

DECLINE IN NORTHERN FUR SEAL (*CALLORHINUS URSINUS*) PUP PRODUCTION ON THE PRIBILOF ISLANDS

ROD G. TOWELL

ROLF R. REAM

National Marine Mammal Laboratory,
Alaska Fisheries Science Center,
7600 Sand Point Way NE,
Seattle, Washington 98115, U.S.A.
E-mail: rod.towell@noaa.gov

ANNE E. YORK

P. O. Box 31375,
Seattle, Washington 98103, U.S.A.

The Pribilof Islands in Alaska are home to the majority of the world's breeding population of northern fur seals (*Callorhinus ursinus*). Northern fur seal abundance at breeding colonies on these islands (St. Paul, St. George, and Sea Lion Rock) is monitored using estimates of pup production on land because, at any given time, an unknown portion of adult and juvenile fur seals are at sea. Reliable estimates of pup production date to the early 1900s, though the methods used to obtain the estimates have changed over the decades to increase precision. Since 1963, northern fur seal pup production estimates have been conducted using the shear-sampling method (Chapman and Johnson 1968, York and Kozloff 1987). Between 1956 and 1980, the population experienced a significant decline in abundance that was attributed primarily to an experimental harvest of females from 1956 to 1968, and scientific pelagic collections from 1958 to 1974 (York and Hartley 1981). Following this period of decline, fur seal abundance on the Pribilof Islands was relatively stable through the mid-1990s. The lack of population recovery long after the cessation of the female harvest was unforeseen and has yet to be explained.

Since the initiation of the shear-sampling method for pup production estimates, various adjustments have been made to the sampling protocol. These adjustments were mostly minor and adapted to explore the sources of variability in the estimates. Recent pup production estimates have been conducted biennially and have included subsampling of rookeries on St. Paul Island during some years. From 1996 to 2000, 6 or 7 of 14 rookeries had direct surveys done, and pup production for the whole of St. Paul Island was extrapolated from these sample rookeries (York and Kozloff 1987, York and Towell 1997). Because of the high variance of the estimate in 2000 (York *et al.* 2002) and the resulting imprecision of a negative trend in pup production, a complete survey of pup production for both islands was conducted in 2002. The results confirmed a significant decline in pup production on the Pribilof Islands, and indicated a need for another complete survey. This survey was conducted during

2004 and was used to examine trends, by island, in northern fur seal pup production. Estimates of pup production can, in turn, be used to infer population size.

During 7–26 August 2004, we estimated the number of northern fur seal pups born on the Pribilof Islands. We used the shear-sampling method for all rookeries on St. Paul and St. George islands, except Little Polovina rookery on St. Paul Island. Pup production on Little Polovina was estimated by applying the ratio of pups to breeding males observed on the other St. Paul Island rookeries to the number of breeding males on Little Polovina rookery. Pup estimates for Sea Lion Rock, a small island approximately 500 m from the southern tip of St. Paul, were obtained in 2002, but not in 2004 because of logistical difficulties.

The sampling and estimation protocols followed those of Chapman and Johnson (1968) and York and Kozloff (1987). Briefly, pups were marked by shearing a small patch of hair from the top of their heads. Shearing exposes the silver fur underneath and produces an easily identifiable mark. The number of pups marked on each rookery was approximately 10% of the most recent pup production estimate for each rookery, and the marking effort was allocated proportionally throughout the rookery according to the distribution of breeding males counted in July 2004. After allowing a few days to pass for adequate mixing of the marked and unmarked animals, each rookery was sampled twice without replacement (pups are not counted more than once during a sampling occasion) by multiple observers. Each observer obtained estimates of the proportion of marked animals for each rookery.

For each observer, the estimate of the pup population at the time of marking was the number of marked animals divided by the proportion of sheared pups among all those sighted in the samples. An estimate for each sampling occasion was calculated as the average across observers, and the estimate for the rookery was the mean over the two sampling occasions. The final estimates of pup production included observations of dead pups that were individually marked and counted on one occasion at each rookery; these counts represented minimum estimates of the numbers of dead pups. Marking and sampling methods used on St. George Island were identical to those used on St. Paul Island.

From 7 to 14 August, 14,561 pups were marked by shearing on St. Paul Island. The ratio of marked to unmarked pups was determined on two occasions by two observers for each rookery during 12–26 August. These ratios were obtained independently and each observer obtained samples of marked and unmarked pups from the entire rookery. Each sampling day was considered an independent replicate from which the variance was computed for each rookery. Dead pups were counted (Antonelis 1992) on all rookeries except Little Polovina during 2004. The estimated number of pups born, standard error of the estimate, number of dead pups, and pup mortality rates for each sampled rookery on St. Paul Island are given in Table 1.

