

Appendix A. Raw data tables

Table A1. The raw data used for the central Gulf of Alaska.

| Year | Non-pup count | Pup count ¹ | <i>J/T</i> metric ⁶ | Sample size for <i>J/T</i> metric # of measurements (# of haul-outs) |
|------|--------------------|------------------------|--------------------------------|---|
| 1976 | 24678 ² | no data | no data | n.a. |
| 1977 | no data | no data | no data | n.a. |
| 1978 | 27155 ⁷ | 17835 | no data | n.a. |
| 1979 | 28460 ⁷ | 19886 | no data | n.a. |
| 1980 | no data | no data | no data | n.a. |
| 1981 | no data | no data | no data | n.a. |
| 1982 | no data | no data | no data | n.a. |
| 1983 | no data | no data | no data | n.a. |
| 1984 | no data | 15019 | no data | n.a. |
| 1985 | 19002 ² | no data | 0.3788 | 7182 (13) |
| 1986 | no data | 11598 | no data | n.a. |
| 1987 | no data | no data | no data | n.a. |
| 1988 | no data | no data | no data | n.a. |
| 1989 | 8552 ² | 6394 | 0.4843 | 3039 (11) |
| 1990 | 7050 ² | 4648 | 0.5025 | 2752 (16) |
| 1991 | 6273 ² | 4057 | 0.4801 | 2468 (16) |
| 1992 | 5721 ² | 3646 | 0.5255 | 2409 (19) |
| 1993 | no data | 3176 | no data | n.a. |
| 1994 | 4520 ³ | 2831 | 0.3706 | 2536 (19) |
| 1995 | no data | no data | no data | n.a. |
| 1996 | 3915 ³ | no data | 0.3698 | 1971 (17) |
| 1997 | 3352 ³ | 2056 | 0.4007 | 1924 (15) |
| 1998 | 3467 ⁴ | 1876 | 0.4095 | 2090 (16) |
| 1999 | no data | no data | no data | n.a. |
| 2000 | 3180 ⁴ | 1675 | 0.4769 | 2489 (17) |
| 2001 | no data | 1540 | no data | n.a. |
| 2002 | 3366 ⁴ | 1608 | 0.4483 | 2237 (18) |
| 2003 | no data | no data | no data | n.a. |
| 2004 | 3055 ⁵ | 1578 | no data | n.a. |

1. Based on the sum of the Marmot, Sugarloaf, Chowiet, Chirokof, and Outer Island

rookery's pup counts. Table 8 in Fritz, L. W. and C. Stinchcomb. 2005. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in the western stock in Alaska, June and July 2003 and 2004. U.S. Department of Commerce., NOAA Tech.

Memo. NMFS-AFSC-153, 56 p. and Sease, J. L., J. P. Lewis, D. C. McAllister, R. L. Merrick and S. M. Mello. 1993. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1992. U.S. Department of Commerce., NOAA Tech. Memo. NMFS-AFSC-17, per interpolation discussed in supplementary methods. The 1978 Outer Island, pup count was interpolated (interpolated value = 843) since the actual count was a rough estimate from a boat rather than a ground count.

2. The nonpup count here is the nonpup count for trend rookeries and haulouts. Table 4 in Sease, J. L., J. P. Lewis, D. C. McAllister, R. L. Merrick and S. M. Mello. 1993. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in Southeast Alaska, the Gulf of Alaska, and Aleutian Islands during June and July 1992. U.S. Department of Commerce., NOAA Tech. Memo. NMFS-AFSC-17.
3. Table 4 in Sease, J. L., and T. R. Loughlin. 1999. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in Alaska, June and July 1997 and 1998. U.S. Department of Commerce., NOAA Tech. Memo. NMFS-AFSC-100.
4. Table 3 in Sease, J. L., and C. J. Gudmundson. 2002. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) from the western stock in Alaska, June and July 2001 and 2002. U.S. Department of Commerce., NOAA Tech. Memo. NMFS-AFSC-100.
5. Table 4 in Fritz, L. W. and C. Stinchcomb. 2005. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) in the western stock in Alaska, June and July 2003 and 2004. U.S. Department of Commerce., NOAA Tech. Memo. NMFS-AFSC-153. This is the count adjusted for the increased accuracy of the new medium-format

photography which replaced the 35mm photographs used previously. This adjustment is based on a cross-validation discussed in Fritz and Stinchcomb (2005). The unadjusted count was 2944.

6. The J/T measurement method was initially presented in Holmes and York (2003). The measurements listed here do not exactly match those in Holmes and York (2003) since more haul-out measurements were taken to supplement those used in that paper.

