult males to be harvested annually for subsistence purposes on St. George Island. From 2009 to 2013, the St. George Island harvest averaged 91 subadults per year. The harvest of males older than pups caused a greater loss to the population than a harvest of an equal number of pups (Table 40). The Towell 2007 model projected a smaller population size than the Lander 1981 model creating a much larger percentage loss of 7+ year old males.

The impact of accidental female mortality of either 10% (15 animals) or 50% (75 animals) was negligible (Table 41) and resulted in less than a 2% reduction of the population when counting the difference in the population of females and their associated pup production in the final projection year. The estimates from the Towell 2007 model should be viewed with skepticism because very low overall production was estimated (approximately ¼ of current estimates) and was not consistent with maintaining the population.

NMFS regulations in 2014 allowed for up to 2,000 subadult males to be harvested annually on St. Paul Island during the subsistence harvest season that ends on 8 August. ASPCI requests to harvest up to 2,000 male fur seals annually, which would include a spring hunt of up to 6 year old males, and summer and fall harvesting of male pups and subadults. In order to assess the potential impacts to the population, extreme scenarios were simulated. St. Paul Island residents harvested an average of 340 subadult males from 2009 to 2013 and this level of harvest was compared to the requested levels of harvest (Table 42).

Similar to the St. George Island request, 10% and 50% accidental harvests of female pups for the St. Paul Island proposal was analyzed. It is not known whether the assumptions used in the St. George Island analysis for accidental female mortality will apply to St. Paul Island, however, these alternatives would be informative to subsequent decision-making. The projections related to assumptions regarding accidental female mortality (Table 43) are presented to show the relative value of females to the population in comparison to males. Whereas it would be highly unlikely for females to be accidentally killed prior to the breeding season, females could be accidentally harvested during the juvenile and pup harvests (24 June to 31 December). Although not likely, and not requested, a scenario of 1,000 juvenile females harvested was considered and modeled as an extreme alternative. Very little recent female age structure data were available for accidental harvest (12 aged tooth samples from accidentally killed females on both islands since 1994) but this estimate was applied based on those data. The Towell model estimated just over one-quarter of the current estimated production on St. Paul Island and resulted in much higher rates of loss that may not be realistic.

DISCUSSION

Two survival models were used with the same fecundity schedule, which produced notable differences in the population projections after 25 years. Lander's (1981) survival schedule projected a population of males 1.5 times greater, and a population of females two times greater than Towell's (2007) survival schedule. Whereas the Towell (2007) model results in pup production that was 25% and 27% of the 2012 estimate for St. George and St. Paul Islands, respectively; the Lander (1981) schedule was identical (100%) to the St. George Island and slightly higher (107%) than the St. Paul Island 2012 estimate. Neither survival schedule was likely to be an accurate description of the current population due to the lack of current survival and reproduction estimates. The survival schedule was fixed for the 25-year projection period for

simplicity; however, it would be more probable for those parameters to vary annually. The impact to the population of harvesting older animals, regardless of sex, was greater than for harvesting younger animals. This result would need to be taken into consideration if future harvests include a much greater number than those of the last 5 years. Given the model assumptions and proposal for St. George Island, the proposed harvest would have a minimal impact on the female population and its pup production (< 1.0%) for all projected scenarios.

Table 40. -- Projected total male population, percent loss of total males given harvest, projected age greater than 7 years, and percent loss of age 7+ years after 25 years given annual harvests on St. George Island.

Harvest strategy	Total males	Percent loss	Age 7+	Percent loss
Towell (2007) survival estimates				
No harvest	18,557		2,296	
500 Subadult males	16,876	9.06	1,446	37.02
450 Subadult males and 50 male pups	16,930	8.77	1,517	33.93
350 Subadult males and 150 male pups	17,037	8.19	1,659	27.75
91 Subadult males,(current harvest)	18,252	1.64	2,142	6.70
91 Subadult males & 150 pups	17,884	3.63	2,100	8.56
500 Male pups	17,412	6.17	2,156	6.12

Table 40. -- Cont.

Lander(1981) survival estimates				
No harvest	27,125		4,105	
500 Subadult males	25,332	6.61	3,392	17.38
450 Subadult males and 50 male pups	25,343	6.57	3,436	16.30
350 Subadult males and 150 male pups	25,369	6.47	3,531	13.99
91 Subadult males (current harvest)	26,798	1.21	3,975	3.18
91 Subadult males and 150 pups	26,295	3.06	3,899	5.03
500 Male pups	25,447	6.19	3,850	6.22

Table 41. -- Projected total female population, percent loss of total males given harvest, projected age greater than 7 years, and percent loss of age 7+ years after 25 years given annual harvests on St. George Island.

