Fur Seal Investigations, 1994

by
E. H. Sinclair (editor)
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by

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"Pups gather in large groups called..."

"I estimated 5000 seals in sight before we launched the..."

"Pup tagging began in 1940..."

"The passerby box has alleviated..."

"Length and weight data on..."

"All shearers are equipped..."

"From the catwalks we were able to observe..."
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This document is being made available in .PDF format for the convenience of users; however, the accuracy and correctness of the document can only be certified as was presented in the original hard copy format.
The collection of papers contained in this report describes field research conducted in 1994 on northern fur seals (Callorhinus ursinus) by researchers and research associates of the National Marine Mammal Laboratory (NMML), Seattle, Washington. This is the 51st annual or semi-annual publication on northern fur seal research conducted by the NMML and its predecessor the Marine Mammal Biological Laboratory since 1940. Population numbers and factors that influence or indicate fluctuation in population health are monitored annually by NMML on all U.S. breeding rookeries. Northern fur seal research was conducted by NMML in 1994 under Marine Mammal Permit Number 837.

Population parameters of northern fur seals monitored on St. Paul and St. George Islands (Pribilof Islands) in 1994 included direct counts of adult males (15,729, St. Paul; 2,660 St. George), and mark-recapture estimates of the number of pups born (204,995, St. Paul; 22,244, St. George) (Antonelis et al., this volume). Counts of dead fur seals of all ages were incorporated into population estimates. Adult male counts declined overall in 1994, after 4 years of increasing male counts due to the 1984 cessation of the commercial harvest of juvenile males on St. Paul Island. Population trends, based on pup numbers, remained stable on St. Paul Island and continued to decline on St. George Island.

In addition to population assessment, a new sampling technique was tested for pup estimates on the Pribilof Islands in
1994 (York and Towell, this volume). The new design decreases disturbance to the rookeries and may increase the accuracy of counts, and will probably be employed in future population assessments.

The mean mass, lengths, and sex ratios of pups on St. Paul and St. George Islands were examined in 1994 and compared to previous years as indicators of trends in population health (Towell et al., this volume). Male pups were larger than female pups, but other comparisons between islands and years were less conclusive. Future studies will consider the combined use of length and mass to create condition indices of pups.

Weights of known-age juvenile males taken in the 1991-94 subsistence harvests on St. Paul Island were compared (Caruso and Baker, this volume). Overall, males harvested in 1992 were heavier than those in other years, but bias in size selection during the harvest may have occurred.

Entanglement of male northern fur seals in marine debris appeared to increase throughout the late 60s and early 70s, then peak in 1976. In 1994, island-wide surveys of female northern fur seals on St. Paul Island showed an increase in entanglement rates from 1992 and 1993 (Robson et al., this volume). Similar to observations in previous years, the incidence of entanglement increased as the breeding season progressed, possibly due to the higher rate of entanglement among younger seals that arrive later in the season. All entangled animals were captured and disentangled on an opportunistic basis.
A total of 1,482 northern fur seal pups and 3,691 non-pups were counted on Bogoslof Island in 1994 (Piatt and Goley, this volume). The number of pups is 67% higher than 1993 counts and is consistent with a trend of increasing counts since the late 1980s.

Studies conducted on the San Miguel Island northern fur seal population in 1994 included pup production and condition, and the effects of the 1992-93 El Niño on population growth (Melin et al., this volume) A total of 2,452 live pups were counted representing the highest recorded counts since the San Miguel Island colony was discovered in 1968.
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</tr>
</tbody>
</table>
INTRODUCTION

by

Elizabeth H. Sinclair

Between 1911 and 1984, northern fur seal research was carried out by Canada, Japan, Russia and the United States under the Treaty for the Preservation and Protection of Fur Seals and Sea Otters. Since 1984, studies have been carried out independently by cooperating former member nations.

The Pribilof Islands (St. Paul Island and St. George Island) fur seal population of approximately 800,000 animals is the largest among U.S. rookeries (Figs. 1-3) and comprises roughly 80% of the world's population of northern fur seals. Northern fur seals were designated as depleted in 1988 under the Marine Mammal Protection Act due to declining numbers of animals on St. George Island and a flat trend in population growth on St. Paul Island. A moratorium on commercial harvesting of fur seals was imposed on St. Paul Island in 1984 and on St. George Island in 1973 because of depressed population levels, however a subsistence harvest continues on both islands. There is no subsistence or commercial harvest on the remaining U.S. rookeries (Figs. 4 and 5).

Russian names given to rookeries on the Pribilof Islands are translated in Table 1. Terms specific to fur seal research are defined in Appendix A.

Research on northern fur seals in 1994 was conducted under Marine Mammal Permit number 837.
Figure 1. Location of the four northern fur seal breeding rookeries within U.S. waters.
Figure 2.--Location of northern fur seal rookeries (present and extinct), hauling grounds, and harvesting areas, St. Paul Island, Alaska.
Figure 3.--Location of northern fur seal rookeries (present and extinct), hauling grounds, and harvesting areas, St. George Island, Alaska.
Figure 4.--Fur seal rookeries on Bogoslof Island, Alaska.
Figure 5. Location of northern fur seal breeding colonies, San Miguel Island, California.
Table 1.--English translations of Russian names for Pribilof rookeries and hauling grounds.

<table>
<thead>
<tr>
<th>Island and Russian name</th>
<th>English translation</th>
<th>Comments and derivation of name</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Paul Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vostochni</td>
<td>---</td>
<td>From &quot;Novoctoshni&quot; meaning &quot;place of recent growth&quot;; applied to Northeast Point, which was apparently at one time an island that has since been connected to St. Paul Island by drifting sand.</td>
</tr>
<tr>
<td>Morjovi</td>
<td>Walrus</td>
<td>Historically, walruses hauled out here in summer.</td>
</tr>
<tr>
<td>Polovina</td>
<td>Halfway</td>
<td>Halfway to Northeast Point from the village.</td>
</tr>
<tr>
<td>Kitovi</td>
<td>Of &quot;kit&quot;</td>
<td>When whaling fleets were active in the Bering Sea between 1849 and 1856, a large right whale killed by some ship’s crew drifted ashore here.</td>
</tr>
<tr>
<td>Gorbatch</td>
<td>Humpback</td>
<td>Apparently refers to the &quot;hump like&quot; nature of the scoria slope above the rookery.</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>Thick</td>
<td>In this case, thick headland on which the rookery is located.</td>
</tr>
<tr>
<td>Zapadni</td>
<td>West</td>
<td>Western part of the island.</td>
</tr>
<tr>
<td>Lukanin</td>
<td>---</td>
<td>Named after a Russian pioneer sailor who was said to have harvested over 5,000 sea otters from St. Paul Island in 1787.</td>
</tr>
<tr>
<td>Zoltoi (hauling ground)</td>
<td>Golden</td>
<td>Named to express the metallic shimmering of the sands.</td>
</tr>
<tr>
<td>St. George Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staraya Artil</td>
<td>---</td>
<td>Old settlement or village. There was once a settlement or village adjacent to the rookery.</td>
</tr>
<tr>
<td>Sea Lion Rock</td>
<td>Sea lion</td>
<td>These animals haul out but do not breed here.</td>
</tr>
</tbody>
</table>
In accordance with provisions originally established by the Interim Convention on Conservation of North Pacific Fur Seals, the National Marine Mammal Laboratory (NMML) continues to monitor the status of fur seal populations on the Pribilof Islands. To meet this objective, data on population size, age and sex composition, and natural mortality are collected annually following the methods described by Antonelis (1992).

**Population Parameters**

Population characteristics monitored in 1994 include the numbers of adult males, pups born, and mortalities of fur seals on St. Paul Island and St. George Island.

**Sex Composition of Seals Harvested**

A total of 1,616 sub-adult male seals were killed in the subsistence harvest by St. Paul Island residents in 1994 (Table 2). One female fur seal was harvested accidentally on St. Paul Island. On St. George Island, 161 sub-adult male seals were taken in the subsistence harvest in 1994 (Table 3).

**Living Adult Male Seals Counted**

Adult male seals were counted by section for each rookery (see Appendix A glossary for definitions of terms) on
Table 2.--Date, location, and number of subadult male seals killed in subsistence harvest drives on St. Paul Island, Alaska, in 1994.

<table>
<thead>
<tr>
<th>Date</th>
<th>Rookery</th>
<th>Number Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 27</td>
<td>Reef</td>
<td>28</td>
</tr>
<tr>
<td>July 6</td>
<td>Reef</td>
<td>58</td>
</tr>
<tr>
<td>July 7</td>
<td>Zapadni Reef</td>
<td>27</td>
</tr>
<tr>
<td>July 8</td>
<td>Zapadni</td>
<td>41</td>
</tr>
<tr>
<td>July 9</td>
<td>Polovina</td>
<td>56</td>
</tr>
<tr>
<td>July 13</td>
<td>Lukanin</td>
<td>77</td>
</tr>
<tr>
<td>July 14</td>
<td>Zapadni Reef</td>
<td>50</td>
</tr>
<tr>
<td>July 15</td>
<td>Reef</td>
<td>66</td>
</tr>
<tr>
<td>July 18</td>
<td>Polovina</td>
<td>46</td>
</tr>
<tr>
<td>July 19</td>
<td>Kitovi</td>
<td>54</td>
</tr>
<tr>
<td>July 20</td>
<td>Zapadni Reef</td>
<td>69</td>
</tr>
<tr>
<td>July 21</td>
<td>Zapadni</td>
<td>56</td>
</tr>
<tr>
<td>July 22</td>
<td>Reef</td>
<td>73</td>
</tr>
<tr>
<td>July 23</td>
<td>Northeast Point(^1)</td>
<td>40</td>
</tr>
<tr>
<td>July 25</td>
<td>Polovina(^2)</td>
<td>88</td>
</tr>
<tr>
<td>July 26</td>
<td>Lukanin</td>
<td>64</td>
</tr>
<tr>
<td>July 27</td>
<td>Zapadni Reef</td>
<td>49</td>
</tr>
<tr>
<td>July 28</td>
<td>Reef</td>
<td>69</td>
</tr>
<tr>
<td>July 29</td>
<td>Zapadni</td>
<td>66</td>
</tr>
<tr>
<td>August 1</td>
<td>Polovina</td>
<td>50</td>
</tr>
<tr>
<td>August 2</td>
<td>Lukanin</td>
<td>37</td>
</tr>
<tr>
<td>August 3</td>
<td>Zapadni(^3)</td>
<td>65</td>
</tr>
<tr>
<td>August 4</td>
<td>Zapadni</td>
<td>86</td>
</tr>
<tr>
<td>August 5</td>
<td>Northeast Point(^1)</td>
<td>82</td>
</tr>
<tr>
<td>August 6</td>
<td>Reef</td>
<td>219</td>
</tr>
</tbody>
</table>

\(^1\)Includes Vostochni and Morjovi rookeries
\(^2\)1 female accidentally killed
\(^3\)Seals were taken from two locations. There were not enough seals at the first location.
Table 3.—Date, location, and number of subadult male seals killed in subsistence harvest drives on St. George Island, Alaska, in 1994.

<table>
<thead>
<tr>
<th>Date</th>
<th>Rookery</th>
<th>Number Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2</td>
<td>North</td>
<td>27</td>
</tr>
<tr>
<td>July 6</td>
<td>Zapadni</td>
<td>10</td>
</tr>
<tr>
<td>July 7</td>
<td>North</td>
<td>10</td>
</tr>
<tr>
<td>July 11</td>
<td>North</td>
<td>18</td>
</tr>
<tr>
<td>July 15</td>
<td>Zapadni</td>
<td>21</td>
</tr>
<tr>
<td>July 21</td>
<td>Zapadni</td>
<td>18</td>
</tr>
<tr>
<td>July 23</td>
<td>North</td>
<td>19</td>
</tr>
<tr>
<td>July 26</td>
<td>North</td>
<td>15</td>
</tr>
<tr>
<td>August 4</td>
<td>North</td>
<td>7</td>
</tr>
<tr>
<td>August 5</td>
<td>North</td>
<td>16</td>
</tr>
</tbody>
</table>
St. Paul Island from 14 to 21 July (Appendix Table B-1). A total of 5,715 harem (class 3) and 10,014 idle (classes 2 and 5) adult male seals, also referred to as bulls, were counted on St. Paul Island. On St. George Island, a total of 1,179 harem (class 3) and 1,481 idle (classes 2 and 5) adult male seals were counted from 11 to 14 July. The relative location of the different classes of adult males is illustrated for a typical fur seal rookery-hauling ground complex on the Pribilof Islands in Figure 6. Total numbers of harem and idle bulls counted since 1972 are given in Appendix Table B-2 and the classification and number of adult males counted by rookery for St. Paul and St. George Islands are presented in Table 4.

The age structure of male northern fur seals in the Pribilof Island population has achieved most of the change expected following termination of the commercial harvest on St. Paul and St. George Islands in 1984 and 1972, respectively. Although there was a slight increase in the count of territorial males with females (class 3) on St. George Island between 1993 and 1994 (4.5%), the count of these males on St. Paul Island was lower in 1993 than in 1994 (11% less). The total for these males for the Pribilof Islands was therefore lower by about 8.5% in 1994. This decline followed 4 years of increase through recruitment of males that were not killed following the termination of the harvest as they reached the age of reproductive maturity. Evidence of equilibration in the sex ratio among adults is also indicated by the 1994 counts for this
CLASSES OF BULLS

2. TERRITORIAL WITHOUT FEMALES
3. TERRITORIAL WITH FEMALES
5. HAULING GROUND

Figure 6. The relative location of the different classes of adult males for a typical fur seal rookery.
Table 4.—Number of adult male northern fur seals counted, by rookery, Pribilof Islands, Alaska, July 1994.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Date (July)</th>
<th>Class of Adult Male*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>St. Paul Island</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lukanin</td>
<td>14</td>
<td>91</td>
<td>158</td>
</tr>
<tr>
<td>Kitovi</td>
<td>14</td>
<td>173</td>
<td>244</td>
</tr>
<tr>
<td>Reef</td>
<td>21</td>
<td>346</td>
<td>811</td>
</tr>
<tr>
<td>Gorbatch</td>
<td>21</td>
<td>180</td>
<td>477</td>
</tr>
<tr>
<td>Ardiguin</td>
<td>21</td>
<td>31</td>
<td>109</td>
</tr>
<tr>
<td>Morjovi</td>
<td>17</td>
<td>211</td>
<td>297</td>
</tr>
<tr>
<td>Vostochni</td>
<td>17</td>
<td>411</td>
<td>861</td>
</tr>
<tr>
<td>Little Polovina</td>
<td>20</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Polovina</td>
<td>20</td>
<td>34</td>
<td>85</td>
</tr>
<tr>
<td>Polovina Cliffs</td>
<td>20</td>
<td>181</td>
<td>589</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>15</td>
<td>298</td>
<td>633</td>
</tr>
<tr>
<td>Zapadni Reef</td>
<td>19</td>
<td>112</td>
<td>232</td>
</tr>
<tr>
<td>Little Zapadni</td>
<td>19</td>
<td>160</td>
<td>530</td>
</tr>
<tr>
<td>Zapadni</td>
<td>18</td>
<td>290</td>
<td>670</td>
</tr>
<tr>
<td><strong>Island Total</strong></td>
<td></td>
<td>2,528</td>
<td>5,715</td>
</tr>
<tr>
<td><strong>St. George Island</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zapadni</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>12</td>
<td>115</td>
<td>217</td>
</tr>
<tr>
<td>North</td>
<td>13</td>
<td>239</td>
<td>453</td>
</tr>
<tr>
<td>East Reef</td>
<td>13</td>
<td>39</td>
<td>73</td>
</tr>
<tr>
<td>East Cliffs</td>
<td>13</td>
<td>114</td>
<td>230</td>
</tr>
<tr>
<td>Staraya Artil</td>
<td>13</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td><strong>Island Total</strong></td>
<td></td>
<td>664</td>
<td>1,179</td>
</tr>
</tbody>
</table>

*See glossary for description of adult male seal classes.
category of seals, which has fluctuated on the Pribilof Islands without a discernable trend for the last few years (Table 4).

**Number of Pups Born on St. Paul Island in 1994**

The number of pups born on St. Paul Island was estimated in August by adding the estimated number of live pups from a shearing/sampling (mark/recapture) study and the total count of dead pups on all rookeries (except Little Polovina rookery on St. Paul Island\(^1\)). The previous estimate of pup production on all rookeries was obtained in 1992. In 1994 the technique used to sample the number of marked pups and calculate the production estimate was revised to reduce the amount of variability in the estimate (York and Towell, this volume). Additional information on the techniques used to estimate pup production are found in York and Kozloff (1987) and Antonelis (1992).