7. Interpolated based on rookery only counts these years.

Table A2. The raw data used for the western Gulf of Alaska. Footnote references are the same as for Table A1 except where supplemental information is added below table.

| Year | Non-pup count | Pup count ¹ | <i>J/T</i> metric ⁶ | Sample size for <i>J/T</i> metric # of measurements (# of haul-outs) |
|------|--------------------|------------------------|--------------------------------|--|
| 1976 | 8311 ² | no data | no data | n.a. |
| 1977 | no data | no data | no data | n.a. |
| 1978 | 15229 ⁷ | no data | no data | n.a. |
| 1979 | 12128 ⁷ | 9351 | no data | n.a. |
| 1980 | no data | no data | no data | n.a. |
| 1981 | no data | no data | no data | n.a. |
| 1982 | no data | no data | no data | n.a. |
| 1983 | no data | no data | no data | n.a. |
| 1984 | no data | 5700 | no data | n.a. |
| 1985 | 6275 ² | 4985 | 0.3997 | 3225 (7) |
| 1986 | no data | no data | no data | n.a. |
| 1987 | no data | no data | no data | n.a. |
| 1988 | no data | no data | no data | n.a. |
| 1989 | 3908 ² | 2771 | 0.4356 | 808 (6) |
| 1990 | 3915 ² | 2271 | 0.4673 | 1130 (6) |
| 1991 | 3734 ² | 2036 | 0.4608 | 1569 (10) |
| 1992 | 3720 ² | 1879 | 0.5015 | 1960 (13) |
| 1993 | no data | 1857 | no data | n.a. |
| 1994 | 3982 ³ | 1662 | no data | n.a. |
| 1995 | no data | no data | no data | n.a. |
| 1996 | 3741 ³ | 1605 | 0.4247 | 3567 (17) |
| 1997 | 3633 ³ | no data | 0.4337 | 3525 (15) |
| 1998 | 3361 ⁴ | 1493 | 0.3927 | 2865 (16) |
| 1999 | no data | no data | no data | n.a. |
| 2000 | 2840 ⁴ | 1451 | 0.4443 | 1908 (17) |
| 2001 | no data | 1466 | no data | n.a. |
| 2002 | 3221 ⁴ | 1487 | 0.4273 | 1898 (18) |
| 2003 | no data | 1432 | no data | n.a. |
| 2004 | 3456 ⁵ | 1593 | no data | n.a. |

1. Pup count is the sum of counts on the Atkins, Chernabura, Clubbing Rocks and

Pinnacle Rocks rookeries.

Table A3. The raw data for the eastern Aleutian Islands. Footnote references are the same as for Table A1 except where supplemental information is added below table.

| Year | Non-pup count | Pup count ¹ | <i>J/T</i> metric ⁶ | Sample size for <i>J/T</i> metric # of measurements (# of haul-outs) |
|------|--------------------|------------------------|--------------------------------|--|
| 1975 | 19769 ² | no data | no data | n.a. |
| 1976 | 19743 | no data | no data | n.a. |
| 1977 | 19195 | no data | no data | n.a. |
| 1978 | no data | no data | no data | n.a. |
| 1979 | no data | no data | no data | n.a. |
| 1980 | no data | no data | no data | n.a. |
| 1981 | no data | no data | no data | n.a. |
| 1982 | no data | no data | no data | n.a. |
| 1983 | no data | no data | no data | n.a. |
| 1984 | no data | no data | no data | n.a. |
| 1985 | 7505 ² | 4778 | 0.4758 | 2717 (12) |
| 1986 | no data | no data | no data | n.a. |
| 1987 | no data | no data | no data | n.a. |
| 1988 | no data | no data | no data | n.a. |
| 1989 | 3032 ² | no data | 0.3674 | 215 (4) |
| 1990 | 3801 ² | 2075 | 0.5169 | 563 (3) |
| 1991 | 4231 ² | 2119 | 0.4687 | 879 (11) |
| 1992 | 4839 ² | no data | 0.4789 | 1564 (14) |
| 1993 | no data | 1879 | no data | n.a. |
| 1994 | 4421 ³ | 1756 | no data | n.a. |
| 1995 | no data | no data | no data | n.a. |
| 1996 | 4716 ³ | no data | 0.4232 | 1635 (16) |
| 1997 | no data | no data | 0.4709 | 2064 (15) |
| 1998 | 3847 ⁴ | 1474 | 0.4769 | 2661 (14) |
| 1999 | no data | no data | no data | n.a. |
| 2000 | 3840 ⁴ | 1516 | 0.4995 | 1996 (14) |
| 2001 | no data | no data | no data | n.a. |
| 2002 | 3956 ⁴ | 1525 | 0.4400 | 2234 (19) |
| 2003 | no data | no data | no data | n.a. |
| 2004 | 4707 ⁵ | 1744 | no data | n.a. |