The estimate of the total number of pups alive on St. Paul Island at the time of marking in 2004 was 118,784 with an estimated standard error of 1,290. Dead pups were counted on all sampled rookeries from 19 to 26 August. The number of dead pups was estimated to be 4,041 (4,039 counted on sample rookeries and 2 estimated on Little Polovina); the estimated mortality rate for St. Paul during late August was 3.3%. The estimate of the total number of pups born on St. Paul Island in 2004 is the

Table 1. Numbers of northern fur seal, *Callorhinus ursinus*, pups on St. Paul Island, Alaska, in 2004. Estimates of numbers alive at the time of shearing (Live), counts of dead pups (Dead), numbers of pups born (Born), standard error of pups born (SE), and percent pup mortality (Mortality) on each rookery of St. Paul Island.

Rookery	Live	Dead	Born	SE	Mortality
Lukanin	2,993	102	3,095	176.0	3.3
Kitovi	4,800	111	4,911	48.5	2.3
Reef	15,262	456	15,718	492.5	2.9
Gorbatch	9,569	417	9,986	96.0	4.2
Ardiguen	1,158	38	1,196	104.0	3.2
Morjovi	8,781	237	9,018	177.0	2.6
Vostochni	18,872	618	19,490	436.5	3.2
Polovina	2,511	70	2,581	108.0	2.7
Polovina Cliffs	10,889	177	11,066	503.0	1.6
Tolstoi	13,146	639	13,785	560.5	4.6
Zapadni Reef	4,916	171	5,087	245.5	3.4
Little Zapadni	10,021	418	10,439	204.0	4.0
Zapadni	15,799	585	16,384	682.0	3.6
Little Polovina	67	2	69	4.9	2.9
Total St. Paul Island	118,784	4,041	122,825	1,289.8	3.3

sum of the number alive at the time of marking and the number dead, or 122,825 (SE = 1,290). An approximate 95% confidence interval for the number of pups born is 120,039–125,611.

On St. George Island, 1,730 fur seal pups were marked by shearing during 16–18 August. The ratio of marked to unmarked pups was determined on two occasions by three observers for each rookery during 19–23 August. The estimate of total number of pups alive at the time of marking was 16,461 with a standard error of 239 (Table 2). A total of 415 dead pups were counted on all rookeries of St. George Island during 20–24 August. The estimate of the total number of pups born on St. George Island in 2004 is the sum of the number alive at the time of marking and the number dead, or 16,876 (SE = 239; Table 2). The estimated mortality rate for pups

Table 2. Numbers of northern fur seal, *Callorhinus ursinus*, pups born on St. George Island, Alaska, in 2004. Estimates of numbers alive at the time of shearing (Live), counts of dead pups (Dead), numbers of pups born (Born), standard error of pups born (SE), and percent pup mortality (Mortality) on St. George Island.

Rookery	Live	Dead	Born	SE	Mortality
South	3,774	134	3,908	70.0	3.4
North	5,299	96	5,395	25.0	1.8
East Reef	915	20	935	55.0	2.1
East Cliffs	3,305	72	3,377	52.0	2.1
Staraya Artil	974	27	1,001	132.0	2.7
Zapadni	2,194	66	2,260	168.5	2.9
Total St. George Island	16,461	415	16,876	238.9	2.5

was 2.5%. An approximate 95% confidence interval for the number of pups born is 16,291–17,461.

On St. Paul Island, estimated numbers of fur seal pups born in 2004 were 15.7% less than in 2002 (145,716 pups born, SE = 1,629) and 22.6% less than in 2000 (York *et al.* 2002). This compares to a 4.1% decrease on St. George Island between 2002 (17,593 pups born, SE = 527) and 2004 and a 16.3% decrease between 2000 (York *et al.* 2002) and 2004. Estimated pup production has now declined to the level observed on St. Paul Island in 1918 and below the level observed on St. George Island in 1916; through these years, the northern fur seal population was increasing at about 8% (Roppel and Davey 1965) per year, as it was recovering from a pelagic harvest that took place in the late 19th and early 20th centuries.

The two previous censuses on Sea Lion Rock took place in 1994 and 2002; 12,891 (SE = 989) and 8,262 (SE = 191) pups were estimated to have been born in those years, respectively. Pup numbers on Sea Lion Rock declined by approximately 36% between 1994 and 2002. This compares to a decline of about 24% over the same period at rookeries on St. Paul Island. It is difficult to determine if the changes observed on St. Paul Island were different than those on Sea Lion Rock due to the limited number of estimates for Sea Lion Rock.