Harvest strategy	Total females	Percent loss	Production	Percent loss
Towell (2007) survival estimates				
No harvest	20,606		3,996	
Incidental 10% pup take (15)	20,570	0.17	3,989	0.18
Random pup harvest (75)	20,418	0.92	3,959	0.93
Lander (1981) survival estimates				
No harvest	41,688		16,126	
Incidental 10% pup take (15)	41,591	0.18	16,096	0.19
Random pup harvest (75)	41,282	0.93	15,977	0.92

Table 42. -- Projected total male population, percent loss of total males given harvest, projected numbers aged greater than 7 years, and percent loss of age 7+ years after 25 years given annual harvests on St. Paul Island.

Harvest strategy	Total males	Percent loss	Age 7+	Percent loss
Towell (2007) survival estimates				
No harvest	110,768		13,569	
340 subadult males (current harvest)	109,686	0.98	12,964	4.46
2,000 Subadult males	103,960	6.15	10,009	26.24
2,000 Pups	106,279	4.05	13,008	4.13
2,000 Age 6	101,833	8.07	4,543	66.52
350 Subadult, 1,200 pups and 80 Age 6	106,542	3.81	12,248	9.73
Lander (1981) survival estimates				
No harvest	162,278		24,558	
340 Subadult males (current harvest)	161,063	0.75	24,061	2.02
2,000 Subadult males	155,131	4.40	21,637	11.89
2,000 Pups	155,575	4.13	23,543	4.13
2,000 Age 6	156,086	3.82	18,366	25.21
350 Subadult, 1,200 pups and 80 age 6	156,758	3.40	23,190	5.57

Table 43. -- Projected total female population, percent loss of total males given harvest, projected pup production, and percent loss of pup production after 25 years given accidental annual harvests of females on St. Paul Island.

Harvest strategy	Total females	Percent loss	Production	Percent loss
Towell (2007) survival estimates				
No harvest	129,534		26,373	
20 Pups	129,482	0.04	26,363	0.04
20 Juveniles	129,381	0.12	26,270	0.39
200 Pups	129,015	0.40	26,270	0.39
200 Juveniles	128,003	1.18	25,339	3.92
1,000 Pups	126,940	2.00	25,857	1.96
1,000 Juveniles	121,880	5.91	21,119	19.62
Lander (1981) survival estimates				
No harvest	269,445		105,156	
20 Pups	269,335	0.04	105,113	0.04
20 Juveniles	269,252	0.07	105,030	0.12
200 Pups	268,352	0.41	104,729	0.41
200 Juveniles	267,518	0.72	103,812	1.28
1,000 Pups	263,980	2.03	103,019	2.03
1,000 Juveniles	259,812	3.58	98,435	6.39

Whereas the ACSPI's petition includes a maximum of 20 female mortalities due to harvest, various projections were run to investigate the potential impact of a greater harvest of females. Because a rather large overall quota of 2,000 animals was requested, a similar set of projections were estimated to include a harvest of 10% and 50% of the requested quota. For various scenarios, 2% or less loss of females in the population would be expected and a 4% or less loss of pup production (both sexes). However, a larger accidental harvest of females (up to 1,000 in these projections) of juvenile females rapidly begins to impact both the population and resultant production. ASCPI specifically stated in their petition that all harvesting would cease for the year when 20 females had been accidentally killed and would mitigate the resultant impact of the larger harvest of 1,000 females. The models presented were simple projections based on recent pup production, assumed vital rates, no density dependence, no population or production trend, and no variability in parameters. Extreme female harvest examples were presented to show the results of a random harvest of pups under an equal sex ratio assumption for both islands. From 1998 to 2014 the pup production estimates have declined at an annual rate of 4.25%. Care should be taken with any harvest scenario that has the potential to kill females in order to avoid exacerbating the ongoing population decline.

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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, 10-17 July 2013. A dash indicates no section.

Rookery and class of male	Section 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Lukanin															
2	23	16													39
3	73	34													107
5	126	11													137
Kitovi [b]															
2	(7) 11	7	15	20	13										73
3	(10) 14	27	32	38	40										161
5	(22) 7	7	9	16	71										132
Reef															
2	12	29	16	13	19	16	0	20	6	7	1				139
3	52	79	45	48	41	56	0	65	29	25	3				443
5	21	31	31	45	68	13	33	38	11	80	46				417
Gorbatch															
2	22	20	24	8	14	15									103
3	73	52	73	19	51	47									315
5	208	17	30	30	12	19									316
Ardiguin															
2	7														7
3	51														51
5	14														14
Morjovi[c]															
2	(10) 8	10	20	14	19	11									92
3	(68) 52	53	50	29	68	42									362
5	(12)125	13	31	20	14	43									258
Vostochni															
2	6	5	4	13	9	14	8	14	13	9	6	12	23	20	156
3	60	24	33	46	35	64	29	42	37	22	24	71	146	90	723
5	9	3	6	31	51	22	3	2	8	8	3	34	79	46	305
Little Polovina															
2	0														0
3	0														0
5	99														99
Polovina															
2	7	18													25
3	65	59													124
5	59	38													97