From 10 to 18 August, 20,153 pups were shear-marked. The number of pups sheared on each rookery was approximately 10% of the 1992 pup production estimate. Shear marks were allocated proportionally on each rookery by section (Appendix Table B-3) according to the fraction of the rookery total for harem males counted in each section. Counts of harem bulls in 1994 at St. Paul Island were used to determine the allocation of shear marks on pups for each rookery. The ratio of marked to unmarked

\(^1\)A census was not conducted on Little Polovina because the number of pups born there has declined precipitously since 1980, and any disturbance to the rookery was considered inadvisable.
pups was determined by at least three researchers (two of which worked as a pair) on two occasions for each rookery from 19 to 31 August. Each researcher or pair of researchers obtained counts of marked and unmarked pups independently and in different areas to ensure that the entire rookery was well sampled. Each sampling day was considered an independent replicate from which the variance was computed for each rookery.

Dead pups were counted on all rookeries except Little Polovina from 19 to 31 August. Numbers of dead pups counted by section are given in Appendix Table B-4. A summary by rookery of the number of pups sheared, the estimated mean number of pups alive at the time of marking, and the standard error of the estimate is given in Table 5. The estimated number of pups born, the standard error of the estimate, number of dead pups, counts of harem bulls, and ratios of pups to adult males for all rookeries on St. Paul Island are summarized in Table 6. For each sampled rookery, the standard deviation of the pup estimate is computed from the standard error of the two estimates. The estimate for the total number of pups alive on St. Paul Island at the time of marking was 183,924 (SD = 2,028). The number of dead pups was estimated to be 8,180 (8,158 counted on all rookeries and 22 estimated for Little Polovina rookery); the estimated mortality rate for late August was 4.26%. The total number of pups born on St. Paul Island and the approximate 95% confidence interval was 202,995 ± (2.16 X 2,257) or 202,995 ± 4,875. This
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 of the mean (SE), St. Paul Island, Alaska, 1994.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Sheared</th>
<th>E1</th>
<th>E2</th>
<th>Mean</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lukanin</td>
<td>406</td>
<td>3,544</td>
<td>3,726</td>
<td>3,635</td>
<td>91.0</td>
</tr>
<tr>
<td>Kitovi</td>
<td>765</td>
<td>6,347</td>
<td>6,327</td>
<td>6,337</td>
<td>10.0</td>
</tr>
<tr>
<td>Reef</td>
<td>2,249</td>
<td>21,063</td>
<td>21,819</td>
<td>21,441</td>
<td>378.0</td>
</tr>
<tr>
<td>Gorbatch</td>
<td>1,710</td>
<td>14,543</td>
<td>14,861</td>
<td>14,702</td>
<td>159.0</td>
</tr>
<tr>
<td>Ardiguen</td>
<td>243</td>
<td>2,260</td>
<td>2,576</td>
<td>2,418</td>
<td>158.0</td>
</tr>
<tr>
<td>Morjovi</td>
<td>1,401</td>
<td>13,460</td>
<td>12,851</td>
<td>13,156</td>
<td>304.5</td>
</tr>
<tr>
<td>Vostochni</td>
<td>3,007</td>
<td>25,221</td>
<td>28,820</td>
<td>27,020</td>
<td>1,799.5</td>
</tr>
<tr>
<td>Polovina</td>
<td>276</td>
<td>2,221</td>
<td>2,387</td>
<td>2,304</td>
<td>83.0</td>
</tr>
<tr>
<td>Polovina Cliffs</td>
<td>1,839</td>
<td>15,891</td>
<td>16,560</td>
<td>16,225</td>
<td>334.5</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>2,416</td>
<td>24,472</td>
<td>24,717</td>
<td>24,595</td>
<td>122.5</td>
</tr>
<tr>
<td>Zapadni Reef</td>
<td>722</td>
<td>7,063</td>
<td>7,483</td>
<td>7,273</td>
<td>210.0</td>
</tr>
<tr>
<td>Little Zapadni</td>
<td>1,551</td>
<td>15,863</td>
<td>16,671</td>
<td>16,267</td>
<td>404.0</td>
</tr>
<tr>
<td>Zapadni</td>
<td>2,572</td>
<td>28,559</td>
<td>27,577</td>
<td>28,068</td>
<td>491.0</td>
</tr>
</tbody>
</table>
Table 6.--Number of pups alive at the time of marking, its standard deviation (SD), numbers of dead pups, total pups born, mortality rate, idle males, harem males, and ratio of pups alive at marking to harem males, St. Paul Island, Alaska, 1994. The symbol "--" indicates that no data is available.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Pups alive at marking</th>
<th>SD</th>
<th>Dead pups¹</th>
<th>Total pups born</th>
<th>Mortality rate (%)</th>
<th>Idle bulls</th>
<th>Harem bulls</th>
<th>Ratio pups/bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lukarin</td>
<td>3,635</td>
<td>91.0</td>
<td>245</td>
<td>3,880</td>
<td>6.31</td>
<td>266</td>
<td>158</td>
<td>23.01</td>
</tr>
<tr>
<td>Kitovi</td>
<td>6,337</td>
<td>10.0</td>
<td>174</td>
<td>6,511</td>
<td>2.67</td>
<td>485</td>
<td>244</td>
<td>25.97</td>
</tr>
<tr>
<td>Reef</td>
<td>21,441</td>
<td>378.0</td>
<td>1,088</td>
<td>22,529</td>
<td>4.83</td>
<td>1,434</td>
<td>811</td>
<td>26.44</td>
</tr>
<tr>
<td>Gorbach</td>
<td>14,702</td>
<td>159.0</td>
<td>779</td>
<td>15,481</td>
<td>5.03</td>
<td>1,514</td>
<td>477</td>
<td>30.82</td>
</tr>
<tr>
<td>Ardiguen</td>
<td>2,418</td>
<td>158.0</td>
<td>85</td>
<td>2,503</td>
<td>3.40</td>
<td>32</td>
<td>109</td>
<td>22.18</td>
</tr>
<tr>
<td>Morjovi</td>
<td>13,156</td>
<td>304.5</td>
<td>362</td>
<td>13,518</td>
<td>2.68</td>
<td>736</td>
<td>297</td>
<td>44.30</td>
</tr>
<tr>
<td>Vostochni</td>
<td>27,020</td>
<td>1,799.5</td>
<td>1,026</td>
<td>28,046</td>
<td>3.66</td>
<td>1,063</td>
<td>861</td>
<td>31.38</td>
</tr>
<tr>
<td>Polovina</td>
<td>2,304</td>
<td>83.0</td>
<td>54</td>
<td>2,358</td>
<td>2.29</td>
<td>420</td>
<td>85</td>
<td>27.11</td>
</tr>
<tr>
<td>Polovina Cliffs</td>
<td>16,225</td>
<td>334.5</td>
<td>380</td>
<td>16,605</td>
<td>2.29</td>
<td>584</td>
<td>589</td>
<td>27.55</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>24,595</td>
<td>122.5</td>
<td>1,152</td>
<td>25,747</td>
<td>4.47</td>
<td>852</td>
<td>633</td>
<td>38.85</td>
</tr>
<tr>
<td>Zapadni Reef</td>
<td>7,273</td>
<td>210.0</td>
<td>386</td>
<td>7,659</td>
<td>5.04</td>
<td>431</td>
<td>232</td>
<td>31.35</td>
</tr>
<tr>
<td>Little Zapadni</td>
<td>16,267</td>
<td>404.0</td>
<td>996</td>
<td>17,263</td>
<td>5.77</td>
<td>520</td>
<td>530</td>
<td>30.69</td>
</tr>
<tr>
<td>Zapadni</td>
<td>28,068</td>
<td>491.0</td>
<td>1,431</td>
<td>29,499</td>
<td>4.85</td>
<td>1,090</td>
<td>674</td>
<td>41.64</td>
</tr>
<tr>
<td>Little Polovina²</td>
<td>483</td>
<td>29.5</td>
<td>22</td>
<td>505</td>
<td>4.36</td>
<td>587</td>
<td>15</td>
<td>32.20</td>
</tr>
</tbody>
</table>

| Island Total     | 183,924               | 2,028.5| 8,180     | 192,104         | 4.26              | 10,014     | 5,715       | 32.18            |
| Sea Lion Rock    | 12,589                | 989.3 | 302        | 12,891          | 2.34              | --         | --          | --               |

| Total            | 196,513               | 2,256.8| 8,482     | 204,995         | 4.14              | 10,014     | 5,715       | --               |

¹Includes dead pups taken for necropsies; Gorbach (1), Little Zapadni (1), Reef (134), Polovina cliffs (2), and Vostochni (54).

²Pups alive at marking and its standard deviation are calculated from the jackknife ratio estimates of breeding males. Numbers of dead pups are estimated from an average mortality based on all rookeries excluding Little Polovina. Total is estimated from the sum of estimates of live pups and dead pups.
total estimate includes an estimate of 12,891 pups (12,589 = live, 302 = dead) for Sea Lion Rock. Without the Sea Lion Rock estimate, total pup production on St. Paul Island was 192,104; this value is comparable to years when Sea Lion Rock was not evaluated.

The confidence interval for the 1994 estimate of pups born on St. Paul Island was computed by multiplying the standard deviation (calculated as the square root of the sum of the variances for each rookery and assuming counts from the 13 rookeries were independent) by 2.16, the 97.5 percentile of Student's t-distribution with 13 degrees of freedom. Estimates of the number of live pups for Little Polovina rookery were computed from a jackknife estimate of the ratio of pups alive at marking to breeding males on the sampled rookeries (York and Kozloff 1987). The standard deviation of the number of live pups for Little Polovina was then computed from the standard error of the jackknife ratio. An estimate of the number of dead pups at Little Polovina was computed assuming that the mortality rate there was the same as the average mortality of the other rookeries (Table 6). The estimated number of pups born and their 95% confidence intervals for St. Paul Island, 1970-94, are shown in Figure 7. The total estimated number of pups born in 1994 was not significantly different (p = 0.05) from the 1990 and 1992 estimates. Appendix Table B-2 summarizes pup production and mortality excluding Sea Lion Rock since 1972.
Figure 7.—Number of northern fur seal pups born on St. Paul Island, Alaska, 1970-94. Approximate 95% confidence intervals shown.
The number of pups born and the number of harem bulls at
different rookeries on St. Paul Island are highly correlated
(Fig. 8). When numbers of pups born are regressed on numbers of
harem bulls, the value of $R^2$ is about 0.90. The intercept of the
regression line is not significantly different from zero
$P = 0.88$) and was not included in the regression equation; the
slope of the regression line is 32.34 (SE = 1.64), representing
an estimate of the ratio of pups : males.

**Number of Pups Born on St. George Island in 1994**

The number of pups born on St. George Island was also
estimated from a shearing-sampling study conducted on all
rookeries. The most recent estimate of pup production prior to
this study was obtained in 1992. From 18 to 20 August, a total
of 2,698 pups were shear-marked on St. George Island. These
marks were allocated proportionally on all rookeries according to
the fraction of harem bulls counted in 1994 (Appendix Table B-5).
The ratio of marked to unmarked pups on each rookery was
determined by three researchers on two occasions: once from 21 to
23 August and again from 24 to 25 August. A summary by rookery
of the number of pups sheared, the estimated mean number of pups
alive at the time of marking, and the standard error of the
estimate is given in Table 7. Counts of dead pups were made from
21 to 23 August 1994. The ratio of marked to unmarked pups and
the estimate of the number alive was calculated similarly to
Figure 8.—Number of northern fur seal pups alive at the time of sampling versus number of harem bull fur seals for the rookeries of St. Paul Island, Alaska, 1994.
Table 7.-- Number of pups sheared; number of pups estimated to be alive at the time of marking (E1 and E2), the mean number alive (Mean), and the standard error of the mean (SE), St. George Island, Alaska, 1994.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Sheared</th>
<th>E1</th>
<th>E2</th>
<th>Mean</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>430</td>
<td>3,850</td>
<td>4,461</td>
<td>4,156</td>
<td>305.90</td>
</tr>
<tr>
<td>North</td>
<td>966</td>
<td>7,559</td>
<td>7,466</td>
<td>7,513</td>
<td>46.47</td>
</tr>
<tr>
<td>East Reef</td>
<td>121</td>
<td>1,014</td>
<td>864</td>
<td>939</td>
<td>75.00</td>
</tr>
<tr>
<td>East Cliffs</td>
<td>525</td>
<td>4,121</td>
<td>3,718</td>
<td>3,920</td>
<td>201.49</td>
</tr>
<tr>
<td>Staraya</td>
<td>237</td>
<td>1,522</td>
<td>1,582</td>
<td>1,552</td>
<td>30.00</td>
</tr>
<tr>
<td>Zapadni</td>
<td>419</td>
<td>3,218</td>
<td>3,534</td>
<td>3,376</td>
<td>158.00</td>
</tr>
</tbody>
</table>
the method described for St. Paul Island. Since the rookeries on St. George Island are much smaller than on St. Paul Island, one person is capable of sampling the entire rookery.

The estimated total number of pups alive on St. George Island at the time of marking was 21,456 (SD = 410, Table 8). The total number of dead pups was 788 (Appendix Table B-6) and the mortality rate for late August was 3.54%. The total number of pups born on St. George Island and the approximate 95% confidence interval was 22,244 ± (2.447 X 410), or 22,244 ± 1,003. This count is significantly different (P = 0.003) than the 25,160 (SE = 707) observed on St. George Island in 1992. It is not significantly different (P > 0.05) from the predicted number of pups born based on a regression fitted to the 1973-92 data, which showed a 5.0% rate of decline with a predicted number of pups of 20,459 (SE = 1,034). Estimates and 95% confidence intervals of numbers of pups born on St. George Island for 1970-94 are shown in Figure 9. The number of pups born and the number of harem males on St. George Island rookeries are highly correlated (Fig. 10). When the number of pups born are regressed on the number of males, the value of $R^2$ is about 0.95. The marking intercept of the regression line is not significantly different from zero (P = 0.29) and was not included in the regression equation; the slope of the regression line is 17.49 (SE = 0.92).
Table 8.—Number of pups alive at the time of marking, its standard deviation (SD), numbers dead pups, total pups born, mortality rate, idle males, harem males and ratio of pups alive at marking to harem males, St. George Island, Alaska, 1994.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Pups alive at marking</th>
<th>SD</th>
<th>Dead Pups</th>
<th>Total Mortality pups born</th>
<th>Total Mortality rate (%)</th>
<th>Idle Bulls</th>
<th>Harem bulls</th>
<th>Ratio pups/bulls</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>4,156</td>
<td>305.5</td>
<td>117</td>
<td>4,273</td>
<td>2.74</td>
<td>155</td>
<td>217</td>
<td>19.15</td>
</tr>
<tr>
<td>North</td>
<td>7,513</td>
<td>46.5</td>
<td>358</td>
<td>7,871</td>
<td>4.55</td>
<td>476</td>
<td>453</td>
<td>16.58</td>
</tr>
<tr>
<td>East Reef</td>
<td>939</td>
<td>75.0</td>
<td>12</td>
<td>951</td>
<td>1.26</td>
<td>117</td>
<td>73</td>
<td>12.86</td>
</tr>
<tr>
<td>East Cliffs</td>
<td>3,920</td>
<td>201.5</td>
<td>122</td>
<td>4,042</td>
<td>3.02</td>
<td>283</td>
<td>230</td>
<td>17.04</td>
</tr>
<tr>
<td>Staraya</td>
<td>1,552</td>
<td>30.0</td>
<td>54</td>
<td>1,606</td>
<td>3.36</td>
<td>139</td>
<td>65</td>
<td>23.88</td>
</tr>
<tr>
<td>Zapadni</td>
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<td>158.0</td>
<td>125</td>
<td>3,501</td>
<td>3.57</td>
<td>311</td>
<td>141</td>
<td>23.94</td>
</tr>
<tr>
<td>Island Total</td>
<td>21,456</td>
<td>409.4</td>
<td>788</td>
<td>22,244</td>
<td>3.54</td>
<td>1,481</td>
<td>1,179</td>
<td>18.20</td>
</tr>
</tbody>
</table>
Figure 9.--Number of northern fur seal pups born on St. George Island, Alaska, 1970-94. Approximate 95% confidence intervals are shown.
Figure 10.—Number of northern fur seal pups alive at the time of sampling versus number of harem bull fur seals for the rookeries on St. George Island, Alaska, 1994.
Counts of Dead Fur Seals Older Than Pups and Collection of Teeth

The rookeries and adjacent beaches of St. Paul and St. George Islands (except Little Polovina) were surveyed for dead fur seals older than pups during July and August 1994 (Table 9). In 1994, tooth samples were collected from a total of 277 (76 males and 201 females) and 23 (6 males and 17 females) animals found dead on St. Paul and St. George Islands, respectively. Tooth samples (usually canines) were collected from all dead fur seals other than pups whenever possible. Appendix Table B-7 summarizes the total number of dead male and female fur seals from which teeth were collected from 1965 to 1994.
Table 9.--Number of animals older than pups found dead on the Pribilof Islands from which teeth were collected during August 1994. Numbers in parentheses are animals with no teeth and sex was identified.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Males</th>
<th>Females</th>
<th>unidentified</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>St. Paul Island</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lukanin</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Kitovi</td>
<td>2(1)</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Reef</td>
<td>14(5)</td>
<td>23(2)</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Gorbatch</td>
<td>7</td>
<td>26(2)</td>
<td>3</td>
<td>38</td>
</tr>
<tr>
<td>Ardiguen(^1)</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Morjovi</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Vostochti</td>
<td>5</td>
<td>32</td>
<td>3</td>
<td>40</td>
</tr>
<tr>
<td>Polovina</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Polovina Cliffs</td>
<td>2</td>
<td>12</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>6(2)</td>
<td>31(1)</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td>Zapadni Reef</td>
<td>2</td>
<td>9</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Little Zapadni</td>
<td>7</td>
<td>16</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Zapadni</td>
<td>24</td>
<td>28</td>
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<td>52</td>
</tr>
<tr>
<td><strong>Total St. Paul</strong></td>
<td>84</td>
<td>207</td>
<td>16</td>
<td>307</td>
</tr>
<tr>
<td><strong>St. George Island</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
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<td>2</td>
</tr>
<tr>
<td>North</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>East Reef</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>East Cliffs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Staraya Artil</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Zapadni</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total St. George</strong></td>
<td>6</td>
<td>17</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total both Islands</strong></td>
<td>90</td>
<td>224</td>
<td>18</td>
<td>332</td>
</tr>
</tbody>
</table>

\(^1\)Teeth for dead adults from Ardiguen were included in Gorbach.
NEW SAMPLING DESIGN FOR ESTIMATING NUMBERS
OF FUR SEAL PUPS ON THE PRIBILOF ISLANDS

by

Anne E. York and Rodney G. Towell

Since 1962, the estimates of the size of the northern fur seal pup population have been obtained using the "shearing-sampling" method (Champman and Johnson 1968, York and Kozloff 1987). The safety of the crew, the accuracy of the estimate, and the minimization of disturbance to rookeries are major concerns; therefore, the work is done as the breeding structure breaks up, but before pups spend most of their time in the water. During early August, large numbers of pups (approximately 10% of the population) are marked by shearing a small patch of hair from the top of the head; this exposes the pale underfur and produces an easily identifiable mark (Antonelis 1992). The marking effort is allocated throughout the rookery so that each pup has an approximately equal chance of being marked (Chapman and Johnson 1968).