Because the standard errors of the estimates of pups born varied widely (Fig. 1), we estimated the annual rate of decline with a weighted regression of the logarithm of numbers of pups born on year, with weights equal to the inverse of the standard error of the logarithm of the annual pup estimate. During 1998–2004, the average rate of decline on St. Paul Island was 6.00% (SE = 0.70%, $P = 0.01$) and 4.56% (SE = 0.43%, $P = 0.01$) on St. George Island. The rate of decline on the Pribilof Islands (excluding Sea Lion Rock) was 5.83% (SE = 0.53%, $P = 0.01$) since 1998.

The decline in pup production on the Pribilof Islands was substantial during 1998–2004. However, the magnitude of this recent decline is particularly noteworthy given the population dynamics observed over the past three decades. The cessation of the experimental harvest of females in 1968 and pelagic sampling of fur seals for science in 1974 eliminated the harvest pressure on adult females. A recovery of the population should have occurred assuming that the ecosystem could support a population of fur seals similar to the population in the 1950s. We fitted a general additive model to pup counts from each island for the time period 1975–2004 to display the trend in pup production (Fig. 1). Despite cessation of the harvest pressure on females, pup production continued to decline followed by a brief period of stability on both islands (Fig. 1), leading to the current state of decline. On St. Paul Island, pup production declined from 1975 into the early 1980s, but stabilized until 1994. The 1983 and 2004 estimates of pup production are 65% and 44%, respectively, of the pup production estimate of 1975. The changes in pup production were even more dramatic on St. George Island, where the decline continued until 1990. Estimated pup production in 1990 and 2004 amount to 54% and 39% of the 1977 pup production estimate, respectively. Currently estimated pup production on the Pribilof Islands is less than half of the estimated production at the end of female harvesting. Thus, the population has failed to recover, or even stabilize, following the removal of a major source of female mortality.

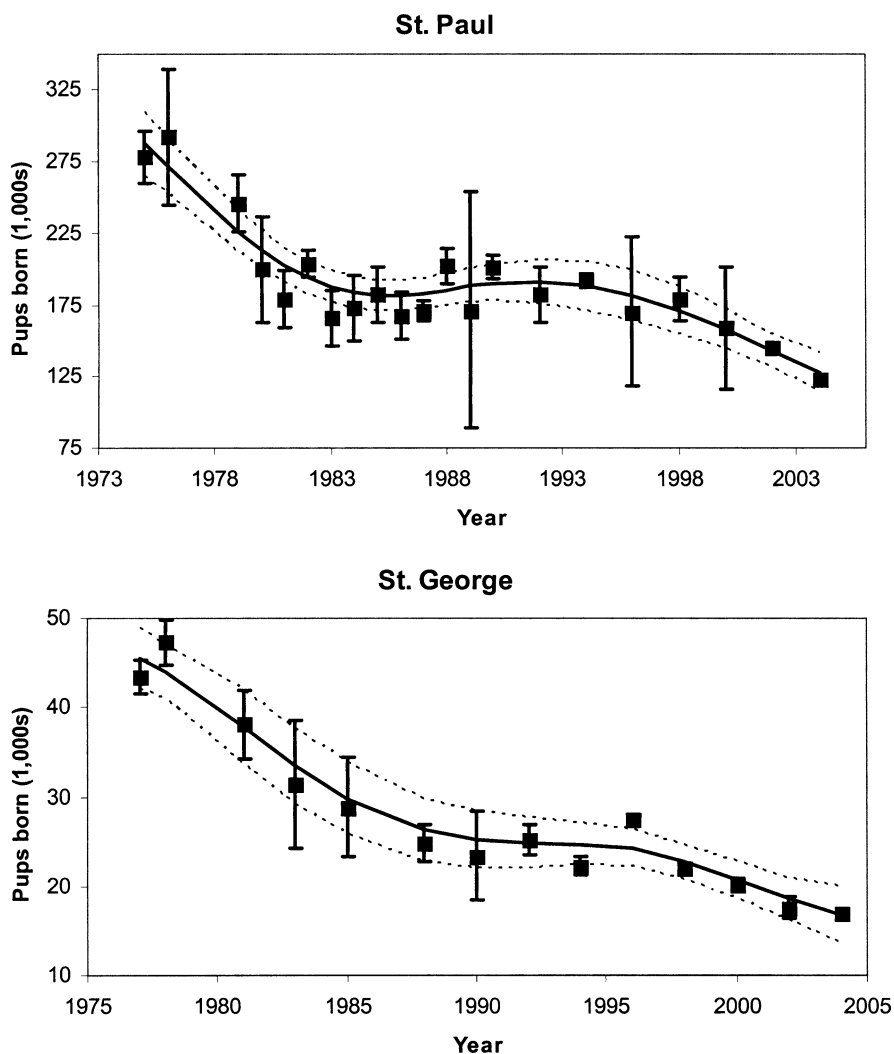


Figure 1. Northern fur seal, *Callorhinus ursinus*, pups born on the Pribilof Islands, 1975–2004. Error bars are approximate 95% confidence intervals. Smooth line is the predicted values from the weighted general additive model and the dashed line represents an approximate 95% confidence interval on the general additive model.