1. Pup count is a sum of pup counts on the Adugak, Akun, Akutan, Bogoslof, and Ugamak rookeries.

Appendix B. Effect of haul-out sites on the J/T metric

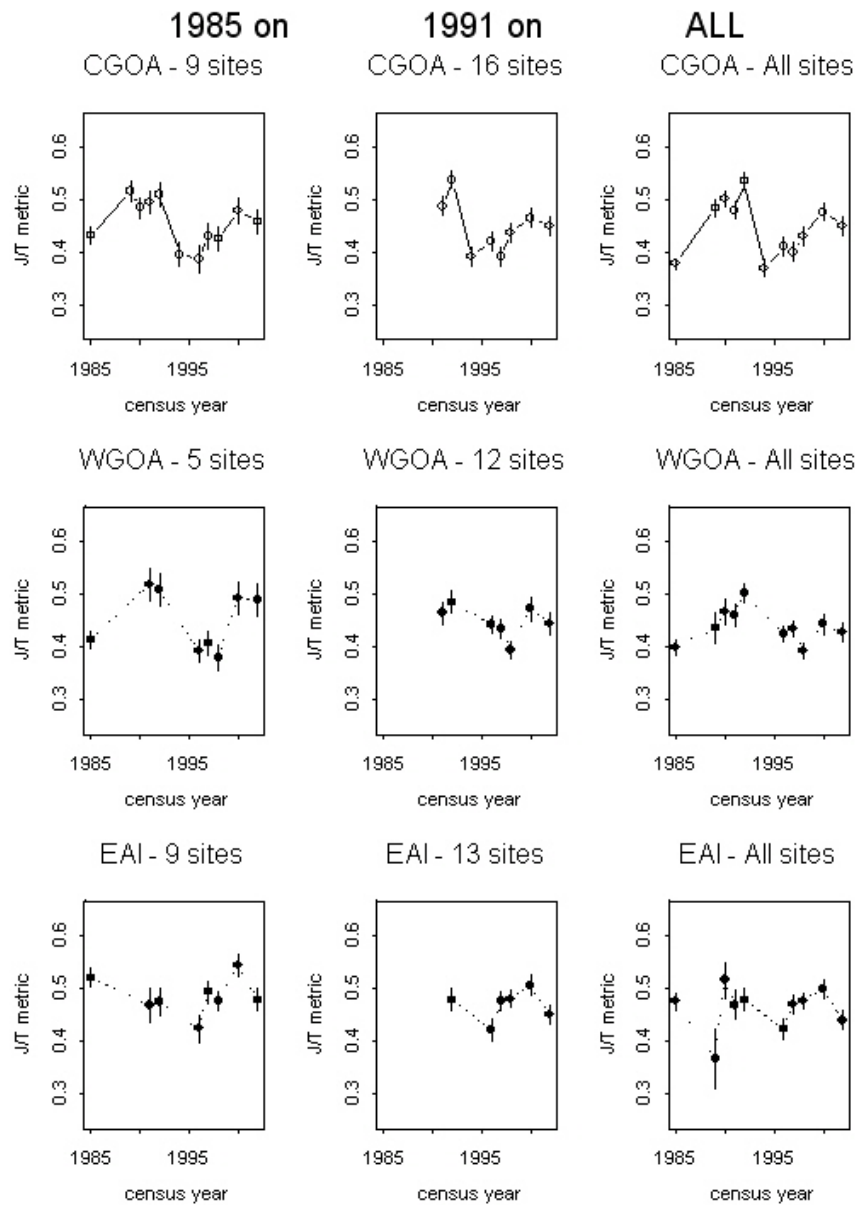


Figure B1. The J/T metric using only those haul-outs that were surveyed every year (left panels), using those surveyed regularly in the 1990s (middle panels), and using every photographed haul-out (right panels).

Appendix C. Life-history matrices

The 32 x 32 female-only age-structured life-history matrix for Steller sea lions (\mathbf{A} in Eq. 3 in the main text) is shown in Table 1 (main text). The matrix is a birth-pulse Leslie matrix where row 1 column i is the number of 1-month old pups produced by age $i+1$ females multiplied by the survival rate from age i to age $i+1$. Thus when the matrix multiplication, $\vec{N}_{t+1} = \mathbf{A} \times \vec{N}_t$, is performed, the first element of \vec{N}_{t+1} is the female pup numbers (at 1-month of age) in year $t+1$. Rows i , $i > 1$, in the matrix contain the survivorships from age i to $i+1$, along the diagonal. The s_i and f_i terms in \mathbf{A} have been estimated different ways in different published studies based on data from 1975 to 1978 on Marmot Island, and these different estimates give rise to the four different life-history matrices are used in this study. Although each matrix is based on a published matrix, there are some slight modifications, namely an increasing juvenile survivorship pattern across all matrices and inclusion of neonate survivorship. The number of female 1-month old pups produced by females of age i equals f_i , the late-term pregnancy rate times 0.5 to get female fetuses only, multiplied by s_n , neonate survivorship from age 0 (late-term fetus) to age 1-month when the pup survey occurs. This early pup survivorship was estimated as 0.949 from the average of the fraction of dead pups observed during the 1978 and 1979 pup counts in the CGOA: 492 (dead) to 6720 (live) in 1978 and 526 (dead) to 14763 (live) in 1979. The rest of the s_i and f_i terms which specify the survivorship and fecundity schedule for each matrix are discussed below and are given in Table C1.