A few days after shearing (to allow mixing of the marked and unmarked animals), each rookery is sampled to estimate the proportion of marked animals. Samplers proceed through the rookery and sample groups of 25 animals and record the number of sheared animals within the group (Chapman and Johnson 1968). There are many possible ways to allocate the resampling effort. In the past, samplers worked independently and counted different groups of pups. On St. Paul Island, this was important because many of the rookeries are large and this enabled the samplers to
divide the work more easily by working on different parts of a rookery and complete the census in a timely fashion. Generally, the division of sampling on the rookery has been done in two different ways. For narrow rookeries with very little area of inland extensions, the samplers proceed abreast along the length of the rookery. The sampler nearest the water would usually stay 5-10 m ahead of the other sampler(s) so that pups would not be driven into the water before a count was obtained. The samplers typically communicated with each other concerning what groups of pups they were counting and did not count the same groups. For rookeries with large inland extensions, the rookery was divided in advance by picking areas demarcated by obvious landmarks.

The estimate of numbers of pups on the rookery is obtained by dividing the number of animals sheared on that rookery by the fraction of sheared animals observed during the resampling. There are several ways to estimate the variance, but in most cases, we usually estimated the number of pups on two sampling occasions and calculated the standard deviation from the empirical standard error of the estimate (Chapman and Johnson 1968). If two samples were not available, we used the formulas of Chapman (1951) from Seber (1982).

The purpose of this paper is to consider a new sampling design for the resampling portion of the shearing-sampling process. Samplers worked in pairs since we have always been concerned about the potential bias and different variability of individual samplers. Also, we wished to determine if reasonable estimates of the pup population could be obtained by resampling
on only one occasion. Sampling on one occasion would also minimize disturbance to the rookery. The plan was to resample the rookeries as in previous years (sample each rookery on two occasions), but individual teams of two samplers each would do the work together so that their counts could be considered as replicate sample counts of the particular part of the rookery. In this manner, we could compare individual samplers and also assess the effect of using this sampling design but with resampling on only one occasion. In addition, we briefly assess the possibility of using this design as a training vehicle for new observers.

Resampling Design in Detail

Pups were sheared from 10 to 18 August 1994 following techniques used in previous years (Antonelis 1992). Samplers worked in two teams of two persons each that were determined in advance. The four samplers drew their place in a random fashion. There are three sets of distinct teams of two persons each: Set 1: \{A,B\} and \{C,D\}, Set 2: \{A,C\} and \{B,D\}, and Set 3: \{A,D\} and \{B,C\}. The resampling was designed so that each distinct set of teams of two persons each was used approximately the same number of times and so that the first and second resampling of a rookery were done by a different set of teams. For example, if teams \{A, B\} and \{C,D\} resampled Reef on occasion 1, then either \{A,C\} and \{B,D\} or \{A,D\} and \{B,C\} resampled that rookery on occasion 2. Randomization under these requirements resulted in the schedule in Table 10:
Table 10.—Allocation of resighting effort by four samplers (A, B, C, and D) as two teams of two samplers each on two sampling occasions for St. Paul Island, AK, August 1994. The resampling was designed so that each distinct set of teams of two persons each was used approximately the same number of times and so that the first and second resampling of a rookery were done by a different set of teams.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>First resampling</th>
<th>Second resampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vostochni</td>
<td>AD BC</td>
<td>AC BD</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>AC BD</td>
<td>AD BC</td>
</tr>
<tr>
<td>Gorbatch</td>
<td>AD BC</td>
<td>AB CD</td>
</tr>
<tr>
<td>Polovina Cliffs</td>
<td>AB CD</td>
<td>AC BD</td>
</tr>
<tr>
<td>Polovina</td>
<td>AB CD</td>
<td>AD BC</td>
</tr>
<tr>
<td>Lukanin</td>
<td>AB CD</td>
<td>AD BC</td>
</tr>
<tr>
<td>Kitovi</td>
<td>AD BC</td>
<td>AC BD</td>
</tr>
<tr>
<td>Reef</td>
<td>AC BD</td>
<td>AD BC</td>
</tr>
<tr>
<td>Ardiguen</td>
<td>AD BC</td>
<td>AB CD</td>
</tr>
<tr>
<td>Morjovi</td>
<td>AC BD</td>
<td>AB CD</td>
</tr>
<tr>
<td>Zapadni Reef</td>
<td>AB CD</td>
<td>AC BD</td>
</tr>
<tr>
<td>Zapadni</td>
<td>AC BD</td>
<td>AB CD</td>
</tr>
<tr>
<td>Little Zapadni</td>
<td>AC BD</td>
<td>AB CD</td>
</tr>
<tr>
<td>Little Polovina</td>
<td>AB CD</td>
<td>AC BD</td>
</tr>
<tr>
<td>Sea Lion Rock</td>
<td>AB CD</td>
<td>AD BC</td>
</tr>
</tbody>
</table>
Three of the four samplers were experienced and the fourth was instructed in the basics of resampling. The samplers were instructed to do the resampling as before; that is, the teams could "hip-hop" or divide up the rookery using landmarks and not overlap each other, but within the team, the samplers could resample the same animals. It was not necessary for them to specify which animals they were counting, only the general area. It was desirable for each member of the sampling team to have about the same number of subsamples. The teams needed to discuss this in advance so that they would work more or less consistently over the resampling period but they were instructed to not compare counting results so as to keep their observations as independent as possible. The previous requirement for each sample is the same as before: each pup should have an approximately equal chance of appearing in a sub-sample and the sub-samples by each team should be disjointed.

**Calculation of the Estimate**

The formulas for the estimates of the number and standard deviation of pups on a rookery under the new sampling plan are simple adjustments to the previously published estimates. Under the old sampling plan, with two samplers, the estimate for a given rookery and sampling occasion is calculated in the following way. Let $X_1, X_2, \ldots X_n$ be counts of numbers of sheared animals in $n$ groups of 25 animals by sampler 1, and $Y_1, Y_2, \ldots Y_n$
be the counts by sampler 2; recall that the counts are non-overlapping and disjointed, so that in some cases \( m \) and \( n \) could be different. The estimate of the fraction of sheared is the total number of sheared animals counted divided by the total number of animals resampled. In this case, this is

\[
f = \frac{(\sum_{i=1}^{n} x_i + \sum_{i=1}^{m} y_i)}{25(m+n)}.
\]  

(1)

The estimate of the number of pups alive at the time of sampling for that occasion is \( \hat{N} = s/f \). There are several ways to estimate the variance of \( \hat{N} \). In the past, we have usually followed the advice of Chapman and Johnson (1968) and determined the fraction of marked animals on two occasions. The estimate of the number of live pups is the mean of the two resulting estimates and the variance is the empirical variance from two sampling occasions: if \( f_1 \) and \( f_2 \) are estimates of the fraction of marked animals on occasions 1 and 2, then \( \hat{N}_1 = s/f_1 \) and \( \hat{N}_2 = s/f_2 \),

\[
\hat{N} = .5(\hat{N}_1 + \hat{N}_2)
\]

\[
\text{Var}(\hat{N}) = .5 \sum_{i=1}^{2} (\hat{N}_i - \hat{N})^2 = .25(\hat{N}_1 - \hat{N}_2)^2.
\]  

(2)

When estimates were not available from two (or more) sampling occasions, \( \hat{N} = s/f \) and the variance of the estimate was calculated using the following formula:

\[
\text{Var}(\hat{N}) = \frac{(s+1)(t+1)(s-r)(t-r)}{(r+1)^2(r+2)}.
\]  

(3)
s is the total number of sheared animals, \( t \) is the total number of animals resampled, which is equivalent to the denominator in Equation (1), and \( r \) is the number of sheared animals that were resighted, which is equivalent to \( \Sigma x_i + \Sigma y_i \), the numerator in Equation (1) above.

To adjust the above estimates under the new sampling design, we apply Equation (1) to the two-team design. To weigh each observer equally, we use the sum of the mean number of sheared pups in the numerator instead of using the sum of the total observations for the observers within the team. Likewise, we use the mean number of samples for the team (averaged over the team members) for the denominator. These formulas easily generalize to the cases in which there are more than two team members, or if the teams do not have the same number of members. Conceptually the form of the equation is:

\[
f = \frac{\text{Average total sheared pups Team 1} + \text{Average total sheared pups Team 2}}{25(\text{Average number of resamples Team 1} + \text{Average number of resamples Team 2})}.
\]

For the case of two teams with two members each, let \( X_{1,1}, X_{1,2}, \ldots \) \( X_{1,n1} \) be counts of sheared pups among 25 pups for team 1 observer 1, \( X_{2,1}, X_{2,2}, \ldots \) \( X_{2,n2} \) counts for team 1 observer 2, \( Y_{1,1}, Y_{1,2}, \ldots \) \( Y_{1,m1} \) for team 2 observer 1, and \( Y_{2,1}, Y_{2,2}, \ldots \) \( Y_{2,m2} \) for team 2 observer 2 for a given rookery and sampling occasion. Let \( m = .5(m_1 + m_2) \) be the mean of \( m_1 \) and \( m_2 \), \( n = .5(n_1 + n_2) \) the mean of \( n_1 \) and \( n_2 \). The average number of sheared animals seen by team 1 is \( t_1 = .5(\Sigma x_{11} + \Sigma x_{12}) \) and \( t_2 = .5(\Sigma y_{11} + \Sigma y_{12}) \) for team 2. When resampling is done on two occasions, two estimates \( \hat{N}_1 \) and \( \hat{N}_2 \) are
available and an estimate of the number and standard deviation of pups are the empirical mean and the standard error, respectively (identical to Equation 2). These formulas were used to compute the pup estimates on each rookery of St. Paul Island (Table 11).

If resampling is done on only one occasion, it is still possible to estimate the population size and standard deviation. We compare three methods for variance estimation to investigate the effect of resampling only once. The first method repeats what has been done in the past when only one sample is available (Equation 3) except that we replace $t$, the total number of resampled seals by the mean number of resampled seals (calculated across teams) and $r$, the total number of marked animals that are resampled with its mean (again calculated across teams). The second is a bootstrap method wherein we resample (with replacement) counts by individual samplers, compute the estimated numbers of pups on the rookery for each subsample, and use the variance of those numbers as the estimated variance of the number of pups born on the rookery. In the third, we consider the work by each team member as a replicate and compute estimates of the mean and variance for each team and sum those to obtain the estimates for the rookery. We compare these methods for the first and second resampling for 1994 to the estimates based on both samples.

**Results**

The mean number of sheared animals in the 25 pup samples is shown for each sampler (Fig. 11). One sampler (D) consistently
Table 11.—Numbers of pups marked by shearing on each rookery, estimates of pup abundance for each sampling occasion (Est. 1 and Est 2), average number of groups of 25 pups in resighting samples, estimates of standard error (SE1, based on the bootstrap, SE2 based on adjustment to formula 2, and SE3 calculated assuming each team's estimate is a replicated estimate for the rookery (See text for details), and fraction of marked animals appearing in the resamples.

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Sheared</th>
<th>Est1</th>
<th>Samples</th>
<th>Fraction</th>
<th>SE1</th>
<th>SE2</th>
<th>SE3</th>
<th>Est2</th>
<th>Samples</th>
<th>Fraction</th>
<th>SE1</th>
<th>SE2</th>
<th>SE3</th>
<th>Est</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lukanin</td>
<td>406</td>
<td>3,544</td>
<td>94.5</td>
<td>0.23</td>
<td>204.05</td>
<td>294.82</td>
<td>568.47</td>
<td>3,726</td>
<td>79.0</td>
<td>0.19</td>
<td>494.60</td>
<td>346.99</td>
<td>107.77</td>
<td>3,635</td>
</tr>
<tr>
<td>Kitovi</td>
<td>769</td>
<td>6,347</td>
<td>183.5</td>
<td>0.24</td>
<td>377.21</td>
<td>380.01</td>
<td>167.08</td>
<td>6,327</td>
<td>137.5</td>
<td>0.18</td>
<td>431.43</td>
<td>452.22</td>
<td>418.96</td>
<td>6,337</td>
</tr>
<tr>
<td>Reef</td>
<td>2,255</td>
<td>21,063</td>
<td>389.5</td>
<td>0.17</td>
<td>865.87</td>
<td>913.38</td>
<td>92.97</td>
<td>21,819</td>
<td>328.5</td>
<td>0.15</td>
<td>943.35</td>
<td>1,047.75</td>
<td>102.39</td>
<td>21,441</td>
</tr>
<tr>
<td>Gorbachev</td>
<td>1,714</td>
<td>14,543</td>
<td>275.0</td>
<td>0.16</td>
<td>766.51</td>
<td>749.15</td>
<td>923.35</td>
<td>14,861</td>
<td>221.5</td>
<td>0.13</td>
<td>817.65</td>
<td>869.02</td>
<td>126.75</td>
<td>14,702</td>
</tr>
<tr>
<td>Ardiguen</td>
<td>243</td>
<td>2,260</td>
<td>43.0</td>
<td>0.18</td>
<td>173.89</td>
<td>283.18</td>
<td>52.60</td>
<td>2,576</td>
<td>40.5</td>
<td>0.17</td>
<td>337.29</td>
<td>332.52</td>
<td>16.83</td>
<td>2,418</td>
</tr>
<tr>
<td>Morjovi</td>
<td>1,404</td>
<td>13,460</td>
<td>222.5</td>
<td>0.16</td>
<td>658.96</td>
<td>776.77</td>
<td>1,040.73</td>
<td>12,851</td>
<td>256.0</td>
<td>0.18</td>
<td>632.68</td>
<td>681.00</td>
<td>9.31</td>
<td>13,156</td>
</tr>
<tr>
<td>Vostokhni</td>
<td>3,013</td>
<td>25,221</td>
<td>556.0</td>
<td>0.18</td>
<td>781.76</td>
<td>903.09</td>
<td>608.44</td>
<td>28,820</td>
<td>525.5</td>
<td>0.17</td>
<td>1,074.68</td>
<td>1,077.26</td>
<td>1,726.53</td>
<td>27,020</td>
</tr>
<tr>
<td>Polovina</td>
<td>278</td>
<td>2,221</td>
<td>60.5</td>
<td>0.22</td>
<td>251.88</td>
<td>229.51</td>
<td>159.49</td>
<td>2,387</td>
<td>76.5</td>
<td>0.28</td>
<td>246.78</td>
<td>213.47</td>
<td>172.23</td>
<td>2,304</td>
</tr>
<tr>
<td>Polovina Cliffs</td>
<td>1,846</td>
<td>15,891</td>
<td>469.0</td>
<td>0.25</td>
<td>546.17</td>
<td>592.85</td>
<td>1.55</td>
<td>16,560</td>
<td>363.5</td>
<td>0.20</td>
<td>685.30</td>
<td>730.24</td>
<td>470.28</td>
<td>16,225</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>2,426</td>
<td>24,472</td>
<td>354.0</td>
<td>0.15</td>
<td>1,080.61</td>
<td>1,135.33</td>
<td>1,825.97</td>
<td>24,717</td>
<td>331.5</td>
<td>0.14</td>
<td>1,018.36</td>
<td>1,194.17</td>
<td>107.26</td>
<td>24,595</td>
</tr>
<tr>
<td>Zapadni Reef</td>
<td>723</td>
<td>7,063</td>
<td>195.5</td>
<td>0.27</td>
<td>407.45</td>
<td>404.97</td>
<td>721.43</td>
<td>7,483</td>
<td>114.5</td>
<td>0.16</td>
<td>564.12</td>
<td>600.34</td>
<td>325.66</td>
<td>7,273</td>
</tr>
<tr>
<td>Little Zapadni</td>
<td>1,551</td>
<td>15,863</td>
<td>303.5</td>
<td>0.20</td>
<td>726.05</td>
<td>773.17</td>
<td>278.37</td>
<td>16,671</td>
<td>273.5</td>
<td>0.18</td>
<td>808.48</td>
<td>864.68</td>
<td>227.61</td>
<td>16,267</td>
</tr>
<tr>
<td>Zapadni</td>
<td>2,578</td>
<td>28,559</td>
<td>334.0</td>
<td>0.13</td>
<td>1,126.32</td>
<td>1,384.17</td>
<td>1,044.54</td>
<td>27,577</td>
<td>303.0</td>
<td>0.12</td>
<td>1,238.58</td>
<td>1,408.68</td>
<td>768.23</td>
<td>28,068</td>
</tr>
<tr>
<td>Total</td>
<td>19,206</td>
<td>180,507</td>
<td>2,467.39</td>
<td>2,738.02</td>
<td>2,777.95</td>
<td>186,375</td>
<td>2,780.60</td>
<td>3,001.67</td>
<td>2,050.69</td>
<td>183,441</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 11.--Mean number of sheared animals resampled by each observer on each rookery on two sampling occasions.
recorded the largest fraction of sheared animals so the data were not used in further calculations.