Polovina Cliffs									
	2	8	8	6	7	11	14	7	
	3	50	33	35	57	50	83	66	
	5	7	13	6	3	15	7	9	
Tolstoi									
	2	6	8	5	5	16	37	38	26
	3	25	33	30	50	55	53	57	58
	5	3	10	7	9	11	16	24	148
Zapadni Reef									
	2	43	16						59
	3	125	37						162
	5	92	84						176
Little Zapadni									
	2	11	10	18	18	13	12		82
	3	21	35	41	33	44	54		228
	5	17	18	19	20	18	134		226
Zapadni									
	2	9	15	17	15	19	20	14	13	122
	3	23	37	44	50	48	64	65	52	383
	5	76	15	16	29	11	38	27	266	478

[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, 7-15 July 2014. 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	37	21													58
3	67	28													95
5	62	19													81
Kitovi[b]															
2	(7) 9	7	29	19	19										90
3	(9) 8	19	22	40	32										130
5	(10) 8	13	11	12	36										90
Reef															
2	14	31	13	19	9	12	11	19	5	10	0				143
3	42	70	46	36	40	53	0	71	38	28	5				429
5	12	29	12	30	43	14	18	20	18	21	46				263
Gorbatch															
2	25	16	29	2	14	13									99
3	64	46	60	17	58	61									306
5	169	17	14	54	19	14									287
Ardiguin															
2	5														5
3	36														36
5	6														6
Morjovi[c]															
2	(10) 14	18	19	5	18	12									96
3	(57) 43	45	52	29	62	29									317
5	(17)130	24	19	20	42	30									282
Vostochni															
2	12	7	7	11	12	17	6	6	8	7	1	7	23	14	138
3	44	21	31	45	33	58	25	33	31	22	25	51	138	74	631
5	11	12	13	9	29	45	7	8	24	4	3	32	41	73	311
Little Polovina															
2	0														0
3	0														0
5	68														68

Polovina									
	2	15	8						23
	3	58	41						99
	5	72	24						96
Polovina Cliffs									
	2	13	7	8	12	6	17	13	76
	3	39	23	25	33	42	61	42	265
	5	13	4	6	20	8	10	5	66
Tolstoi									
	2	16	13	7	7	23	17	32	25	140
	3	20	22	24	41	30	31	41	51	260
	5	7	2	4	8	7	9	27	102	166
Zapadni Reef									
	2	57	12						69
	3	119	39						158
	5	67	59						126
Little Zapadni									
	2	8	12	8	19	15	24		86
	3	27	39	45	45	43	57		256
	5	17	6	19	12	31	106		191
Zapadni									
	2	18	12	18	14	22	15	24	12	135
	3	22	36	49	46	41	69	57	60	380
	5	139	3	2	3	10	13	11	132	313

[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, 2014.

	Section															
Rookery	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Lukanin		199	93													292
Kitovi[a]	10	24	56	70	118	96										374
Reef[b]		65	212	135	126	142	196		225	121	75	6				1,303
Gorbatch		170	152	161	49	160	146									838
Ardiguen		81														81
Morjovi[1]	167	129	131	145	78	170	144									964
Vostochni		108	55	75	110	81	140	70	83	75	41	70	124	330	177	1,539
Polovina		105	181													286
Little Polovina																
Polovina Cliffs		133	67	80	109	135	206	182								912
Tolstoi		76	82	71	176	102	121	157	166							951
Zapadni Reef		348	111													459
Little Zapadni		53	112	128	136	135	172									736
Zapadni		60	90	120	143	121	188	160	167							1,049
Sea Lion Rock		459														459
Total																10,243

[a] Section 0 corresponds to 2nd Point South on Morjovi and Kitovi Amphitheater.
[b] Section 7 was combined with Section 6.