A matrix based on Calkins and Pitcher (1982) – CP matrix

For this matrix, the survivorships, s_i , were those estimated originally by Calkins and Pitcher (1982) as presented in their Table 24. These estimates are from the age-distribution observed in the longitudinal sample of Steller sea lions around Marmot Island in the 1970s, which was done by shooting a random sample of animals from the population. Given their smaller size and lack representation near rookeries, individuals younger than 3 years were not equally sampled and were excluded from the analyses. Age was determined by counting the enamel layers in cross-sections of the canine teeth, and pregnancy rates were determined from pregnancies observed in the sampled females. The survivorships in Table C1 are taken from York (1994) Table 1 with the exception of s_0 , s_1 and s_2 . Juvenile survivorship could not be estimated directly from the data. Instead, York (1994) and Calkins and Pitcher (1982), set juvenile survivorship such that the resulting matrix would be stable (maximum eigenvalue equals 1.0). York (1994) made juvenile survivorship equal for the 1st three years while Calkins and Pitcher (1982) had juvenile survivorship increasing with age. In this analysis, we used Calkins and Pitcher's method, which eliminates a sudden jump from older juvenile survival to young adult survival. Thus s_1 and s_2 increase linearly from s_0 towards s_3 , and s_0 is set so that the matrix is stable. Late-term pregnancy rate, f_i , is based on 'percent mature' x 'birth rate' in Table 26 in Calkins and Pitcher (1982) x 0.5 pup sex ratio. 'birth rate' is not precisely birth rate, however, rather it is late-term pregnancy rate. The f_i given in Table C1 are from York (1994), Table 1. Note that the age or i column in both York (1994) and Calkins and Pitcher (1982) is confusing. Early maturing females first become mature at age 3 but give birth at age 4, so f_i is 0 for age 0-3.

Winship and Trites (2006) used a very generic model of Steller sea lions based on the Calkins and Pitcher survivorship and fecundity schedules. The matrix (Table C1) has high adult survivorship, lower age 1-3 survivorship, and a uniform late-term pregnancy rate after age 5. For this study, we changed juvenile survivorship so that juvenile survivorship increased linearly from s_0 to s_4 as for the other matrices. If this is not done, the time-varying model can have the biologically odd behavior of high juvenile survivorship (age 1-3) followed by a sudden step-drop to a much lower survivorship at age 4. No animals are allowed to live beyond age 20 in this model, thus the model has fecundity senescence of a sort since no animals give birth after age 20.

Matrix based on York (1994)'s re-analysis of survivorship rates – Y matrix

The Calkins and Pitcher (1982) survivorships result in an equilibrium age-distribution that does not precisely fit the observed age-distribution. York (1994) re-estimated the Calkins and Pitcher (1982) survivorships using a Weibull hazard model which is a standard model for survivorship. The re-estimated survivorships result in an age-distribution that closely matches the sampled cumulative age-distribution. Table C1 gives the re-estimated survivorship schedule.

There are two differences between the matrix used in this paper and the matrix published in York (1994) in Table 1 in that paper. York (1994) made juvenile survivorship equal for the 1st three years. Here, we used Calkins and Pitcher's method as above and allowed juvenile survivorship to increase with age. Thus s_1 and s_2 were set to increase linearly from s_0 towards s_3 , and s_0 adjusted so that the matrix is stable. The second difference is in the f_i terms. In the matrix described in York (1994), females

erroneously give birth the year that they become pregnant, whereas females give birth in the year after becoming pregnant. Thus the fecundities should be shifted forward by one year. This error is corrected in the f_i values given in Appendix A. This same error appears in the matrix given in Holmes and York (2003). This error does not change the conclusions of either paper, although it does change slightly the estimated natality rate in Holmes and York (2003).

Cited Literature

- Calkins, D. G., and K. W. Pitcher. 1982. Population assessment, ecology and trophic relationships of Steller sea lions in the Gulf of Alaska. Final Report 17, U.S. Department of Commerce, Washington, D. C.
- Holmes, E. E., and A. E. York. 2003. Using age structure to detect impacts on threatened populations: a case study using Steller sea lions. *Conservation Biology* **17**:1794-1806.
- Winship, A. J., and A. W. Trites. 2006. Risk of extirpation of Steller sea lions in the Gulf of Alaska and Aleutian Islands: a population viability analysis based on alternative hypotheses for why sea lions declined in Western Alaska. *Marine Mammal Science* **23**:124-155.
- York, A. E. 1994. The population dynamics of northern sea lions, 1975–1985. *Marine Mammal Science* **10**:38–51.

Table C1. Fecundity and survivorships terms used in the four life-history matrices.

Matrix codes refer to matrices based on different papers: WT (Winship and Trites 2006), CP (Calkins and Pitcher 1982), Y (York 1994), and HFYS (this paper). In all matrices, $s_n = 0.949$.