The estimates of standard error of the pup numbers based on two resampling occasions are smaller than those based on only one sampling occasion (Table 11). This is expected since the standard error declines inversely to the square root of the sample size and theoretically, the standard error of pups numbers based on one subsample should be about $2^{1/2}$, or 1.414 times that based on two subsamples.

There is some evidence that the second sample estimate is greater than the first; for example, on 10 out of 13 rookeries, a higher estimate resulted from the second sample. The probability that we would observe 10 or more second estimates as being larger, if they were not different, is 0.09 (exact binomial test). However, the level of the difference is statistically significant ($P = 0.05$) on one rookery using the theoretical and bootstrap standard errors and on three rookeries using the empirical standard error. The total population sizes are not significantly different from each other (based on any of the three estimates of standard error). The fraction of sheared animals that appeared in the resamples was greater during the first resampling period than the second period for 11 out of 13 rookeries (Fig. 12), probably due to decreased sampling effort during the second period (Table 11) as measured by the average number of 25-pup groups for each sampling time. The three estimates of standard errors for the estimates are somewhat different. Both the bootstrap and theoretical estimates are
Figure 12.--Fraction of sheared animals resampled on the first and second sampling occasions.
highly correlated with the number of pups on the rookery, while
the empirical estimates are not (Fig. 13). The bootstrap and
second resamples are highly correlated \((r = 0.981\) and \(r = 0.983\))
(Fig. 13), whereas this is not the case for the empirical
standard errors \((r = 0.01)\). The standard errors for the total
number of pups on all the rookeries are similar. For standard
errors are generally lower than the theoretical standard errors,
and the empirical standard errors more variable (Fig. 14). The
bootstrap and theoretical standard errors for the first the first
resampling, they range between \(2,467\) (bootstrap), \(2,738\)
(theoretical), and \(2,778\) (empirical) and for the second
resampling, \(2,051\) (empirical), \(2,780\) (bootstrap), and \(3,002\)
(theoretical).

Discussion

The great difference between the observations of the
experienced and inexperienced observers emphasizes the importance
of training samplers. This type of design can be easily used as
a vehicle for the training of samplers -- samplers in training
could be paired with different experienced observers; they could
be taught various techniques for obtaining unbiased estimates and
their results could be compared with the experienced observers at
the end of every day. Although one could argue that the
experienced observers are consistent because they "know" what the
answer should be, observations of the first author and others
indicate that inexperienced samplers tend to see higher fractions
of marked animals. This "cheating observer" question could be
Figure 13.—Relationship between the estimated numbers and standard errors of the estimates of the numbers of northern fur seal pups born on each rookery of St. Paul Island, Alaska during the summer of 1994 for the first and second sampling occasion and three methods of estimating standard errors. Each point represents a rookery.
Figure 14.—Relationship between the estimated standard errors of the estimates of the numbers of northern fur seal pups born on each rookery of St. Paul Island, AK during the summer of 1994 for the first and second sampling occasion and three methods of estimating standard errors. Each point represents a rookery. A: empirical standard error based on variability across teams, B: bootstrap standard error, C: theoretical standard errors, from formula 3.
addressed directly by varying the approximate fraction of marked animals on different rookeries.

Resampling on one occasion appears to be a viable method for obtaining pup population estimates. The trade-off for only resampling once and minimizing disturbance is a slightly higher estimate of the standard error.
Trends in the mass and length of fur seal pups serve as indicators of population health between years and locations. Here we report average mass, lengths, and sex ratios of male and female pups from Tolstoi, Vostochni, Polovina, and Reef rookeries on St. Paul Island (1992, 1994), all rookeries on St. George Island (1992, 1994) and Staraya, North, and South rookeries on St. George Island in 1993.

Methods

Pups were randomly sampled in mid-to late August using techniques described for tagging, sexing and weighing (Antonelis 1992), and length measuring (Robson et al. 1994). On two occasions on St. Paul Island in 1994, however, warm weather conditions made it necessary to release a portion of the pups before they succumbed to heat prostration. Sex was determined from a random sample (Antonelis et al. 1994) of approximately 20% and 10% of the dead pups counted in 1992 and 1994, respectively. Mass was recorded to the nearest 0.25 kg, and length to the nearest centimeter. Variations in mass and length of pups on St. Paul and St. George Islands were analyzed using analysis of variance (ANOVA) on sex, rookery, and shearing status (sheared or non-sheared). Here we limit statistical comparisons to
information collected on similar dates (i.e., within a couple of days) during the breeding season between islands in 1994, and between 1992 and 1994 at St. Paul Island. The data for St. George Island (1992 and 1993) were not used since they were collected approximately 10 days earlier in August than in the other years.

Results and Discussion

Pup Mass and Length

Mean mass, length, and 95% confidence intervals by rookery for male and female northern fur seal pups are illustrated in Figures 15 and 16 for St. Paul Island. Sample sizes, mean mass, mean length and standard deviations for each rookery by sex and year are shown in Appendix Tables C-1 and C-3 for St. Paul Island. The ANOVA of the mass by sex and rookery on St. Paul Island in 1992 and 1994 indicated that there was a significant difference between sexes ($P = 0.01$, Table 12) and rookeries ($P = 0.06$ in 1992, $P = 0.01$ in 1994, Table 12). Significant differences in length measurements of pups on St. Paul Island were also detected in 1992 and 1994 between sex ($P = 0.01$, Table 13) and rookery ($P = 0.01$, Table 13).

Mean mass, length, and 95% confidence intervals by rookery for male and female northern fur seal pups are illustrated in Figures 17 and 18 for St. George Island. Sample sizes, mean mass, mean length and standard deviations for each rookery by sex
Table 12.—Analysis of variance of mass northern fur seal pups on St. Paul Island, Alaska, 1992 and 1994. The most parsimonious (see text for details) model based on sex, shearing status and rookeries is shown.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MSS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>St. Paul 1992</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3629.395</td>
<td>1117</td>
<td>689.414</td>
<td>267.566</td>
<td>1.000</td>
</tr>
<tr>
<td>Sex</td>
<td>689.414</td>
<td>1</td>
<td>689.414</td>
<td>000</td>
<td>1.000</td>
</tr>
<tr>
<td>Shearing</td>
<td>53.234</td>
<td>1</td>
<td>53.234</td>
<td>20.661</td>
<td>1.000</td>
</tr>
<tr>
<td>Rookery</td>
<td>32.365</td>
<td>3</td>
<td>10.788</td>
<td>4.187</td>
<td>0.994</td>
</tr>
<tr>
<td>Rookery X Shearing</td>
<td>10.138</td>
<td>3</td>
<td>3.379</td>
<td>1.312</td>
<td>0.731</td>
</tr>
<tr>
<td>Sex X Shearing</td>
<td>2.360</td>
<td>1</td>
<td>2.360</td>
<td>0.916</td>
<td>0.661</td>
</tr>
<tr>
<td>Sex X Rookery</td>
<td>0.773</td>
<td>3</td>
<td>0.258</td>
<td>0.100</td>
<td>0.040</td>
</tr>
<tr>
<td>Sex X Rookery X Shearing</td>
<td>1.687</td>
<td>3</td>
<td>0.562</td>
<td>0.218</td>
<td>0.116</td>
</tr>
<tr>
<td>Residual</td>
<td>2839.424</td>
<td>1102</td>
<td>2.577</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **St. Paul 1994**               |         |     |          |          |       |
| Total                           | 5791.679| 1924|          |          |       |
| Sex                             | 604.758 | 1   | 604.758  | 239.653  | 1.000 |
| Rookery                         | 241.120 | 3   | 80.373   | 31.850   | 1.000 |
| Shearing                        | 74.188  | 1   | 74.188   | 29.399   | 1.000 |
| Rookery X Shearing              | 23.072  | 3   | 7.691    | 3.048    | 0.972 |
| Sex X Rookery                   | 19.015  | 3   | 6.338    | 2.512    | 0.943 |
| Sex X Shearing                  | 0.011   | 1   | 0.011    | 0.004    | 0.052 |
| Sex X Rookery X Shearing        | 12.214  | 3   | 4.071    | 1.613    | 0.816 |
| Residual                        | 4817.301| 1909| 2.523    |          |       |
Table 13.—Analysis of variance of length of northern fur seal pups on St. Paul Island, Alaska, 1992 and 1994. The most parsimonious (see text for details) model based on sex, shearing status and rookeries is shown.

<table>
<thead>
<tr>
<th>Source</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>St. Paul 1992</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23999.12</td>
<td>1117</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>3157.295</td>
<td>1</td>
<td>3157.295</td>
<td>199.884</td>
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<tr>
<td>Rookery</td>
<td>2863.885</td>
<td>3</td>
<td>954.628</td>
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<tr>
<td>Shearing</td>
<td>404.343</td>
<td>1</td>
<td>404.343</td>
<td>25.598</td>
<td>1.000</td>
</tr>
<tr>
<td>Sex X Rookery</td>
<td>87.659</td>
<td>3</td>
<td>29.220</td>
<td>1.850</td>
<td>0.864</td>
</tr>
<tr>
<td>Sex X Shearing</td>
<td>16.164</td>
<td>1</td>
<td>16.164</td>
<td>1.023</td>
<td>0.688</td>
</tr>
<tr>
<td>Rookery X Shearing</td>
<td>40.984</td>
<td>3</td>
<td>13.661</td>
<td>0.865</td>
<td>0.541</td>
</tr>
<tr>
<td>Sex X Rookery X Shearing</td>
<td>21.959</td>
<td>3</td>
<td>7.320</td>
<td>0.463</td>
<td>0.292</td>
</tr>
<tr>
<td>Residual</td>
<td>17406.83</td>
<td>1102</td>
<td>15.796</td>
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<td></td>
</tr>
</tbody>
</table>

| **St. Paul 1994**            |       |    |       |       |      |
| Total                        | 40593.47 | 1924 |       |       |      |
| Sex                          | 3428.905 | 1 | 3428.905 | 192.574 | 1.000 |
| Rookery                      | 2441.148 | 3 | 813.716 | 45.700 | 1.000 |
| Shearing                     | 426.315 | 1 | 426.315 | 23.943 | 1.000 |
| Rookery X Shearing           | 198.776 | 3 | 66.259 | 3.721 | 0.989 |
| Sex X Rookery                | 98.061 | 3 | 32.687 | 1.836 | 0.861 |
| Sex X Shearing               | 0.147 | 1 | 0.147 | 0.008 | 0.073 |
| Sex X Rookery X Shearing     | 9.217 | 3 | 3.072 | 0.173 | 0.085 |
| Residual                     | 33991.90 | 1909 | 17.806 |       |      |
Figure 15.---Mean mass with 95% confidence intervals of northern fur seal pups weighed during August 1992 and 1994, St. Paul Island, Alaska.
Figure 16.--Mean length with 95% confidence intervals of northern fur seal pups weighed during August 1992 and 1994, St. Paul Island, Alaska.
Figure 17.—Mean mass with 95% confidence intervals of northern fur seal pups measured during August 1992, 1993, and 1994, St. George Island, Alaska.
Figure 18.—Mean length with 95% confidence intervals of northern fur seal pups measured during August 1992, 1993, and 1994, St. George Island, Alaska.
and year are shown in Appendix Tables C-2 and C-4 for St. George Island. The ANOVA for mass indicated that there was a significant difference between sexes \( (P < 0.001 \text{ in } 1992, 1993, \text{ and } 1994; \text{ Table 14}) \) and rookeries \( (P < 0.001 \text{ in } 1992 \text{ and } 1994, P = 0.001 \text{ in } 1993; \text{ Table 14}) \) in all three sample years. The ANOVA for lengths for all sample years also indicated significant differences by sex \( (P < 0.001 \text{ in } 1992, 1993, \text{ and } 1994; \text{ Table 15}) \) and by rookery \( (P < 0.001 \text{ in } 1992 \text{ and } 1994; \text{ Table 15}) \).

Interactions between shearing status, sex, and rookery are considered in our analysis (Tables 12 through 15). Significant differences are likely due to biases associated with selection of lighter pups during the shearing activities (Roppel et al. 1981) or large differences in mean length and mean weight of sheared versus non-sheared pups of either sex on a given rookery.

A separate analysis was conducted to compare the mass and length of pups with similar sample dates, within 3 to 5 days, between islands in 1994 and between years (1992 and 1994) on St. Paul Island. The data for St. George Island was collected approximately 10 days earlier in 1992 and 1993 and was not included in this analysis. The proportion of pups sampled on each rookery was not the same for all years of data collection. Therefore, mean mass for all pups on St. Paul Island was calculated for males and females for 1992 and 1994 by weighing sums of the means for each sampled rookery on the basis of the pup production of that rookery. This was done for each island by weighing the mean according to the fraction of pups that were
Table 14.—Analysis of variance of mass northern fur seal pups on St. George Island, Alaska, 1992-94. The most parsimonious (see text for details) model based on sex, shearing status, and rookeries is shown.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MSS</th>
<th>F</th>
<th>p</th>
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<td><strong>St. George 1992</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1695.872</td>
<td>632</td>
<td>169.86</td>
<td>74.573</td>
<td>1.000</td>
</tr>
<tr>
<td>Sex</td>
<td>169.860</td>
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<td>169.86</td>
<td>74.573</td>
<td>1.000</td>
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<tr>
<td>Rookery</td>
<td>82.197</td>
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<td>16.439</td>
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</tr>
<tr>
<td>Shearing</td>
<td>7.999</td>
<td>1</td>
<td>7.999</td>
<td>3.512</td>
<td>0.937</td>
</tr>
<tr>
<td>Rookery X Shearing</td>
<td>25.631</td>
<td>5</td>
<td>5.126</td>
<td>2.251</td>
<td>0.952</td>
</tr>
<tr>
<td>Sex X Rookery</td>
<td>17.946</td>
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<td>3.589</td>
<td>1.576</td>
<td>0.835</td>
</tr>
<tr>
<td>Sex X Shearing</td>
<td>0.347</td>
<td>1</td>
<td>0.347</td>
<td>0.152</td>
<td>0.303</td>
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<tr>
<td>Sex X Rookery X Shearing</td>
<td>4.721</td>
<td>5</td>
<td>0.944</td>
<td>0.415</td>
<td>0.161</td>
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<tr>
<td>Residual</td>
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<td>609</td>
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</tr>
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<td><strong>St. George 1993</strong></td>
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<td></td>
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<tr>
<td>Total</td>
<td>759.285</td>
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<tr>
<td>Sex</td>
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<td>124.457</td>
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</tr>
<tr>
<td>Rookery</td>
<td>30.025</td>
<td>2</td>
<td>15.013</td>
<td>6.673</td>
<td>0.999</td>
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<tr>
<td>Sex X Rookery</td>
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<td>2.050</td>
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<td>0.597</td>
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<tr>
<td><strong>St. George 1994</strong></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total</td>
<td>3059.410</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Sex</td>
<td>594.554</td>
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<td>594.554</td>
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<td>Rookery</td>
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<tr>
<td>Shearing</td>
<td>15.283</td>
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<td>15.283</td>
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<tr>
<td>Sex X Shearing</td>
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<td>1</td>
<td>2.244</td>
<td>0.825</td>
<td>0.636</td>
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<tr>
<td>Sex X Rookery</td>
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<td>5</td>
<td>2.229</td>
<td>0.819</td>
<td>0.464</td>
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<tr>
<td>Rookery X Shearing</td>
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<td>5</td>
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<td>0.754</td>
<td>0.417</td>
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<tr>
<td>Sex X Rookery X Shearing</td>
<td>11.699</td>
<td>5</td>
<td>2.340</td>
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<tr>
<td>Residual</td>
<td>2345.287</td>
<td>862</td>
<td>2.721</td>
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Table 15.—Analysis of variance of length northern fur seal pups on St. George Island, Alaska, 1992–94. The most parsimonious (see text for details) model based on sex, shearing status, and rookeries is shown.