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 Island, Alaska, 1986-2014. 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
1986	4,603	1,865	167,656	5,086	4	7,771	1,394	1,342	--	--	--	--
1987	3,636	1,892	171,610	3,218	13	7,757	1,303	1,283	--	--	--	--
1988	3,585	3,201	202,229	3,751	4	7,272	1,259	1,258	24,819	827	6	1,212
1989	4,297	6,400	171,534	25,867	4	9,096	1,241	1,163	--	--	--	--
1990	4,430	7,629	201,305	3,724	13	9,128	909	1,666	23,397	2,054	6	928
1991	4,729	9,453	--	--	--	--	736	1,271	--	--	--	--
1992	5,460	10,940	182,437	8,918	13	8,525	1,028	1,834	25,160	707	6	806
1993	6,405	9,301	--	--	--	--	1,123	1,422	--	--	--	--
1994	5,715	10,014	192,104	2,029	13	8,180	1,179	1,481	22,244	410	6	788
1995	5,154	8,459	--	--	--	--	1,242	1,054	--	--	--	--
1996	5,643	9,239	170,125	21,244	6	6,837[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[2]
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[2]
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[2]
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[2]
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[2]

[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 [1].
[c] Error in bull counts, see Appendix Table A-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, 2014.

		Section														
Rookery	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Kitovi[a]	8/18	(0)5	12	26	25	16										84
Gorbatch	8/20	69	50	82	19	32	24									276
Vostochni	8/16	21	12	20	23	38	49	31	23	20	7	16	47	88	31	426
Zapadni Reef	8/17	33	104													137
Polovina Cliffs[b]	8/18							30								

[a] Number in parentheses are number of dead pups counted in Kitovi Amphitheater.
[b] Dead pups were counted and piled on 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, 2014.

Rookery	Section					Total
	1	2	3	4	5	
South	112	121	145			378
North	85	127	170	75	45	502
East Reef	173					173
East Cliffs	264	146				410
Staraya Artil	60	25				85
Zapadni	55	80	55			190
Total						1,738

Appendix Table A-7. -- Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 2014.

Rookery	Date	Section					Total
		1	2	3	4	5	
South	8/25	27	37	16			80
East Cliffs	8/21	84	44				128
Staraya Artil	8/22	27					27

Appendix Table A-8. -- Number of dead northern fur seals counted that were older than pup, Pribilof Islands, Alaska, 1978-2012. Teeth (usually canines) were collected from most of these seals. A dash indicates no data.

	St. Paul Island		St. George Island		Total	
Year	Males	Females	Males	Females	Males	Females
1978	57	87	-	-	57	87
1979	56	66	-[a]	-[a]	56	66
1980	102	117	14	65	116	182
1981	44	83	12	61	56	144
1982	47	117	-	-	47	117
1983	57	66	-	-	57	66
1984	66	72	-	-	66	72
1985	5	34	17	35	22	69
1986	24	67	-	-	24	67
1987	20	90[b]	-	-	20	99
1988	56	112	21	29	77	141
1989	55	162	-	-	55	162
1990	97	151	13	31	110	182
1992	97	265	7	19	104	284
1994	84	223[c]	6	19[d]	90	242
1996	20[e]	92[e]	3	20[f]	23	112[f]
1998[g]	-	-	-	-	-	-
2000	20	77	26	98	46	175
2002[h]	36	107	6	19	42	126
2004[i]	37	85	9	12	46	97
2006[j]	23	37	2	8	25	45
2008[j]	4	41	2	10	6	51
2010[j]	10	52[k]	5	10[l]	32	45
2012[m]	15	37	0	6	15	43
2014[n]	11	43	2	4	13	47

[a] A total of 70 dead adult fur seals of both sexes were counted on the rookeries of St. George Island.
[b] Includes 10 dead adult fur seals of unknown sex.
[c] Includes 16 dead adult fur seals of unknown sex.
[d] Includes 2 dead adult fur seals of unknown sex.
[e] Counts made only on the 6 sample rookeries where dead pups were counted.
[f] Includes 16 dead adult fur seals of unknown sex.
[g] A total of 108 dead adults were counted on St. Paul and 34 dead adults were counted on St. George.

[h] Does not include 8 dead adults that were unidentifiable, had no teeth and both.
[i] Does not include 11 dead adults that were not sexually identifiable.
[j] Only four rookeries were sampled for dead pups and therefore dead adults also.
[k] Teeth not taken from 4 males and 4 females on Reef, nor from 1 female each on VOS, PCL and ZAR.
[l] Teeth were not taken from 1 female on East Cliffs, includes 1 dead adult of unknown sex.
[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

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NMFS-SWR – National Marine Fisheries Service, SW Region
NMML – National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA
OAI – Ocean Associates, Inc.
PBCS – Point Blue Conservation Science
SGTC – St. George Traditional Council
TGSP – Tribal Government of St. Paul, AK
UAA – University of Alaska Anchorage
WPI – Wildlife Pathology International

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