| <i>i</i> | f_i | f_i | f_i | f_i | s_i | s_i | s_i | s_i |
|----------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| age | WT | CP | Y | HFYS | WT | CP | Y | HFYS |
| 0* | 0 | 0 | 0 | 0 | 0.8001 ³ | 0.7420 ³ | 0.7680 ³ | 0.7845 ³ |
| 1 | 0 | 0 | 0 | 0 | 0.8334 ³ | 0.7840 ³ | 0.8221 ³ | 0.8331 ³ |
| 2 | 0 | 0 | 0 | 0 | 0.8667 ³ | 0.8260 ³ | 0.8761 ³ | 0.8316 ³ |
| 3 | 0 | 0 | 0 | 0 | 0.9 | 0.8680 ¹ | 0.9302 ¹ | 0.9302 ¹ |
| 4 | 0 | 0.1008 ¹ | 0.1008 ¹ | 0.0480 ² | 0.9 | 0.8790 | 0.9092 | 0.9092 |
| 5 | 0.315 | 0.17955 | 0.17955 | 0.1695 | 0.9 | 0.8880 | 0.8951 | 0.8951 |
| 6 | 0.315 | 0.26145 | 0.26145 | 0.2215 | 0.9 | 0.8930 | 0.8839 | 0.8839 |
| 7 | 0.315 | 0.315 | 0.315 | 0.27950 | 0.9 | 0.8980 | 0.8746 | 0.8746 |
| 8 | 0.315 | 0.315 | 0.315 | 0.3285 | 0.9 | 0.8740 | 0.8665 | 0.8665 |
| 9 | 0.315 | 0.315 | 0.315 | 0.3285 | 0.9 | 0.8990 | 0.8593 | 0.8593 |
| 10 | 0.315 | 0.315 | 0.315 | 0.3285 | 0.9 | 0.8930 | 0.8527 | 0.8527 |
| 11 | 0.315 | 0.315 | 0.315 | 0.3885 | 0.9 | 0.8960 | 0.8468 | 0.8468 |
| 12 | 0.315 | 0.315 | 0.315 | 0.3885 | 0.9 | 0.8950 | 0.8412 | 0.8412 |
| 13 | 0.315 | 0.315 | 0.315 | 0.3885 | 0.9 | 0.8950 | 0.8360 | 0.8360 |
| 14 | 0.315 | 0.315 | 0.315 | 0.3885 | 0.9 | 0.8950 | 0.8312 | 0.8312 |
| 15 | 0.315 | 0.315 | 0.315 | 0.3885 | 0.9 | 0.8950 | 0.8266 | 0.8266 |
| 16 | 0.315 | 0.315 | 0.315 | 0.3885 | 0.9 | 0.8950 | 0.8223 | 0.8223 |

| | | | | | | | | |
|----|-------|-------|-------|--------|-----|--------|--------|--------|
| 17 | 0.315 | 0.315 | 0.315 | 0.2570 | 0.9 | 0.8950 | 0.8182 | 0.8182 |
| 18 | 0.315 | 0.315 | 0.315 | 0.2570 | 0.9 | 0.8950 | 0.8142 | 0.8142 |
| 19 | 0.315 | 0.315 | 0.315 | 0.2570 | 0.9 | 0.8950 | 0.8105 | 0.8105 |
| 20 | 0.315 | 0.315 | 0.315 | 0.2570 | 0.9 | 0.8950 | 0.8069 | 0.8069 |
| 21 | 0.315 | 0.315 | 0.315 | 0.2570 | 0 | 0.8950 | 0.8034 | 0.8034 |
| 22 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.8001 | 0.8001 |
| 23 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7968 | 0.7968 |
| 24 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7937 | 0.7937 |
| 25 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7907 | 0.7907 |
| 26 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7878 | 0.7878 |
| 27 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7850 | 0.7850 |
| 28 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7822 | 0.7822 |
| 29 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7795 | 0.7795 |
| 30 | 0 | 0.315 | 0.315 | 0 | 0 | 0.8950 | 0.7769 | 0.7769 |
| 31 | 0 | 0.315 | 0.315 | 0 | 0 | 0 | 0 | 0 |

f_i is the fraction of age i females with late-term pregnancies $\times 0.5$ to get female fetuses only (note age i females mate and become impregnated at age $i-1$). s_i is the survivorship from age i to $i+1$.

* age 0 denotes 1-month of age which is the age of pups when the survey occurs.

1. Table 1 from York (1994). Note that in Table 1 (York 1994) the age 'To' column represents the numbering for f_i , whereas the age 'From' column represents the numbering for s_i .
2. Re-estimated in this paper from the original 1970s data. See notes above.

3. s_1 and s_2 increase linearly from s_0 towards s_3 , and s_0 is set so that the dominant eigenvalue of the matrix is equal to 1 (meaning a stable population).

Appendix D. Parameter estimates and AIC_c values for model fits

Table D1. Maximum-likelihood estimates of the historical survivorship and birth rate relative to pre-decline levels. The number of free parameters, K , is the number of scaling factors, 3, times the number of time periods, 3 to 4, plus 3 constants, p_1, p_2, p_3 , and the 3 variances in the likelihood function. $p_{j,k}$ is the scaling factor for juvenile survivorship in time period k . Juvenile survivorship in time period k is (pre-decline juvenile survivorship) $\times p_{j,k}$. $p_{a,k}$ is the scaling factor for adult survivorship in time period k . $p_{f,k}$ is the scaling factor for birth rate in time period k . For all models, the first time period starts in 1983, and the second starts in 1988. The third and fourth (if present) start in the first and second years in column 1, respectively. The Leslie matrices are described in Appendix C.

| Time periods | Leslie matrix | ΔAIC_c | K | $p_{j,1}$ | $p_{j,2}$ | $p_{j,3}$ | $p_{j,4}$ | $p_{f,1}$ | $p_{f,2}$ | $p_{f,3}$ | $p_{f,4}$ | $p_{a,1}$ | $p_{a,2}$ | $p_{a,3}$ | $p_{a,4}$ |
|--------------|---------------|----------------|-----|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1997 | HFYS | 5.454 | 15 | 0.436 | 0.877 | 1.241 | - | 0.908 | 0.841 | 0.813 | - | 0.879 | 0.921 | 0.963 | - |
| 1997 | Y | 7.884 | 15 | 0.421 | 0.882 | 1.267 | - | 0.891 | 0.846 | 0.809 | - | 0.89 | 0.913 | 0.957 | - |
| 1997 | CP | 15.133 | 15 | 0.443 | 0.93 | 1.311 | - | 0.924 | 0.873 | 0.83 | - | 0.872 | 0.892 | 0.952 | - |
| 1997 | WT | 4.9 | 15 | 0.506 | 0.928 | 1.25 | - | 0.931 | 0.86 | 0.813 | - | 0.863 | 0.902 | 0.965 | - |
| 1998 | HFYS | 7.148 | 15 | 0.43 | 0.911 | 1.241 | - | 0.903 | 0.839 | 0.787 | - | 0.881 | 0.918 | 0.981 | - |
| 1998 | Y | 10.631 | 15 | 0.41 | 0.911 | 1.267 | - | 0.885 | 0.844 | 0.81 | - | 0.893 | 0.91 | 0.971 | - |