<table>
<thead>
<tr>
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<tr>
<td><strong>St. George 1992</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>13470.87</td>
<td>633</td>
<td>1075.413</td>
<td>59.449</td>
<td>1.000</td>
</tr>
<tr>
<td>Sex</td>
<td>1075.413</td>
<td>1</td>
<td>1075.413</td>
<td>59.449</td>
<td>1.000</td>
</tr>
<tr>
<td>Rookery</td>
<td>849.131</td>
<td>5</td>
<td>169.826</td>
<td>9.388</td>
<td>1.000</td>
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<tr>
<td>Shearing</td>
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<td>38.621</td>
<td>2.135</td>
<td>0.856</td>
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<td>Sex X Rookery</td>
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<td>46.907</td>
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<tr>
<td>Rookery X Shearing</td>
<td>193.576</td>
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<td>2.140</td>
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<tr>
<td>Sex X Shearing</td>
<td>12.265</td>
<td>1</td>
<td>12.265</td>
<td>0.678</td>
<td>0.589</td>
</tr>
<tr>
<td>Sex X Rookery X Shearing</td>
<td>32.537</td>
<td>5</td>
<td>6.507</td>
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<td>0.124</td>
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<tr>
<td>Residual</td>
<td>11034.79</td>
<td>610</td>
<td>18.090</td>
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<tr>
<td><strong>St. George 1993</strong></td>
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</tr>
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<td>Total</td>
<td>3602.694</td>
<td>218</td>
<td>466.596</td>
<td>32.247</td>
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</tr>
<tr>
<td>Sex</td>
<td>466.596</td>
<td>1</td>
<td>466.596</td>
<td>32.247</td>
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<tr>
<td>Rookery</td>
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<td>0.423</td>
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<td>Sex X Rookery</td>
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<td>24.790</td>
<td>1.713</td>
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<tr>
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<td>3110.885</td>
<td>215</td>
<td>14.469</td>
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<tr>
<td>Total</td>
<td>16453.07</td>
<td>885</td>
<td>2470.125</td>
<td>162.208</td>
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</tr>
<tr>
<td>Sex</td>
<td>2470.125</td>
<td>1</td>
<td>2470.125</td>
<td>162.208</td>
<td>1.000</td>
</tr>
<tr>
<td>Rookery</td>
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<td>78.815</td>
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<td>1.000</td>
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<td>96.075</td>
<td>6.350</td>
<td>0.988</td>
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<tr>
<td>Sex X Rookery</td>
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<td>5</td>
<td>28.857</td>
<td>1.895</td>
<td>0.907</td>
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<tr>
<td>Sex X Shearing</td>
<td>29.610</td>
<td>1</td>
<td>29.610</td>
<td>1.944</td>
<td>0.836</td>
</tr>
<tr>
<td>Rookery X Shearing</td>
<td>55.628</td>
<td>5</td>
<td>11.126</td>
<td>0.731</td>
<td>0.399</td>
</tr>
<tr>
<td>Sex X Rookery X Shearing</td>
<td>135.965</td>
<td>5</td>
<td>27.193</td>
<td>1.786</td>
<td>0.887</td>
</tr>
<tr>
<td>Residual</td>
<td>13126.68</td>
<td>862</td>
<td>15.228</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
contributed by that rookery to the total number of pups born on the island, for St. George Island, and for the total number of pups for rookeries sampled on St. Paul Island.

These fractions are considered representative of the size of the pup population on each rookery and are independent of the mass data. The variance of the weighted mean is estimated as the sum of the product of the squared weight with the variances of the mean mass from each rookery.

The calculations were determined in the following manner:
Let $B_1, B_2, \ldots, B_4$ be the 1992 pup production estimates on the four St. Paul rookeries where studies were conducted during 2 years (1992 and 1994). Let $W_{i,j}$ be the corresponding mean mass of pups on rookery $i$, $i = 1, 4$ for sex $j$ ($j = 1$ for females, $2$ for males) from Appendix Table C-1. Let $V_{i,j}$ be the variance for $W_{i,j}$; $V_{i,j}$ is calculated as the square of the standard deviation (Appendix Tables C-1 and C-2) divided by the sample size (Appendix Tables C-1 and C-2). For example, for females in 1992 the calculation was $V(1,1) = (1.62)^2/116$. For each rookery, $i$, the fraction of pups ($f_i$) contributed by that rookery is computed as:

$$4f_i = B_i / \sum_{i=1}^4 B_i \quad \text{(1)}$$

Then the weighted mean ($M_j$) for sex $j$ is

$$M_j = \sum_{i=1}^4 f_i W_{i,j} \quad \text{(1)}$$
with variance:

\[ S_j^2 = \sum_{i=1}^{4} f_i^2 V_{ij} \]  

(1)

Similar calculations were made for lengths of pups on St. Paul Island and for mass and length of pups on St. George Island where \( B_i \) is replaced by \( P_i = \) number of pups (on a given rookery \( i \)). Significant differences between two means can be assessed by comparing the difference in the two means divided by the square root of the sum of the two corresponding variances to a Student's t-distribution. Degrees of freedom are determined to be the total number of sample points (pups) in year 1, plus the total number of sample points in year 2, less the number of rookeries in year 1, less the number of rookeries in year 2.

The weighing factors (\( f_i \) in the above equations) are shown for 1992 in Appendix Table C-5 for St. Paul Island and in Appendix Table C-6 for St. Paul and St. George Islands in 1994. The estimated mean mass of pups and standard error for each sex for 1992-94 from St. Paul Island and for 1994 from St. George Island are presented in Table 16. The estimated mean length of pups and standard error for each sex for 1992-94 from St. Paul Island and 1994 from St. George Island are shown in Table 17. The calculated t-statistics for each year comparison are summarized for mass (Appendix Table C-7) and length (Appendix Table C-8). The mass of male pups was significantly heavier on St. George Island in 1994 than on St. Paul Island in 1992 and

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>8.90</td>
<td>8.38</td>
<td>10.25</td>
</tr>
<tr>
<td>SE</td>
<td>0.065</td>
<td>0.054</td>
<td>0.084</td>
</tr>
<tr>
<td>Males</td>
<td>9.97</td>
<td>10.07</td>
<td>11.91</td>
</tr>
<tr>
<td>SE</td>
<td>0.070</td>
<td>0.057</td>
<td>0.095</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>St. Paul</th>
<th>St. George</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>76.11</td>
<td>73.21</td>
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<tr>
<td>SE</td>
<td>0.185</td>
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<td>75.95</td>
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<tr>
<td>SE</td>
<td>0.158</td>
<td>0.141</td>
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</table>
1994, however, there was no significant difference in the mass of males on St. Paul Island between 1992 and 1994. Female pups were also significantly heavier (P < 0.001) on St. George Island in 1994 than on St. Paul Island in 1994 or 1992, and female pups on St. Paul Island were significantly heavier (P < 0.001) in 1994 than 1992. Males and females on St. Paul Island were significantly longer in 1992 compared to 1994 on St. Paul Island and St. George Island (P < 0.001). Male and female lengths on St. George Island in 1994 were significantly greater than lengths on St. Paul Island in 1994 (P < 0.001).

Sex Ratios

The fraction of female fur seal pups (live and dead) sampled on St. Paul and St. George Islands are summarized by rookery in Tables 18 and 19. On two occasions on St. Paul Island, it was necessary to release pups before they succumbed to heat prostration. This may have introduced biases to the sex ratio analysis. An analysis of the sex ratios by rookery was conducted by using a General Linear Interactive Modelling (S-Plus) program assuming that the fraction of females in each section was a binomial random variable. The logit of the fraction of females \( \log(p/(1-p)) \) was modelled as a linear function of rookery and year of sample. The results from that analysis (Table 20) can be interpreted like an ANOVA except that the significance of a factor is judged by comparing the total sum of squares explained by that factor with a Chi-square random variable with degrees of freedom equal to the degrees of freedom of that factor.
Table 18.—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 Island, Alaska, August 1992-94. The fraction of females is significantly greater than 50% (P = 0.95) for bold items.

<table>
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</thead>
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<td></td>
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<td>Total</td>
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<td>250</td>
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<td>Vostochni</td>
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<td>383</td>
</tr>
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<td>285</td>
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<td>Total</td>
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<tr>
<td>South</td>
<td>63</td>
<td>113</td>
</tr>
<tr>
<td>Total</td>
<td>291</td>
<td>634</td>
</tr>
</tbody>
</table>
Table 19.—Numbers of female pups, total number of pups, and fraction (that are female) of northern fur seal pups sampled during dead pup counts on St. Paul Island, Alaska, August 1992 and 1994. The fraction of females is significantly greater than 50% \((P = 0.95)\) for bold items.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reef</td>
<td>139</td>
<td>342</td>
<td>0.406</td>
<td>99</td>
<td>196</td>
<td>0.505</td>
</tr>
<tr>
<td>Vostochni</td>
<td>87</td>
<td>210</td>
<td>0.414</td>
<td>64</td>
<td>142</td>
<td>0.451</td>
</tr>
<tr>
<td>Pol. Cliffs</td>
<td>36</td>
<td>82</td>
<td>0.439</td>
<td>14</td>
<td>22</td>
<td>0.636</td>
</tr>
<tr>
<td>Tolstoi</td>
<td>96</td>
<td>214</td>
<td>0.449</td>
<td>40</td>
<td>82</td>
<td>0.488</td>
</tr>
<tr>
<td>Total</td>
<td>358</td>
<td>848</td>
<td>0.422</td>
<td>217</td>
<td>442</td>
<td>0.491</td>
</tr>
<tr>
<td>East Reef</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>East Cliffs</td>
<td>4</td>
<td>22</td>
<td>0.182</td>
<td>11</td>
<td>16</td>
<td>0.688</td>
</tr>
<tr>
<td>Staraya Artil</td>
<td>31</td>
<td>68</td>
<td>0.456</td>
<td>7</td>
<td>9</td>
<td>0.778</td>
</tr>
<tr>
<td>North</td>
<td>22</td>
<td>44</td>
<td>0.500</td>
<td>25</td>
<td>60</td>
<td>0.417</td>
</tr>
<tr>
<td>Zapadni</td>
<td>28</td>
<td>59</td>
<td>0.475</td>
<td>9</td>
<td>20</td>
<td>0.450</td>
</tr>
<tr>
<td>South</td>
<td>21</td>
<td>44</td>
<td>0.477</td>
<td>10</td>
<td>17</td>
<td>0.588</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td>237</td>
<td>0.447</td>
<td>63</td>
<td>123</td>
<td>0.512</td>
</tr>
</tbody>
</table>

1Includes the following dead pups taken for mortality studies: Reef 70 females, 93 males; Vostochni 23 females, 37 males; Staraya 27 females, 33 males; Zapadni 12 females, 15 males.

2Includes the following dead pups taken for mortality studies: Reef 65 females, 64 males; Vostochni 26 females, 31 males; Tolstoi 1 female, 1 male.
Table 20.—Analysis of deviance for dependence of sex-ratio on rookery and year sampled of northern fur seal pups on the Pribilof Islands, Alaska 1992–94. Fraction of females modeled as a general linear model with binomial errors and logit link functions. The "reduction in deviance" is the amount the residuals are reduced when the given factor is entered into the model in order of significance; the deviance is the weighted residual sum of squares for the model.

<table>
<thead>
<tr>
<th>Factor</th>
<th>df</th>
<th>Deviance</th>
<th>df</th>
<th>reduction</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Paul Island</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Mean</td>
<td>15</td>
<td>19.654</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>14</td>
<td>9.127</td>
<td>1</td>
<td>10.527</td>
<td>0.001</td>
</tr>
<tr>
<td>Rookery</td>
<td>11</td>
<td>8.651</td>
<td>3</td>
<td>0.476</td>
<td>0.924</td>
</tr>
<tr>
<td>St. George Island</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Mean</td>
<td>22</td>
<td>35.452</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rookeries</td>
<td>17</td>
<td>24.332</td>
<td>5</td>
<td>11.121</td>
<td>0.049</td>
</tr>
<tr>
<td>Year</td>
<td>16</td>
<td>21.863</td>
<td>1</td>
<td>2.468</td>
<td>0.116</td>
</tr>
</tbody>
</table>
When all categories are considered simultaneously, the addition of the year term for St. Paul Island reduces the deviance significantly ($P = 0.001$). That is, one rejects the null hypothesis of no significant difference in the fraction of females among the years (i.e., the fraction of females was significantly different from 50% in 1992 ($P < 0.001$), but not in 1994 ($P = 0.064$).

On St. George Island, there is no significant difference in the fraction of females between rookeries for 1992 and 1994 ($P = 0.088$). The percentage of female pups (45.6%) in 1992 was significantly different than 50% ($P = 0.005$); however, in 1994, the percentage of female pups (48.9%) was not significantly different from 50% ($P = 0.224$). Analysis for St. George Island was also done without including data from South rookery. From plots of live and dead pup sex ratios for 1992 and 1994 (Fig. 19), South rookery looked to be quite different than all other rookeries on St. George Island. Year becomes a significant factor ($P = 0.027$) when South rookery is not included in the analysis. There is no significant difference in the two models ($P = 0.027$): the model with and the model without South Rookery included.

The fraction of females (all rookeries combined) sampled in 1992 and 1994 on St. Paul Island and St. George Island are presented in Table 21. The ordering of frequency of females is shown below. A line joins groups whose sex ratios were not
Figure 19. -- Fraction of female pups, live and dead, on the Pribilof Islands, Alaska, 1992 and 1994.
Table 21.—Numbers of female pups, total number of pups, and fraction (that are female) of live northern fur seals pups captured during weighing operations and dead pups counted during dead pup counts on St. Paul Island and separate samples on St. George Island, Alaska, for the years 1992-94.

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Paul</td>
<td>494</td>
<td>1118</td>
<td>0.442</td>
<td>926</td>
<td>1926</td>
<td>0.481</td>
</tr>
<tr>
<td>St. George</td>
<td>291</td>
<td>634</td>
<td>0.459</td>
<td>430</td>
<td>886</td>
<td>0.485</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Paul</td>
<td>358</td>
<td>848</td>
<td>0.422</td>
<td>217</td>
<td>442</td>
<td>0.491</td>
</tr>
<tr>
<td>St. George</td>
<td>106</td>
<td>237</td>
<td>0.447</td>
<td>63</td>
<td>123</td>
<td>0.512</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Paul</td>
<td>852</td>
<td>1966</td>
<td>0.433</td>
<td>1143</td>
<td>2368</td>
<td>0.483</td>
</tr>
<tr>
<td>St. George</td>
<td>397</td>
<td>871</td>
<td>0.456</td>
<td>493</td>
<td>1009</td>
<td>0.489</td>
</tr>
</tbody>
</table>
significantly different from each other. For example, the fraction of female pups in the sample from St. Paul Island in 1994 and from St. George Island in 1994 (SP94, SG94) was significantly greater than St. Paul Island in 1992 (SP92) sample.

SP92 < SG92 < SP94 < SG94

Significant differences between two frequencies were assessed by comparing the difference in the two frequencies divided by the square root of the sum of the two corresponding variances to a Student's T-distribution with degrees of freedom equal to the sum of the sample size in each group minus 2 (Fleiss 1973).