It is unclear why pup production has declined on the Pribilof Islands. Fur seal condition, survival, or reproductive rates may have been affected by factors such as climate change (York 1995), interactions with commercial fisheries (Trites 1992), or predation (Springer *et al.* 2003). Interestingly, while pup production on the Pribilof Islands has been falling, a recently established population at Bogoslof Island in the eastern Aleutian Islands has been increasing in recent years. In 1980, two pups were observed on Bogoslof Island, a small island in the Bering Sea approximately 40 nautical miles (74 km) west of Dutch Harbor, Alaska. The last census of pup

production on Bogoslof Island was conducted in 1997 using the shear-sampling method (Ream *et al.* 1999). In September 1997, there were an estimated 5,055 (SE = 32.6) pups alive at the time of marking. Forty-one dead pups were counted at the time of marking and were added to the estimate of live pups for an estimate of 5,096 pups born in 1997. The annual growth rate on Bogoslof Island from 1980 to 1997 was 59% (SE = 2.29% and $P < 0.001$). Ream *et al.* (1999) concluded that the rate of increase in pup production on Bogoslof Island was influenced by immigration, most likely from the Pribilof Islands. However, owing to the difference in magnitude between the Bogoslof and Pribilof Island populations, the immigration of animals to Bogoslof does not account for the declines noted in the Pribilof population.

ACKNOWLEDGMENTS

We thank all the National Marine Mammal Laboratory employees, volunteers and local inhabitants of the Pribilof Islands for the collection of these data. The research was conducted under Marine Mammal Protection Act Permit Numbers 782-1455 and 782-1708, issued to the National Marine Mammal Laboratory.

LITERATURE CITED

- ANTONELIS, G. A. 1992. Northern fur seal techniques manual. U. S. Department of Commerce, NOAA Technical Memorandum NMFS F/NWC-214. 47 pp.
- CHAPMAN, D. G., AND A. M. JOHNSON. 1968. Estimation of fur seal pup populations by randomized sampling. *Transactions of the American Fisheries Society* 97:264–270.
- REAM, R. R., J. D. BAKER AND R. G. TOWELL. 1999. Bogoslof Island studies, 1997. Pages 81–91 *in* E. H. SINCLAIR AND B. W. ROBSON, eds. *Fur seal investigations, 1997*. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-106.
- ROPPEL, A. Y., AND S. P. DAVEY. 1965. Evolution of fur seal management on the Pribilof Islands. *Journal of Wildlife Management* 29:448–463.
- SPRINGER, A. M., J. A. ESTES, G. B. VAN VLIET, T. M. WILLIAMS, D. F. DOAK, E. M. DANNER, K. A. FORNEY AND B. PEISTER. 2003. Sequential megafaunal collapse in the North Pacific Ocean: An ongoing legacy of industrial whaling? *Proceedings of the National Academy of Sciences* 100:12223–12228.
- TRITES, A. W. 1992. Northern fur seals: Why have they declined? *Aquatic Mammals* 18:3–18.
- YORK, A. E. 1995. The relationship of several environmental indices to the survival of juvenile male northern fur seals (*Callorhinus ursinus*) from the Pribilof Islands. Pages 317–327 *in* R. J. BEAMISH, ed. *Climate change and northern fish populations*. Canadian Special Publication of Fisheries and Aquatic Sciences 121.
- YORK, A. E., AND J. R. HARTLEY. 1981. Pup production following harvest of female northern fur seals. *Canadian Journal of Fisheries and Aquatic Sciences* 38:84–90.
- YORK, A. E., AND P. KOZLOFF. 1987. On estimating the number of fur seal pups born on St. Paul Island, 1980–86. *Fisheries Bulletin* 85:367–375.
- YORK, A. E., AND R. G. TOWELL. 1997. Can we return to estimating numbers of northern fur seals from subsamples of rookeries? Pages 77–98 *in* E. H. SINCLAIR, ed. *Fur seal investigations, 1995*. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-86.
- YORK, A. E., R. G. TOWELL, R. R. REAM AND C. W. FOWLER. 2002. Population assessment, Pribilof Islands, Alaska, 2000–2001. Pages 7–31 *in* B. W. ROBSON, ed. *Fur seal investigations, 2000–2001*. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-134.

Received: 18 February 2005

Accepted: 20 September 2005