| | | | | | | | | | | | | | | | |
|-----------|------|--------|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1998 | CP | 17.332 | 15 | 0.442 | 0.998 | 1.311 | - | 0.929 | 0.902 | 0.84 | - | 0.869 | 0.882 | 0.963 | - |
| 1998 | WT6 | 10.993 | 15 | 0.504 | 0.952 | 1.25 | - | 0.934 | 0.869 | 0.844 | - | 0.863 | 0.899 | 0.971 | - |
| 1999 | HFYS | 12.193 | 15 | 0.39 | 0.901 | 1.241 | - | 0.897 | 0.829 | 0.813 | - | 0.885 | 0.925 | 0.996 | - |
| 1999 | Y | 17.131 | 15 | 0.454 | 0.955 | 1.267 | - | 0.899 | 0.871 | 0.872 | - | 0.886 | 0.897 | 0.976 | - |
| 1999 | CP | 22.312 | 15 | 0.393 | 0.991 | 1.311 | - | 0.913 | 0.872 | 0.879 | - | 0.878 | 0.888 | 0.974 | - |
| 1999 | WT | 17.42 | 15 | 0.487 | 0.945 | 1.25 | - | 0.925 | 0.844 | 0.865 | - | 0.866 | 0.905 | 0.988 | - |
| 1992;1997 | HFYS | 0 | 18 | 0.42 | 0.734 | 0.565 | 0.935 | 0.869 | 0.762 | 0.703 | 0.641 | 0.899 | 0.928 | 1.002 | 1.068 |
| 1992;1997 | Y | 3.46 | 18 | 0.465 | 0.787 | 0.603 | 0.967 | 0.882 | 0.805 | 0.701 | 0.613 | 0.894 | 0.916 | 0.988 | 1.053 |
| 1992;1997 | CP | 6.385 | 18 | 0.481 | 0.818 | 0.621 | 0.998 | 0.903 | 0.827 | 0.725 | 0.628 | 0.882 | 0.889 | 0.965 | 1.029 |
| 1992;1997 | WT | 6.197 | 18 | 0.453 | 0.731 | 0.592 | 0.894 | 0.887 | 0.755 | 0.67 | 0.585 | 0.884 | 0.921 | 0.989 | 1.077 |
| 1993;1997 | HFYS | 7.341 | 18 | 0.42 | 0.739 | 0.591 | 0.986 | 0.871 | 0.754 | 0.724 | 0.657 | 0.898 | 0.934 | 1 | 1.053 |
| 1993;1997 | Y | 10.365 | 18 | 0.493 | 0.827 | 0.666 | 1.054 | 0.89 | 0.82 | 0.732 | 0.645 | 0.889 | 0.908 | 0.978 | 1.029 |
| 1993;1997 | CP | 14.262 | 18 | 0.506 | 0.85 | 0.675 | 1.08 | 0.91 | 0.834 | 0.754 | 0.657 | 0.877 | 0.887 | 0.961 | 1.013 |
| 1993;1997 | WT | 9.436 | 18 | 0.491 | 0.794 | 0.682 | 0.998 | 0.905 | 0.783 | 0.707 | 0.621 | 0.876 | 0.915 | 0.976 | 1.045 |
| 1992;1998 | HFYS | 4.161 | 18 | 0.42 | 0.74 | 0.622 | 0.974 | 0.871 | 0.761 | 0.7 | 0.646 | 0.899 | 0.929 | 0.998 | 1.075 |