Summary

Consistent with earlier evaluations of pup mass data (York and Antonelis 1990, York and Towell 1993), the only clear pattern of how mass of pups varied is by sex: males outweighed females. Also, male pups are longer than female pups. Female pups on St. George Island in 1994 outweighed male pups on St. Paul Island in the same year. This may be an island difference since the male pups on St. George Island in 1994 were heavier than the female pups. Significant differences between islands in 1994 and between years on the same island were demonstrated for mass and length of pups. On St. Paul Island, the mass of male pups in
1994 was not significantly different than 1992, however, the length of male and female pups was significantly greater on St. Paul Island in 1992 than on St. George Island in 1994. The mass of male pups on St. George Island in 1994 was significantly greater than males on St. Paul Island in 1992 and 1994. The mass of female pups on St. Paul Island in 1992 was significantly less than female pups on St. Paul and St. George Islands in 1994. Male and female pups on St. George Island in 1994 were significantly longer than male and female pups on St. Paul Island in 1994. Significant differences in the sex ratio of pups between years and islands were usually indicated in most instances by a percentage of females that was less than 50%. These differences in mass, length, and sex ratio may reflect variability in the environmental influences on the condition of pups and their mothers. Undetected biases in sampling techniques may also be responsible for the differences detected in this study. Future studies will be designed to minimize possible sources of biases due to methodology and explore the combined use of length and mass to create condition indices of pups.

by

Robert V. Caruso and Jason D. Baker

Total body weight and age of subadult male northern fur seals killed during the 1991-94 St. Paul Island subsistence harvest were compared to determine whether there were weight differences between those years for 2-, 3- and 4-year-old males sampled. Subadult males were sampled opportunistically during the 1991-94 subsistence harvests. Immediately following death, each seal was weighed to the nearest kilogram and the upper snout removed for the extraction of the canine teeth (Antonelis 1992). To estimate ages, the number of annual dentin layers were counted on each canine tooth following the methods of Scheffer (1950).

Weights and ages were determined for 12.2% (n = 201), 18.1% (n = 269), 18.8% (n = 285), and 18.6% (n = 300) of the subadult males killed during the subsistence harvests in 1991 through 1994, respectively (Table 22).

A two-factor ANOVA of weight with factors of year and age showed that weight varied significantly with age (P < 0.001) and between years (P < 0.01). There was no significant interaction between year and age (P = 0.42). To determine which year's weight differed for particular ages, single-factor ANOVA were conducted for each age class and the results analyzed with multiple contrasts using the Student-Newman-Keuls test (Zar 1974).
Table 22.--Weights of subadult male northern fur seals taken in
the subsistence harvest on St. Paul Island, Alaska
1991-94.

<table>
<thead>
<tr>
<th>Year</th>
<th>Age</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>89</td>
<td>105</td>
</tr>
<tr>
<td>% of sample</td>
<td>44.2</td>
<td>52.2</td>
</tr>
<tr>
<td>mean weight (kg)</td>
<td>21.4</td>
<td>25.9</td>
</tr>
<tr>
<td>SD</td>
<td>2.7</td>
<td>3.6</td>
</tr>
<tr>
<td>1992</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>109</td>
<td>148</td>
</tr>
<tr>
<td>% of sample</td>
<td>40.5</td>
<td>55.0</td>
</tr>
<tr>
<td>mean weight (kg)</td>
<td>22.3</td>
<td>26.4</td>
</tr>
<tr>
<td>SD</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>125</td>
<td>156</td>
</tr>
<tr>
<td>% of sample</td>
<td>43.8</td>
<td>54.7</td>
</tr>
<tr>
<td>mean weight (kg)</td>
<td>20.9</td>
<td>25.8</td>
</tr>
<tr>
<td>SD</td>
<td>3.1</td>
<td>3.6</td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>125</td>
<td>172</td>
</tr>
<tr>
<td>% of sample</td>
<td>41.7</td>
<td>57.3</td>
</tr>
<tr>
<td>mean weight (kg)</td>
<td>21.5</td>
<td>25.2</td>
</tr>
<tr>
<td>SD</td>
<td>3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>448</td>
<td>581</td>
</tr>
<tr>
<td>% of sample</td>
<td>42.5</td>
<td>55.1</td>
</tr>
<tr>
<td>mean weight (kg)</td>
<td>21.5</td>
<td>25.8</td>
</tr>
<tr>
<td>SD</td>
<td>3.0</td>
<td>3.4</td>
</tr>
</tbody>
</table>
Comparing years for all ages combined, 1992 weights were significantly heavier than 1991 ($P < 0.05$), 1993, and 1994 ($P < 0.01$). Weights of harvested males in 1991, 1993, and 1994 did not differ significantly.

Two-year-olds sampled in 1992 were significantly heavier than those sampled in 1991 ($P < 0.05$) and 1993 ($P < 0.01$). Although the mean weight in 1994 was about the same as in 1991, no significant difference could be detected between 1992 and 1994.

Three-year-olds sampled in 1992 were significantly heavier than those sampled in 1994 ($P < 0.05$). However, 3-year-olds in 1992 did not differ significantly from those in 1991 and 1993, and weights of 3-year-olds in 1991, 1993, and 1994 did not differ significantly.

There was no significant difference in the mean weight of 4-year-olds among years. Sample sizes for this age class were very small (Table 22).

Males harvested in 1992 were heavier on average than those in 1991, 1993, and 1994. This difference was most notable in the 2-year-old age class and may reflect either a change in size selection among the sealers, a real difference in weight of available males, or a combination of both factors.
Entanglement of northern fur seals (Callorhinus ursinus) in marine debris has been studied since the early 1980s by the National Marine Mammal Laboratory (NMML) in cooperation with the National Research Institute of Far Seas Fisheries (NRIFSF), the Aleut community of St. Paul Island, and other organizations (Fowler and Baba 1991, Fowler et al. 1992). Surveys of entanglement among subadult male fur seals were conducted in conjunction with the commercial harvest until 1985 (Scordino and Fisher 1983, Scordino 1985) and using research roundups after the cessation of the commercial harvest (Fowler 1987, Fowler et al. 1992). Adult female entanglement has been studied by Bigg (1979), Scordino and Fisher (1983), Scordino (1985), DeLong et al. (1988), and Kiyota and Fowler (1994). Rates of entanglement for males appeared to increase from the mid-1960s to the mid-1970s reaching a peak in 1976 at 0.76% among subadult males (Fowler 1987, Fowler et al. 1992, Kiyota and Fowler 1994). Entanglement studies from 1988 to 1992 indicate a decline in the rate of entanglement among both subadult males and females (Fowler and Ragen 1990, Fowler et al. 1992, Kiyota and Fowler 1994).

Here we report on the type of entangling debris and the number of fur seals that were disentangled in 1994. We also
provide information on seasonal and annual (1991-94) rates of entanglement among adult female fur seals.

Methods

During the course of the 1994 northern fur seal research activities on St. Paul and St. George Islands, fur seals entangled in marine debris were captured and debris was removed. Efforts begun in 1993 to remove debris from seals rounded up during the subsistence harvest were continued in 1994 in cooperation with Aleut community members on both islands. Fur seals were also disentangled during the counts of adult males, pup production studies, female foraging studies and other miscellaneous research activities from July to October. Tags were applied to entangled seals of the size historically taken during the commercial harvest (Fowler et al. 1992) for use in assessing the entanglement rate and survival. Information on type of entangling debris and the degree of wounding was recorded.

In 1994, island-wide surveys of entangled adult female fur seals by NRIFSF scientists were conducted on St. Paul Island using the techniques described by Kiyota and Fowler (1994). All rookeries were surveyed in conjunction with the counts of adult males from 15 to 21 July. Two study sites on Reef rookery were surveyed on 21 July, 31 July, and 10 August to detect changes in the rate of female entanglement between years and during the course of the breeding season. Locations of entangled females were recorded and attempts were made to locate and disentangle
these seals using a portable blind or later in the season during pup production studies.

Results and Discussion

A total of 93 fur seals were disentangled on St. Paul Island and 26 on St. George Island during the 1994 field season (Appendix Table D-1). Approximately equal numbers of male seals were captured during the early (n = 47, 27 June-8 August) and late (n = 46, 10 August-2 September, 24 September-10 November) portions of the field season (Appendix Table D-2) on St. Paul Island. More adult females were captured during the late season (St. Paul n = 15, St. George n = 4) than the late season (St. Paul n = 1, St. George n = 0) due to greater accessibility to females on breeding areas during pup production and late-season foraging studies.

Comparisons between numbers of seals disentangled during research activities during 1993 and 1994 field seasons are difficult due to variable effort and methods between years. During bull counts on St. Paul Island, where an effort was made to disentangle seals in both years, 14 seals were disentangled in 1993 and 17 in 1994. During the subsistence harvest, 10 seals were disentangled in 1993 and 17 in 1994. Prior to the initiation of efforts to capture seals and remove debris in 1993, 5 entangled seals were observed but the debris was not removed. It is possible that these seals were captured and disentangled at a later date and therefore the total of 10 entangled seals represents a minimum estimate for 1993.
For all age and sex categories of seals, trawl net was the most frequently removed type of debris on both islands (Appendix Table D-3) found on 55.2% (n = 48) and 45.5% (n = 10) of all seals in 1994 on St. Paul and St. George Islands, respectively. Plastic packing bands, the second most numerous debris type, were removed from 23.0% (n = 20) of all seals on St. Paul Island and 31.8% (n = 7) on St. George Island. During 1993, trawl net accounted for 41.2% (n = 14) and packing bands for 38.2% (n = 13) of entangling debris removed from all seals on St. Paul Island (Appendix Table D-4). On St. George Island, trawl net was removed from 8 seals (88.9%) and a loop of string from 1 seal (11.1%) while no seals entangled in packing bands were observed in 1993.

The incidence of trawl net and packing bands on subadult males on St. Paul Island during all research activities was 60.4% and 18.7% in 1994, compared with 47.5% and 22.5% for the same two categories of debris in 1992 during the roundups of subadult males. This suggests a possible increase in the proportion of trawl net found on subadult males since 1992, however differences in methodology (e.g., roundups vs. visual inspection of haul outs from a distance) may account for differences observed in 1993-94.

Twenty female fur seals were disentangled during the course of the research season, most (n = 18) during pup production studies. Trawl net (30%), miscellaneous line (30%), and packing bands (20%) were the most common debris types removed from females (Appendix Table D-3).
Plastic bait bags used in the Bering Sea crab fishery were observed for the first time in 1994 and removed from three seals (a pup, a 4-5 year old male, and an adult male) on St. Paul Island. This debris consists of a lightweight plastic mesh bag hanging from a loop of synthetic line attached to a plastic hook.

Seven entangled and 10 scarred (evidence of previous entanglement) adult female fur seals were observed during female entanglement surveys (Appendix Table D-5). The rate of entanglement among females was calculated at 0.023% for entangled females, 0.033% for scarred females and 0.056% for the two categories combined. The 1994 data show an increase in the observed rate of entangled and entangled and scarred females combined from 1992 and 1993 (Appendix Table D-5) (Kiyota and Fowler 1994, Kiyota unpublished data). As in previous years, the observed incidence of entanglement increased as the breeding season progressed (Appendix Table D-6). This may be due to a higher rate of entanglement among younger seals (Kiyota and Fowler 1994, Croxall et al. 1990), which tend to haul out later in the season.
Northern fur seals (*Callorhinus ursinus*) were censused on Bogoslof Island, eastern Aleutians, on 18 August 1994. A total of 1,482 pups (including 10 dead pups) and 3,691 non-pups (adult and subadult fur seals) were observed on beaches. Three fur seals were observed with monofilament line around their necks, and two fur seals with flipper tags were observed. A total of 90 Steller sea lions (*Eumetopias jubatus*) were counted on beaches and in the water at the southeast tip of the island. The number of pups counted represented a 67% increase over counts conducted in 1993, and continues an exponential increase in pup production at Bogoslof Island that began in the late 1980s.

Methods

During the course of studies on the diet and breeding ecology of Tufted Puffins (*Fratercula cirrhata*) on Bogoslof Island, Alaska, on 18 August 1994, we conducted a population census of northern fur seals. We used methods suggested by J. Baker (pers. comm.) and described by Ream and Towell (1993). Fur seals were distributed along beaches on the east, west, and south side of the island. Pups were concentrated in three areas: south of the 1992 Dome on the east side; south of Kenyon Dome on
the west side, and east of Castle Rock on the south side (Fig. 4).

Fur seals were counted directly while walking next to or through all rookeries and haul-out areas on the island, except for a small area on the north end of the island between Kenyon Dome and the 1992 Dome. In all areas, animals were categorized as pups or non-pups (1 year of age or older). Owing to limitations on time, no attempt was made to differentiate various age or sex classes of non-pup fur seals.

Counts were made by three observers. One censused pups only, one censused non-pups, while one person recorded data and helped search for pups. East and south side beaches were censused between 0930 and 1230 h. The west beach was censused between 1400 and 1830 h. Pup counts on the east side were relatively straightforward as the beach is sandy and all animals were viewed easily. Pup counts on the west and south sides were more laborious as the beaches are composed of large boulders and pups were usually in hollows among the boulders, making counts difficult. Censusing of non-pups was difficult in all areas because of their large numbers and rapid movements on the beach. We tried to count non-pups in discrete blocks ahead of us as we approached them, and before they scrambled down the beach toward the water. Estimates of non-pups were likely conservative for all areas. Pup counts were probably conservative on the west and south beaches.
Results

Overall, a total of 5,173 northern fur seals were counted on beaches at Bogoslof Island; including 3,691 adults and sub-adults, and 1,482 pups (10 dead).

On the east and south beaches, a total of 2,515 adult and sub-adult fur seals were counted on beaches and in the water. Three animals had monofilament line around their necks, and one tagged animal was observed. The tag could not be read, but it was a monel tag attached to the front flipper. At the northeast rookery (south of 1992 Dome), a total of 253 live and 2 dead pups were observed. The mean group size was 7.91 pups (± 10.2 SD, n = 32). No pups were observed along most of the east side south of this rookery. On the south beach (east of Castle Rock), 209 live pups were counted. The mean group size was 13.1 pups (± 13.0 SD, n = 16).

On the west beach between Kenyon Dome and Castle Rock, a total of 1,176 adult and sub-adult fur seals were counted. These counts were minimum estimates. One seal with a monel tag on a front flipper was observed, but the tag could not be read. At this rookery, a total of 1,010 live and 8 dead pups were counted. The mean group size was 7.16 pups (± 9.24 SD, n = 141).

A total of 90 Steller lions were counted. Most (n = 66) were on the beach or in the water (n = 18) at the southeast tip of the island, while a few (n = 6) were on the west beach near Castle Rock. No other species of marine mammal were observed.
Discussion

The population of northern fur seal pups at Bogoslof Island is continuing to increase exponentially (Fig. 20). After initial colonization in the early 1980s, the pup population grew at a rate of 57% per annum up to 1988 (Loughlin and Miller 1989). Between 1990 and 1993, the pup population exploded at a rate of about 130% per annum (Ream and Towell 1993). Our data suggest that the rate of increase has tapered off, being only 67% between 1993 and 1994. We counted pups carefully, so this apparent decline in rate of increase is probably real and not an artifact of survey effort.

Data unavailable to Ream and Towell (1993) and included in Figure 20 is a census of fur seals conducted at Bogoslof on 28 August 1991 by A. Manville and J. Hague (memo to G.V. Byrd, Alaska Maritime National Wildlife Refuge). They counted 4,839 adults and juveniles and 413 pups of the year for a total of 5,252 fur seals. At least 10 fur seals were seen entangled in trawl net fragments.

Presumably, most of the growth in pup production has resulted from immigration of breeding adults from the Commander and Pribilof Islands (Loughlin and Miller 1989). Our census of non-pups suggested a decline in populations between 1993 and 1994, but this must be considered as tenatative because of the difficulty in counting these animals, and the relatively minimal effort that we expended in counting non-pups compared to the effort in 1993 (Ream and Towell 1993). On the other hand,
Figure 20.--Number of northern fur seals (*Callorhinus ursinus*) observed on Bogoslof Island, Alaska, 1976-1994.
unpublished estimates from 1991 suggest that the non-pup population may have peaked in 1991 and is now declining or stabilizing. Given the many sources of error in counting non-pups, more annual counts are needed to resolve the trend.

Steller sea lions appear to be continuing their decline at Bogoslof Island (Merrick et al. 1987, Loughlin et al. 1992). Numbers have decreased from a high of 3,300 in 1979, to 1,300 in 1985, to 682 in 1989, to our count of 90 in 1994. However, as our count was conducted late in the breeding season, it must represent a minimum number.
Population monitoring studies of the northern fur seal population at San Miguel Island, California (34°01' N, 120°26' W) have been conducted since the discovery of the colony in 1968. The San Miguel Island northern fur seal rookery is located at the southern extreme of the northern fur seal's range and although it is located in the Southern California Bight, San Miguel Island remains cool and windy under normal environmental conditions and provides suitable habitat for northern fur seals. However, the Southern California Bight is periodically affected by strong El Niño events, such as the 1982-83 El Niño event, which caused sea surface temperatures to increase 1-3°C above normal for extended periods of time (DeLong and Antonelis 1991, DeLong and Melin 1992).