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|-----------|------|--------|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1992;1998 | Y | 8.877 | 18 | 0.451 | 0.783 | 0.635 | 0.982 | 0.874 | 0.784 | 0.684 | 0.615 | 0.899 | 0.922 | 0.986 | 1.069 |
| 1992;1998 | CP | 9.504 | 18 | 0.428 | 0.772 | 0.611 | 0.968 | 0.882 | 0.78 | 0.69 | 0.608 | 0.893 | 0.901 | 0.969 | 1.056 |
| 1992;1998 | WT | 17.248 | 18 | 0.552 | 0.778 | 0.798 | 1.104 | 0.909 | 0.792 | 0.719 | 0.67 | 0.874 | 0.902 | 0.958 | 1.031 |
| 1993;1998 | HFYS | 10.82 | 18 | 0.395 | 0.712 | 0.627 | 0.966 | 0.864 | 0.738 | 0.708 | 0.647 | 0.902 | 0.941 | 1.006 | 1.075 |
| 1993;1998 | Y | 16.075 | 18 | 0.523 | 0.868 | 0.823 | 1.191 | 0.897 | 0.835 | 0.757 | 0.706 | 0.885 | 0.898 | 0.951 | 1.005 |
| 1993;1998 | CP | 17.738 | 18 | 0.479 | 0.828 | 0.716 | 1.085 | 0.896 | 0.801 | 0.727 | 0.649 | 0.885 | 0.893 | 0.959 | 1.03 |
| 1993;1998 | WT | 17.327 | 18 | 0.543 | 0.829 | 0.869 | 1.164 | 0.92 | 0.815 | 0.747 | 0.697 | 0.869 | 0.902 | 0.952 | 1.011 |
| 1992;1999 | HFYS | 12.072 | 18 | 0.433 | 0.731 | 0.678 | 1.034 | 0.868 | 0.757 | 0.694 | 0.668 | 0.898 | 0.927 | 0.998 | 1.075 |
| 1992;1999 | Y | 17.105 | 18 | 0.47 | 0.779 | 0.684 | 1.013 | 0.88 | 0.794 | 0.679 | 0.628 | 0.895 | 0.918 | 0.99 | 1.075 |
| 1992;1999 | CP | 16.272 | 18 | 0.378 | 0.695 | 0.578 | 0.897 | 0.871 | 0.753 | 0.653 | 0.593 | 0.9 | 0.911 | 0.987 | 1.081 |
| 1992;1999 | WT | 22.803 | 18 | 0.594 | 0.796 | 0.935 | 1.25 | 0.923 | 0.825 | 0.776 | 0.748 | 0.868 | 0.888 | 0.938 | 1.005 |
| 1993;1999 | HFYS | 15.595 | 18 | 0.409 | 0.705 | 0.691 | 1.013 | 0.865 | 0.738 | 0.703 | 0.663 | 0.901 | 0.939 | 1.007 | 1.075 |
| 1993;1999 | Y | 20.396 | 18 | 0.55 | 0.867 | 0.937 | 1.266 | 0.909 | 0.86 | 0.792 | 0.752 | 0.879 | 0.89 | 0.939 | 0.992 |
| 1993;1999 | CP | 22.458 | 18 | 0.597 | 0.916 | 0.964 | 1.311 | 0.943 | 0.904 | 0.827 | 0.778 | 0.862 | 0.866 | 0.927 | 0.983 |
| 1993;1999 | WT | 21.272 | 18 | 0.574 | 0.828 | 0.964 | 1.25 | 0.93 | 0.838 | 0.786 | 0.746 | 0.865 | 0.894 | 0.942 | 1 |

Table D2. Maximum-likelihood estimates of the constants and variances for each model. See text for explanation of the constants. p_1 translates to the expected average number (x 1000) of pre-decline female pups in the CGOA. The value, p_2 , from column 4 is the scaling factor that translates the nonpup trend count into the total (unobserved) number of nonpup females in the population: $(1/p_2) \times \text{nonpup trend count} = \text{total number (unobserved) of nonpup females}$. p_3 is the scaling factor for the juvenile-fraction metric (see text).

| Time periods | Leslie matrix | p_1 ($\div 1000$) | p_2 | p_3 | σ^2 | σ^2 | σ^2 |
|--------------|---------------|--------------------------|-------|-------|-------------------|----------------|------------------|
| | | | | | nonpup (x1000) | pup (x1000) | J/T (x1000) |
| 1997 | HFYS | 9.52 | 0.458 | 0.359 | 3.097 | 0.914 | 2.761 |
| 1997 | Y | 9.50 | 0.478 | 0.368 | 3.121 | 0.892 | 3.555 |
| 1997 | CP | 9.52 | 0.498 | 0.379 | 3.662 | 1.183 | 3.68 |
| 1997 | WT | 9.53 | 0.446 | 0.37 | 3.659 | 0.794 | 2.521 |
| 1998 | HFYS | 9.53 | 0.456 | 0.359 | 4.362 | 0.811 | 2.392 |
| 1998 | Y | 9.51 | 0.478 | 0.369 | 4.744 | 0.749 | 3.254 |
| 1998 | CP | 9.52 | 0.5 | 0.405 | 5.575 | 0.955 | 3.431 |

| | | | | | | | |
|-----------|-------|------|-------|-------|-------|-------|-------|
| 1998 | WT | 9.50 | 0.452 | 0.377 | 5.66 | 0.873 | 2.227 |
| 1999 | HFYS | 9.51 | 0.462 | 0.347 | 5.497 | 0.8 | 2.81 |
| 1999 | Y | 9.50 | 0.482 | 0.396 | 6.719 | 0.847 | 3.15 |
| 1999 | CP | 9.51 | 0.502 | 0.387 | 7.452 | 0.891 | 4.023 |
| 1999 | WT | 9.51 | 0.452 | 0.364 | 7.683 | 0.908 | 2.409 |
| 1992;1997 | HFYS | 9.52 | 0.458 | 0.229 | 2.403 | 0.934 | 0.527 |
| 1992;1997 | Y1994 | 9.52 | 0.472 | 0.253 | 2.426 | 1.195 | 0.501 |
| 1992;1997 | CP | 9.53 | 0.496 | 0.254 | 2.742 | 1.312 | 0.483 |
| 1992;1997 | WT | 9.52 | 0.45 | 0.22 | 2.762 | 1.148 | 0.571 |
| 1993;1997 | HFYS | 9.53 | 0.456 | 0.241 | 2.538 | 0.917 | 0.975 |
| 1993;1997 | Y | 9.53 | 0.47 | 0.287 | 2.534 | 1.178 | 0.901 |
| 1993;1997 | CP | 9.54 | 0.494 | 0.284 | 2.956 | 1.257 | 0.946 |
| 1993;1997 | WT | 9.53 | 0.446 | 0.259 | 2.77 | 0.992 | 0.937 |
| 1992;1998 | HFYS | 9.51 | 0.458 | 0.233 | 3.158 | 0.883 | 0.576 |
| 1992;1998 | Y | 9.52 | 0.474 | 0.246 | 3.845 | 1.106 | 0.49 |