In January 1992, El Niño conditions similar to the 1982-83 El Niño occurred along the California coast. Sea surface temperatures near San Miguel Island were elevated throughout 1992 and 1993 and returned to normal in 1994. Similar to the effects of the 1982-83 El Niño, the fur seal population at San Miguel Island experienced decreased pup production, high pup mortality and lower weights of pups at 3 months of age in the 1992 breeding season (Melin and DeLong 1994). However, unlike the 1982-83 event, pup production returned to pre-El Niño levels the
following year, indicating that adult female survival probably
did not decrease significantly during this event (Melin et al.
1994). Although pup production was high in 1993, pup weights
remained depressed suggesting that adult females were still
experiencing difficulty in obtaining food during the 1993
breeding season (Melin et al. 1994). Monitoring studies
conducted in 1994 continued to investigate the effects of the
1992-93 El Niño event on the population growth and health of the
northern fur seals at San Miguel Island. Estimates of pup
production, condition, and mortality were determined. Survival
of tagged individuals was also monitored.

Methods

Observations and Census of Adults

Daily observations of northern fur seals at San Miguel
Island began 11 May and continued through 8 July 1994 in Adams
Cove. Observations were conducted from two blinds overlooking
the Adams Cove rookery (approximately 20 m above and 40 to 300 m
horizontal distance from the breeding animals). One blind was
located at the northeast edge and the other at the southeast edge
of the rookery.

Observations were made using a 60 mm zoom scope or
binoculars. Every 1 to 3 days during the observation period,
territorial bulls (class 2 and 3) were counted. Arrival dates of
territorial bulls and females were also recorded.
Live Pup Census and Pup Mortality

Live pup counts were conducted on 31 July in Adams Cove and on 7 August at Castle Rock. The live pup census in Adams Cove was conducted by two observers using binoculars and counting pups in each breeding group. At Castle Rock, geographic markers were used as boundaries for counting pups in groups. The mean was calculated from the total counts of the two observers. The standard error was calculated using the sum of the variances from the two independent counts for each group of pups.

Three fur seal pup mortality surveys, one each in June, July, and August were conducted in Adams Cove. In June, pups were not collected from within the breeding groups because of the potential for disturbance to newborn pups and pregnant females. In the July and August surveys, pups were collected from the entire fur seal rookery. Each dead pup was counted, removed from the territory, and then stacked in an area away from the survey area to minimize the possibility of counting the same pup twice during the season. At Castle Rock, dead pups were counted once during the live pup census. The total dead pup count at each location, Adams Cove and Castle Rock, is the sum of the dead pups counted by each observer at each area.

Pup Tagging and Growth

On 6 October, 300 northern fur seal pups were tagged with pink plastic roto tags in Adams Cove. Tags with the same number were placed on both foreflippers of each pup. Each pup was sexed, weighed, and measured (length and girth).
Resight Effort

Efforts to resight tagged juvenile and small adult male fur seals at San Miguel Island were conducted regularly throughout the season. Resight efforts for tagged females were conducted on 9 July, 31 July, and 4 August. Tagged individuals were identified by reading tags on the foreflippers. Observations of tagged individuals were conducted using binoculars, a 60 mm zoom scope or a high-power reflective scope. The tag numbers, behavior, and general condition of tagged individuals were recorded.

Results

Observation and Census of Adults

In 1994, the first territorial male arrived on 11 May at Adams Cove on San Miguel Island. The maximum number of territorial males with females in their territory was 97 on 3 July. An additional 46 territorial males held territories without females on this date.

The first adult female arrived 26 May and gave birth the next day. Other females began arriving on 29 May and the onset of pupping occurred on 30 May.

Pup Census

A total of 2,452 live pups were counted in Adams Cove and at Castle Rock (Table 23). In Adams Cove, the mean count was 1,572 (SE = 10.7) pups. A mean of 880 pups (SE = 15.4) was calculated for pups on Castle Rock. These counts are the highest recorded since the discovery of the colony (Fig. 21).
Table 23.—Northern fur seal pup counts at Adams Cove and Castle Rock, San Miguel Island and total for San Miguel Island 1994. Number live and dead is the minimum number of pups in the population.

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>Mean Number Live</th>
<th>Number Dead</th>
<th>Total</th>
<th>% Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number SE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adams Cove</td>
<td>Jul 31</td>
<td>1,572</td>
<td>120</td>
<td>1692</td>
<td>7.1</td>
</tr>
<tr>
<td>Castle Rock</td>
<td>Aug 7</td>
<td>880</td>
<td>62</td>
<td>942</td>
<td>6.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2,452</td>
<td>182</td>
<td>2634</td>
<td>6.9</td>
</tr>
</tbody>
</table>

1Date of live pup count.
2Number of dead pups is a cumulative count over the season, beginning at the end of June; does not include mortalities early in the season.
3Should be used only as an index of pup mortality.
Figure 21. Northern fur seal pup counts at Adams Cove and Castle Rock and the total pup count for San Miguel Island, California, 1980-1994.
A minimum of 120 dead pups in Adams Cove were counted over the study season (Table 23). Several factors affect the accuracy of the dead pup counts in Adams Cove: 1) fur seals give birth near the beach crest and dead pups may get washed to sea between surveys, 2) Adams Cove is a sandy beach and dead pups may be buried between surveys and 3) pup mortality in June has not been assessed because California sea lions are also pupping and breeding at this time and are sensitive to disturbance. Therefore, it is important to note that the mortality estimate reported here is only useful in detecting trends in mortality over time. The minimum mortality rate for northern fur seal pups using the dead pup survey estimate was 7.1% for the Adams Cove population in 1994.

At Castle Rock, 62 dead pups were counted during a single survey (Table 23). The observed mortality rate of fur seal pups on Castle Rock was 6.6%. Castle Rock is a rocky substrate and dead pups are more likely to remain on the rookery for longer periods of time. However, a mortality estimate from a single survey may also underestimate the mortality because of decomposition of carcasses and because the survey is conducted a full month after the highest period of mortality has occurred.

Pup Growth

In 1994, the mean weights of male (x = 11.6 kg) and female (10.2 kg) pups were significantly greater than pups in 1993 (ANOVA, males: F = 37.25, P < .000, females: F = 16.9, P < .000)
Although the lengths were not different for pups in 1993 and 1994, the girth of males was significantly lower for pups in 1993 (ANOVA, $F = 15.5$, $P < .000$) (Table 24). The girths of female pups were lower in 1993 but the difference was not significant.

**Resight Effort**

Fifty-four tagged female and 82 tagged male fur seals were sighted throughout the season (Table 25). Nine cohorts were represented by the tagged individuals. Of the nine cohorts represented, over half of the resighted females were 5 or 6 years old (53.4%) and most of the males were between 4 and 6 years old (71.1%) (Table 25). The 14-year-old females were the oldest tagged animals sighted and two of these females were attending pups.

**Discussion**

**Population Monitoring**

The northern fur seal population at San Miguel Island continued to increase in 1994. Territorial bull counts and live pup counts, as indices of population growth, showed significant increases over 1993, at 28.6% and 16%, respectively. These increases, along with increased pup weights and girths, indicate that the northern fur seal population was no longer experiencing negative effects from the 1992-93 El Niño.

The arrival of females and the onset of pupping during the last week of May is similar to the dates observed in other
Table 24.—Length and girth of northern fur seal pups three months of age at Adams Cove, San Miguel Island in 1993 and 1994. P-value is derived from a one-way analysis of variance (ANOVA) by years.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean Length (cm)</th>
<th>P-value</th>
<th>Mean Girth (cm)</th>
<th>P-value</th>
<th>Mean Weight (kg)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>74</td>
<td>76.4±3.7</td>
<td></td>
<td>52.6±4.1</td>
<td></td>
<td>9.2±1.6</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>144</td>
<td>76.7±3.8</td>
<td>.61</td>
<td>53.7±4.3</td>
<td>0.08</td>
<td>10.2±1.7</td>
<td>0.00*</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>71</td>
<td>78.6±3.6</td>
<td></td>
<td>53.6±4.5</td>
<td></td>
<td>9.7±1.9</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>155</td>
<td>79.5±4.0</td>
<td>.12</td>
<td>56.2±4.6</td>
<td>0.00*</td>
<td>11.6±2.0</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

* Significant at $\alpha = .05$ 1994, the girth of males was significantly lower for pups in 1993 compared to 1994 (ANOVA, F = 15.5, P < .000). The girths of female pups were lower in 1993 relative to 1994, but the difference was not significant.
Table 25.—Number of tagged northern fur seals sighted at, Cove, San Miguel Island, California from May through August 1994.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>n</th>
<th>Number sighted</th>
<th>Percent of cohort sighted</th>
<th>Percent of 1994 sightings</th>
<th>n</th>
<th>Number sighted</th>
<th>Percent of cohort sighted</th>
<th>% of 1994 sightings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>102</td>
<td>4</td>
<td>3.92</td>
<td>7.41</td>
<td>104</td>
<td>0</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1985</td>
<td>43</td>
<td>2</td>
<td>4.65</td>
<td>3.70</td>
<td>56</td>
<td>4</td>
<td>7.14</td>
<td>4.88</td>
</tr>
<tr>
<td>1986</td>
<td>51</td>
<td>4</td>
<td>7.84</td>
<td>7.41</td>
<td>48</td>
<td>4</td>
<td>8.33</td>
<td>4.88</td>
</tr>
<tr>
<td>1987</td>
<td>56</td>
<td>3</td>
<td>5.36</td>
<td>5.56</td>
<td>43</td>
<td>5</td>
<td>11.63</td>
<td>6.10</td>
</tr>
<tr>
<td>1988</td>
<td>192</td>
<td>15</td>
<td>7.81</td>
<td>27.78</td>
<td>195</td>
<td>16</td>
<td>8.21</td>
<td>19.51</td>
</tr>
<tr>
<td>1989</td>
<td>159</td>
<td>16</td>
<td>10.06</td>
<td>29.63</td>
<td>195</td>
<td>30</td>
<td>15.38</td>
<td>36.58</td>
</tr>
<tr>
<td>1990</td>
<td>85</td>
<td>5</td>
<td>5.88</td>
<td>9.26</td>
<td>114</td>
<td>13</td>
<td>11.40</td>
<td>15.85</td>
</tr>
<tr>
<td>1992</td>
<td>163</td>
<td>0</td>
<td>----</td>
<td>----</td>
<td>136</td>
<td>1</td>
<td>0.01</td>
<td>1.22</td>
</tr>
</tbody>
</table>
non-El Niño years (Antonelis et al. 1988, Antonelis and DeLong 1985). During 1983 and 1993, the onset of pupping occurred after the first week of June, 1 week later than in normal years (Antonelis and DeLong 1985, Melin and DeLong 1994). Temte (1985) suggested that a specific photoperiod is required for implantation to occur in northern fur seal females. In years affected by El Niño conditions, the warmer sea surface temperatures may shift the distribution of northern fur seals farther north in search of prey. If females are distributed far enough north that the photoperiod required for the stimulation of hormones to initiate implantation is a week later, then the date of first birth would also be approximately a week later.

Physical condition probably also plays a role in the timing of reproductive events. Poorer physical condition during El Niño years may also affect implantation and gestation. The occurrence of the arrival of adult females and the first birth at approximately the same time in 1994 as in other non-El Niño years suggests that implantation occurred within the normal time period. This may be a reflection of a shift in the pelagic distribution of females to their normal feeding areas during the winter, improved physical condition of females, or a combination of these conditions during the winter of 1994.

The 1994 pup mortality rate in Adams Cove (7.1%) was the same as the 1993 mortality rate (Melin, unpublished data) but was lower than the 24% mortality rate observed in 1992 (Melin and DeLong 1994). The mortality rates for both Adams Cove and Castle Rock are higher than those observed for the Pribilof Island
population in 1990 (4.5%) (York and Fowler 1992) but lower than those reported by DeLong (1982) for San Miguel Island in the 1970s (22%). The difference in the mortality rates between the Pribilof and San Miguel Island populations may be due to differences in habitat. During each breeding season at San Miguel Island, at least 2 days and often more are extremely hot (in excess of 30°C). If these hot days occur early in the season, fur seal pups may die due to heat prostration (DeLong 1982). In addition, the majority of fur seal breeding territories are located along the beach crest and during periods of high tides. These tides may flood the breeding territories and pups may be washed to sea before they are able to swim efficiently. Neither of these conditions are characteristic of the Pribilof Island rookeries which perhaps accounts for the higher natural mortality rate seen at San Miguel Island.

The apparent difference in pup mortality rates for San Miguel Island between the 1970s and 1990s may be due to differences in survey methods. DeLong (1982) reported that during the period from 1969 to 1978, most pup mortalities (70%) occurred early in the season before the mean birthing date, and approximately 50% of all pup mortalities occurred within the first week of life. However, in these years, the fur seal population was small and breeding groups were located close to the blind site allowing accurate observation of births and deaths of individual pups. Because of redistribution of most of the fur seal territories far from the observation blinds in the 1980s, the method of assessing pup mortality has changed from assessing
mortality of individuals over the season to assessing overall mortality over periods of time. If most pups still die shortly after birth or within the first week, it is probable that a high percentage of pups that die were not observed during the first survey in each year in the 1990s. Therefore, the pup mortality rates reported for the 1990s should be used as indices of pup mortality only and an underestimate of the actual mortality. Since pup mortality has been assessed by the same methods in 1992, 1993, and 1994, the mortality rates reported for these years provide comparable estimates for assessing the trend in mortalities over the last 3 years.

The increase in the mean pup weight in 1994 from 1993 provides further evidence that the population was recovering from the effects of the El Niño. Mean pup weights are used as an index of pup health. Pup weights also reflect the health of the female because the weight gain is almost exclusively due to the volume and fat content of the female's milk. The return of pup weights to pre-El Niño levels supports the suggestion that females found sufficient prey during their foraging trips through the lactation period and were probably in better physical condition in 1994 than in 1993.

Girth is also an index of the physical condition of pups. The increase in pup girths in 1994 is further evidence that pups were in better condition in 1994 than in 1993 at 3 months of age. The similarity in lengths of pups in the 2 years suggests that pup growth was not retarded in 1993 despite El Niño conditions.

Assessment of survival of tagged northern fur seals at
San Miguel Island has become increasingly difficult because the population continues to establish territories along the beach crest, far from the observation blinds. In addition, the sympatric distributions of California sea lions and northern fur seals in Adams Cove has precluded tag reading early in the breeding season (in an attempt to minimize disturbance). Therefore, when evaluating the tag resight data, the lack of sightings of animals from specific cohorts does not necessarily mean that the animals were not present.

In 1994, resight efforts for tagged adult females were conducted on 3 days, but since a proportion of females are always at sea, not all tagged females in the population were observed. However, the distribution of females sighted from individual cohorts may represent their relative presence in the population. For example, the number of females sighted in 1994 from the 1989 cohort may suggest that these females occur in a higher proportion within the population than females from other cohorts.

Sub-adult and juvenile males are accessible throughout the season because they haul out in areas outside the California sea lion breeding areas. The lack of sighting of males from specific cohorts may more accurately reflect the absence of these cohorts on the rookery.

The low frequency of sighting older animals of either sex may be a result of relatively high tag loss on older animals (many individuals with only one tag or tag scars on both flippers). In addition, if animals retain their tags, the numbers are often worn and unreadable on older animals.
The absence of sightings of animals from the 1982-84 cohorts during 1994 is interesting. DeLong and Antonelis (1991) reported a complete loss of the 1983 cohort of northern fur seals, and to date no animals have been resighted from this cohort. The lack of sightings of animals from the 1982 and 1984 cohorts is difficult to explain, but may reflect of survival or more probably higher tag loss among older animals. The relationship of age and tag loss in fur seals is currently under investigation.

Fur Seals and El Niño

Although the 1992-93 El Niño exhibited similar oceanographic characteristics to the 1982-83 El Niño, it did not severely impact the northern fur seal population at San Miguel Island. The northern fur seal population experienced decreased pup production and high pup mortality in 1992, but in 1993, pup production increased and pup mortality decreased. In 1994, the increasing trend in population growth continued.

The question of survival of the 1992 and 1993 cohorts remains unanswered. These cohorts may experience a higher mortality in their first year because they were weaned at lower weights. These data should be obtained by the end of the 1996 breeding season.

The northern fur seal population at San Miguel Island provides a unique opportunity to study the population dynamics of a species breeding at the extreme of its range. In addition, northern fur seals at San Miguel Island are competing with another successful pinniped species (California sea lions) for
rookery space and forage resources. Current studies of the northern fur seal population at San Miguel Island focus on density-dependent (interspecific competition) and non-density-dependent (El Niño events) mechanisms of northern fur seal population regulation. These studies are important in understanding the dynamics of a rapidly expanding population that may potentially conflict with other species for the resources of the California Current ecosystem.
Acknowledgments

The authors wish to acknowledge the assistance of research associates and volunteers (Appendix E) without whom the fur seal program could not meet its extensive research goals. The editor acknowledges the reviewers (Jason Baker and Bud Antonelis), technical editors (Gary Duker and James Lee), and support staff of the Alaska Fisheries Science Center (AFSC) who have contributed extensively to the quality of this volume. A special thanks to Larry Merculief, The City of St. Paul employees, and the people of St. Paul Island, for their support of our research efforts on the island.

The frontispiece and chapter illustrations are from a water-color by Katherine Zecca (AFSC) based on photographs taken by numerous fur seal researchers including Bud Antonelis, Charles Fowler, Bruce Robson, and Paula White.