| | | | | | | | |
|-----------|------|------|-------|-------|-------|-------|-------|
| 1992;1998 | CP | 9.52 | 0.498 | 0.224 | 4.279 | 1.062 | 0.475 |
| 1992;1998 | WT | 9.53 | 0.444 | 0.282 | 3.175 | 1.002 | 1.56 |
| 1993;1998 | HFYS | 9.52 | 0.458 | 0.227 | 3.132 | 0.912 | 1.019 |
| 1993;1998 | Y | 9.53 | 0.468 | 0.331 | 3.359 | 0.938 | 1.425 |
| 1993;1998 | CP | 9.53 | 0.494 | 0.269 | 4.164 | 1.088 | 1.001 |
| 1993;1998 | WT | 9.54 | 0.444 | 0.31 | 3.051 | 0.971 | 1.729 |
| 1992;1999 | HFYS | 9.54 | 0.456 | 0.242 | 3.219 | 0.935 | 1.048 |
| 1992;1999 | Y | 9.52 | 0.472 | 0.255 | 3.489 | 1.527 | 0.737 |
| 1992;1999 | CP | 9.52 | 0.5 | 0.194 | 3.712 | 1.418 | 0.702 |
| 1992;1999 | WT | 9.53 | 0.444 | 0.328 | 3.125 | 0.949 | 2.852 |
| 1993;1999 | HFYS | 9.53 | 0.456 | 0.237 | 2.813 | 1.026 | 1.543 |
| 1993;1999 | Y | 9.52 | 0.47 | 0.364 | 2.976 | 0.999 | 2.287 |
| 1993;1999 | CP | 9.50 | 0.494 | 0.377 | 3.006 | 1.215 | 2.074 |
| 1993;1999 | WT | 9.53 | 0.444 | 0.338 | 2.849 | 0.972 | 2.724 |

Appendix E. Summary of studies with estimates of percent time animals are resting on land

Table E1. Summary of studies which report the proportion of time onshore for Steller sea lions. Some studies do not adjust for the tendency of Steller sea lions to forage at night and haul-out on land during the day. In this case, the proportion of time onshore is an underestimate of daytime sightability. All studies are from the Gulf of Alaska except Higgins et al. (1988).

| Reference | Type of animal | Proportion of time onshore | Year, Location, Season, Method |
|---|--|--|--|
| Brandon (2000, Table 3.2) | Females nursing pups on rookery | 63% ¹ | 1993, Chirikof Is. (CGOA), June/July Satellite tracking |
| Call et al. (2007), K. Call, pers. comm.. | Juveniles age 11-25 months | 43% ² | CGOA, June/July Satellite tracking |
| Higgins et al. (1988, Figure 2) | Females nursing 8-14 day old pups on rookery Females nursing 15-21 day old pups on rookery Females nursing 35-47 day old pups on rookery | 60% ² 40% ² 30% ² | 1983, Ana Nuevo Is., CA, June/July Observation of focal animals |
| Loughlin et al. (2003, Table 1) | Juveniles age 11-12 mos. (3 animals) | 50% ² | 1994-2000, GOA & Aleutians, May/June Satellite tracking |
| Maniscalco et al. (2006) | Adult females on rookery: pups < ~60 days old Adult females on rookery: pups > ~60 days old | 59% ¹ 36% ¹ | June 1-August 18, 2001-2004, CGOA August 18 – Nov 1, 2002-2004, CGOA Observation of focal animals on rookery |

| | | | |
|--|---|---|--|
| Merrick and Loughlin (1997) | Females nursing pups on rookery (7 animals) Females nursing yearling (2 animals) and females with no pup (3 animals) | 48.5% ¹ 10.1% ¹ | 1988-1993, GOA & Aleutians, June/July 1988-1993, GOA&Aleutians, Nov-March Satellite tracking |
| Milette and Trites (2003, Table 2 and Figure 3) Milette (1999, Table 3.2) | Females nursing 15-day old pups on rookery Females nursing 47-day old pups on rookery | 66% ¹ 40% ¹ | 1994/1995, Sugarloaf Is. (CGOA), May-Aug Video analysis of marked female attendance |
| Trites and Porter (2002, Table 1) | Females nursing yearlings Yearlings (19-22 mos) | 22% ¹ 15% ² 40% ² | 1996, Forrester Is. (EGOA), January-April Satellite tracking |

1. No correction for daylight versus night attendance patterns.

2. Corrected for daylight versus night attendance pattern

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