APPENDIX A

Glossary

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

Bachelor
Young male seals aged 2-5 years

Classification of adult male fur seals

Class 1
(shoreline) Full-grown males apparently attached to "territories" spaced along the water's edge at intervals of 10-15 m. Most of these animals are wet or partly wet, and some acquire harems of one to four females between 10 and 20 July. They would then be called harem males (class 3). Class 1 males should not be confused with Class 2 animals, which have definite territories, whereas the shoreline males appear to be attached to such sites but may not be in all cases.

Class 2
(territorial without females) Full-grown males that have no females, but are actively defending territories. Most of these animals are located on the inland fringe of a rookery: some are between Class 1(shoreline) and Class 3(territorial with females) males, and a few are completely surrounded by Class 3 males and their harems.

Class 3
(territorial with females) Full-grown males actively defending territories and females. Most Class 3 males and their harems combine to form a compact mass of animals. Isolated individuals, usually with small harems, may be observed at each end of a rookery, on sandy beaches, and in corridors leading to inland hauling grounds. Some
territorial males have as few as one or two females. Should these females be absent during counts, their pups are used as a basis for putting the adult male into Class 3 rather than Class 2.

**Class 4**
(territorial with females)

Full-and partly grown males on the inland fringe of a rookery. A few animals too young and too small to include in the count may be found here. Though some Class 4 males may appear to be holding territories, most will flee when approached or when prodded with a pole.

**Class 5**
(hauling grounds)

The hauling grounds contain males from May to late July and a mixture of males and females from then on. The counts include males that obviously are adults and all others that have a mane and the body conformation of an adult. Male included in the count are approximately 7 years of age and older.

**Drive**

The act of surrounding and moving groups of seals form one location to another.

**Hauling ground**

An area, usually near a rookery, on which nonbreeding seals congregate. See rookery.

**Haul out**

The act of seals moving from the sea onto shore at either a rookery or hauling ground.

**Kleptogyny**

The act of an adult male seal (primarily classes 1, 2, or 3) seizing an adult female from another male's territory.

**Known-age**

Refers to a seal whose age is known because the animal bears an inscribed tag or other type of mark.

**Marked**

Describes a seal that has been marked by attaching an inscribed metal or plastic tag to one or more of its flippers, by hair clipping, or by bleaching.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark recoveries</td>
<td>Recovery (sighting) of a seal that has been marked by one of several methods. See marked.</td>
</tr>
<tr>
<td>Rookery</td>
<td>An area on which breeding seals congregate. See Hauling ground.</td>
</tr>
<tr>
<td>Roundup</td>
<td>Biologists surround and herd juvenile male fur seals close to the location they haul out.</td>
</tr>
<tr>
<td>Vibrissae (facial whiskers)</td>
<td>To determine the relative age structure of females in a population, the color of their whiskers are used. Facial vibrissae are black at birth and remain black through age 3 years; become mixed (black and white) at ages 4 and 5 years; and by age 7, the vibrissae usually are entirely white.</td>
</tr>
</tbody>
</table>
APPENDIX B

Tabulations of adult male northern fur seals counted by rookery, size class, and rookery section

Table B-1.--Number of adult male northern fur seals counted, by class and rookery section, St. Paul Island, Alaska, 14-21 July 1994. A dash indicates no section...............................118

Table B-2.--Number of harem and idle males, pups born, number of rookeries sampled, standard deviation (SD) of the number of pups born and the number of dead pups on the Pribilof Islands, Alaska, 1975-1994. A double-dash indicates no data.................................119

Table B-3.--Number of northern fur seal pups sheared on each rookery of St. Paul Island and Sea Lion Rock, Alaska, 1994.................................120

Table B-4.--Number of dead northern fur seal pups counted by section on each rookery of St. Paul Island, Alaska, (including Sea Lion Rock), 1994........121

Table B-5.--Number of northern fur seal pups sheared on each rookery of St. George Island, Alaska, 1994........122

Table B-6.--Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 1994.................................122

Table B-7.--Number of dead northern fur seals counted that were older than pups, Pribilof Islands, Alaska, 1965-94. Teeth (n=88) (usually canines) were collected from most of these seals. A double-dash indicates no data.................................123
Appendix Table B-1.—Number of adult male northern fur seals counted, by class and rookery section, St. Paul Island, Alaska, 14-21 July 1994. A dash indicates no section.

<table>
<thead>
<tr>
<th>Rookery and</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>class of male</td>
<td>142</td>
<td>142</td>
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a See Glossary for a description of the classes of adult males seals.
b Numbers in parentheses are the adult males counted in Kitov Amphitheater.
c Numbers in parentheses are the adult males counted on the second point south of Sea Lion Neck.
d Numbers in parentheses are the adult males counted on Zapadni Point Reef.
Appendix Table B-2--Number of harem and idle males, pups born, number of rookeries sampled, standard deviation (SD) of the number of pups born and the number of dead pups on the Pribilof Islands, Alaska, 1975-94. A double-dash indicates no data.

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Appendix Table B-3—Number of northern fur seal pups sheared on each rookery of St. Paul Island and Sea Lion Rock, Alaska, 1994.

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Total** 20,153

* Numbers in () are for Kitovi Amphitheater and 2nd Point South of Morjovi.

** Total pups to be sheared is 10% times the total number of pups born in the previous pup estimate. Marks are allocated to section based on the number of harem bulls.
Appendix Table B-4--Number of dead northern fur seal pups counted by section on each rookery of St. Paul Island, Alaska (including Sea Lion Rock), 1994.

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Dead pups from Kitov Amphitheater (1) are included in sec.1 of Kitov.
Dead pups removed for necropsies from Reef and Vostochni are added but not by section.
Appendix Table B-5.--Number of northern fur seal pups sheared on each rookery of St. George Island, Alaska, 1994.

<table>
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Appendix Table B-6.--Number of dead northern fur seal pups counted by section on the rookeries of St. George Island, Alaska, 1994.

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Appendix Table B-7.—Number of dead northern fur seals counted that were older than pups, Pribilof Islands, Alaska, 1965–94. Teeth (n=88) (usually canines) were collected from most of these seals. A double-dash indicates no data.

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<td>22</td>
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</table>

^aA total of 70 dead fur seals of both sexes that were older than pups were counted on the rookeries of St. George Island.

^bIncludes 10 dead fur seals of unknown sex.

^cIncludes 16 dead fur seals of unknown sex.

^dIncludes 2 dead fur seals of unknown sex.
APPENDIX C

Sample size, mean weights, and standard deviation for male and female northern fur seal pups.

Table C-1.--Sample size (n), mean weights (w) and standard deviation (sd) for a sample of male and female pups on St. Paul Island, Alaska during August 1992 and 1994..........................126

Table C-2.--Sample size (n), mean weights (w) and standard deviation (sd) for a sample of male and female pups on St. George Island, Alaska during August 1992-94.........................127

Table C-3.--Sample size (n), mean length (l) and standard deviation (sd) for a sample of male and female pups on St. Paul Island, Alaska during August 1992 and 1994..........................128

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Table C-6.--Fraction of northern fur seal pups contributed by each sample rookery to total number of pups born on St. Paul Island, Alaska, and St. George Island, Alaska, 1994............................130

Table C-7.--Calculated t-statistics for comparison between years of mean mass of northern fur seals on St. Paul Island and St. George Island, Alaska. Significantly different years are in bold text...131

Table C-8.--Calculated t-statistics for comparison between years of mean lengths of northern fur seals on St. Paul Island and St. George Island, Alaska. Significantly different years are in bold text...131
Appendix Table C-1. Sample size (n), mean weights (w) and standard deviation (sd) for a sample of male and female pups on St. Paul Island, Alaska during August 1992 and 1994.

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Appendix Table C-2.—Sample size (n), mean weights (w) and standard deviation (SD) for a sample of male and female pups on St. George Island, Alaska during August 1992–94.

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Appendix Table C-3.—Sample size (n), mean length (l) and standard deviation (sd) for a sample of male and female pups on St. Paul Island, Alaska during August 1992 and 1994.

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Appendix Table C-4.—Sample size (n), mean length (l) and standard deviation (sd) for a sample of male and female pups on St. George Island, Alaska during August 1992–94.

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Appendix Table C-5.--Fraction of northern fur seal pups contributed by each sample rookery to total number of pups born on St. Paul Island, Alaska, 1992.

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Appendix Table C-6.--Fraction of northern fur seal pups contributed by each sample rookery to total number of pups born on St. Paul Island and St. George Island, Alaska, 1994.

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Appendix Table C-7.--Calculated t-statistics for comparison between years of mean mass of northern fur seals on St. Paul Island and St. George Island, Alaska. Significantly different years are in bold text.

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Appendix Table C-8.--Calculated t-statistics for comparison between years of mean lengths of northern fur seals on St. Paul Island and St. George Island, Alaska. Significantly different years are in bold text.

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APPENDIX D

Removal of debris from entangled seals

Table D-1. --Removal of entanglement debris from northern fur seals during research activities and subsistence harvests on St. Paul and St. George Islands, Alaska...................... 134

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<th>Debris type</th>
<th>Activity</th>
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</tr>
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<td>male</td>
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<td>Reef</td>
<td>male</td>
<td>3-4</td>
<td>trawl net</td>
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<td>male</td>
<td>3</td>
<td>cord</td>
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<td>-</td>
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<td>4</td>
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<td>-</td>
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<td>female</td>
<td>4</td>
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<td>8/26/94</td>
<td>Vostochni</td>
<td>male</td>
<td>juv</td>
<td>line</td>
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</tr>
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<td>-</td>
</tr>
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<tr>
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<td>Vostochni</td>
<td>male</td>
<td>2</td>
<td>trawl net</td>
<td>misc</td>
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<tr>
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<td>Vostochni</td>
<td>unk.</td>
<td>pup</td>
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**ST. GEORGE ISLAND**

<table>
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<th>Date</th>
<th>Location</th>
<th>Sex</th>
<th>Age</th>
<th>Debris type</th>
<th>Activity</th>
<th>Tag no.</th>
</tr>
</thead>
<tbody>
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</tr>
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<th>Age</th>
<th>Debris type</th>
<th>Activity</th>
<th>Tag no.</th>
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</thead>
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<tr>
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<td>male</td>
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<td>packing band</td>
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<td>shearing</td>
<td>1721</td>
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<tr>
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<td>East Cliffs</td>
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<td>shearing</td>
<td></td>
</tr>
<tr>
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<td>East Cliffs</td>
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<td>male</td>
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<td>trawl net</td>
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<td>1723</td>
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<tr>
<td>8/22/94</td>
<td>North</td>
<td>male</td>
<td>4</td>
<td>trawl net</td>
<td>shearing</td>
<td></td>
</tr>
<tr>
<td>8/23/94</td>
<td>East Cliffs</td>
<td>male</td>
<td>4</td>
<td>trawl net</td>
<td>shearing</td>
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</tr>
<tr>
<td>8/23/94</td>
<td>Staraya</td>
<td>male</td>
<td>adult</td>
<td>Misc net</td>
<td>shearing</td>
<td></td>
</tr>
<tr>
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<td>Staraya</td>
<td>male</td>
<td>3</td>
<td>packing band</td>
<td>shearing</td>
<td></td>
</tr>
<tr>
<td>8/24/94</td>
<td>Staraya</td>
<td>male</td>
<td>2-3</td>
<td>packing band</td>
<td>shearing</td>
<td></td>
</tr>
<tr>
<td>8/24/94</td>
<td>East Reef</td>
<td>male</td>
<td>3</td>
<td>packing band</td>
<td>shearing</td>
<td></td>
</tr>
<tr>
<td>8/24/94</td>
<td>East Reef</td>
<td>male</td>
<td>3</td>
<td>trawl net</td>
<td>shearing</td>
<td></td>
</tr>
<tr>
<td>8/24/94</td>
<td>North</td>
<td>female</td>
<td>adult</td>
<td>trawl net</td>
<td>shearing</td>
<td></td>
</tr>
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</table>
Appendix D-2.—Removal of debris from Northern fur seals on St. Paul and St. George Islands, Alaska, in 1994 listed by research activity.

<table>
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<tr>
<th></th>
<th>Subadult Male</th>
<th>Adult Male</th>
<th>Female</th>
<th>Pup</th>
<th>Unknown</th>
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<td></td>
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<tr>
<td>Bull counts</td>
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<td>9</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Harvest</td>
<td>15</td>
<td>4</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pup production</td>
<td>22</td>
<td>1</td>
<td>14</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Misc.</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>--</td>
</tr>
<tr>
<td><strong>St. George</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bull counts</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Harvest</td>
<td>6</td>
<td>1</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Pup production</td>
<td>14</td>
<td>--</td>
<td>4</td>
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<tr>
<td>Misc.</td>
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<td>--</td>
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</table>
Appendix Table D-3.—Debris removed from northern fur seals in 1993 shown by number and percent of total\(^1\) (in parentheses) for different age and sex categories.

<table>
<thead>
<tr>
<th></th>
<th>Trawl net fragments</th>
<th>Packing bands</th>
<th>Cord, rope and string</th>
<th>Monofilament net fragment</th>
<th>Crab pot bait bags</th>
<th>Misc. items</th>
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<tbody>
<tr>
<td><strong>St. Paul Island</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subadult males</td>
<td>32 (60.4)</td>
<td>10 (18.7)</td>
<td>6 (11.3)</td>
<td>-</td>
<td>-</td>
<td>5 (9.4)</td>
</tr>
<tr>
<td>All seals(^2)</td>
<td>48 (55.2)</td>
<td>20 (23.0)</td>
<td>11 (12.6)</td>
<td>1 (1.1)</td>
<td>3 (3.4)</td>
<td>8 (9.2)</td>
</tr>
<tr>
<td><strong>St. George Island</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subadult males</td>
<td>9 (40.9)</td>
<td>5 (22.7)</td>
<td>2 (9.1)</td>
<td>-</td>
<td>-</td>
<td>1 (4.5)</td>
</tr>
<tr>
<td>All seals</td>
<td>10 (45.5)</td>
<td>7 (31.8)</td>
<td>4 (18.2)</td>
<td>-</td>
<td>-</td>
<td>1 (4.5)</td>
</tr>
<tr>
<td><strong>St. Paul and St. George Islands</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Females(^3)</td>
<td>6 (30.0)</td>
<td>4 (20.0)</td>
<td>6 (30.0)</td>
<td>1 (5.0)</td>
<td>-</td>
<td>2 (10.0)</td>
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</table>

\(^1\)Net debris not identified specifically by material or gear type (unidentified net) was not used in percentage calculations (removed from 5 seals on St. Paul and 4 seals on St. George).

\(^2\)Males and females from all age classes.

\(^3\)Total number of females for both islands combined.
Appendix Table D-4.---Number of dead northern fur seal pups counted by section on rookeries of St. Paul Island, Alaska (including Sea Lion Rock), 1994.

<table>
<thead>
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<th>Rookery</th>
<th>Date</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14 necropsies</th>
<th>Total</th>
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<td>8/24</td>
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<td>74</td>
<td>79</td>
<td>50</td>
<td>55</td>
<td>27</td>
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<td>8/24</td>
<td>26</td>
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<tr>
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<td>139</td>
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<td>Vostochni</td>
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<td>16</td>
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<td>55</td>
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<td>42</td>
<td>68</td>
<td>234</td>
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<td>8460</td>
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</table>

---

1 Dead pups from Kitov Amphitheater (1) are included in sec. 1 of Kitovi

2 Dead pups removed for necropsies from Reef and Vostochni are added but not by section.
Appendix Table D-5.--Observed incidence and rate of female entanglement on St. Paul Island based on surveys of all major rookeries.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number Counted</th>
<th>Year Number</th>
<th>Rate (%)</th>
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<th>Entangled Scarred Ent + Scarred</th>
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<td>16009</td>
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Appendix Table D-6.--Change in entanglement among females at Reef Rookery during July and early August, 1992-94.

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APPENDIX E

Scientific staff engaged in northern fur seal field research in 1994

National Marine Mammal Laboratory (NMML)
Howard W. Braham, Director
Robert V. Miller, Deputy Director
Thomas R. Loughlin, Leader, Alaska Ecosystem Program
George A. Antonelis, Leader, Northern Fur Seal Program

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Appendix Table E.--continued.

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**Research Associates and Cooperators**

**Affiliation Code**
- COR - College of the Redwoods, California
- CSG - City of St. George, St. George Island, Alaska
- CSP - City of St. Paul, St. Paul Island, Alaska
- IND - Independent
- NBS - National Biological Survey, Anchorage, Alaska
- NMFSJ - National Marine Fisheries Service Regional Office, Juneau, Alaska
- NRIFS - National Research Institute of Far Seas Fisheries, Shimizu, Japan
- NSF - National Science Foundation, post-doctoral position
- UAF - University of Alaska, Fairbanks, Alaska
- UCSC - University California at Santa Cruz
- WPI - Wildlife Pathology International
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