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MEMORANDUM FOR: Jim Balsiger, Alaska Regional Office

FROM: Douglas DeMaster, AFSC *DD*

SUBJECT: Regional and Overall Trends and Trend Analysis of the Eastern Distinct Population Segment (DPS) of Steller Sea Lion

As part of your preparation of the Draft Status Review of the Eastern Distinct Population Segment (eDPS) of Steller Sea Lion (Draft Status Review), you have requested information on trends and trend analysis for the stock from the Alaska Fisheries Science Center. The information below was originally sent to the AKR at different times in response to specific queries. Here we include all of that information in a single memo that supersedes those previous documents and provides a single citable source for the Draft Status Review.

This memo has four parts: A) an accounting of published material summarizing Steller sea lion counts by region; B) a memo sent to Dana Seagars on 17 February, 2012 that calculated the trends by region; C) a revised model created in early March using a more conventional method of trend analysis; and D) an estimate for pup counts at two sites in the eDPS in 2002.

A. Regional and Overall Trends

Southeast Alaska and British Columbia

In the northern portion of the range of the eastern DPS of Steller sea lion (southeast Alaska and British Columbia), Steller sea lion populations have increased at rates exceeding 3% per year since the 1970s and have expanded their use of terrestrial habitats northward (Pitcher et al. 2007; Olesiuk 2008; Fisheries and Oceans Canada 2010; NMML, unpublished; Tables 1 and 2; Figures 1 and 2). Pup production increased at a rate of $3.6\% \text{ y}^{-1}$ ($P < 0.001$; 95% confidence interval of $2.7\% - 4.4\% \text{ y}^{-1}$) between 1979 and 2009 in southeast AK, and at a rate of $3.9\% \text{ y}^{-1}$ ($P < 0.001$; $2.1\% - 5.6\% \text{ y}^{-1}$) between 1971 and 2006 in British Columbia. Note that the long-term (1970s through 2006 or 2009) log-linear regression model underestimates the most recent pup counts in both southeast Alaska and in British Columbia (Figure 1). Thus, the rates of increase in pup production in both regions for just the last decade likely exceed the long-term average. Counts of adult and juvenile sea lions (non-pups) at trend sites (those consistently surveyed) have also increased significantly in both regions, at a rate of $1.4\% \text{ y}^{-1}$ ($P = 0.001$; $0.7\% - 2.1\% \text{ y}^{-1}$) between 1982 and 2010 in southeast AK, and $3.5\% \text{ y}^{-1}$ ($P < 0.001$; $2.6\% - 4.4\% \text{ y}^{-1}$) between 1971 and 2006 in British Columbia. Counts of non-pups in southeast Alaska have been more variable than those in other regions, particularly in the 2000s, which appear to have

depressed estimates of non-pup population growth in this area. The high variability in southeast Alaska non-pup counts may be related to movement of sea lions to take advantage of seasonally available prey resources (e.g., anadromous fish; DeMaster 2009; Fritz and Gelatt 2010)

In the 1970s, there was only a single functional rookery in southeast Alaska, the Forrester Complex, which produced 2,187 pups in 1979. During the 1980s, however, a new rookery became established on Hazy Island (638 pups counted in 1990), and between 1990 and 2005, three new rookeries became established in the northern half of southeast Alaska (White Sisters, Graves Rock and Biali Rock). By 2009, pup production at these four new rookeries totaled 3,407 where 30 years previously only 32 were counted, an increase of over 100-fold. At the Forrester Complex, pup production also increased, but by less than 2-fold during this same time period (N=4,036 in 2009).

In British Columbia, the pattern of increase in pup production at rookeries has been different than in southeast Alaska, with the establishment of a single dominant rookery. In the 1970s, there were five small rookeries on Maggot, Sartine and Triangle Islands (together they form the Scott Islands), plus North Danger Rocks and Cape St. James that each produced less than 350 pups. By 2006, production at one rookery, Triangle Island, had increased over 13-fold (from 181 in 1971 to 2,674 in 2006), while at all of the other four rookeries combined, production increased by only a factor of 1.25 (from 760 to 1,366 pups). In addition, there is evidence from the 2006 survey that a new rookery may be forming on Virgin Rocks, where 55 pups were counted.

Washington, Oregon and California

While Steller sea lions haulout throughout their eastern DPS range from central California through southeast Alaska, there are no breeding rookeries along a more than 600 mile stretch of the Pacific coastline between the northern end of Vancouver Island and Orford Reef in Oregon. Because there are no rookeries in Washington State, the southern portion of the eastern DPS range has primarily been monitored in Oregon and California. Breeding populations in both states have increased significantly since the 1970s. However, a rookery at the southern end of the range in California (on San Miguel Island in the Channel Islands) was abandoned in the early 1980s (Stewart et al. 1993). Counts of Steller sea lions in the Channel Islands peaked in the late 1930s and declined considerably in the 1940s and 1950s (Pitcher et al. 2007). Currently, the southernmost rookery is on Año Nuevo Island (37° 6'N), about 230 miles north of San Miguel Island.

The earliest reliable pup counts in Oregon were conducted in 1990 at both Rogue and Orford Reefs, and pup production has increased at 3.0% y^{-1} ($P=0.011$; 1.6%-4.4% y^{-1}) through 2009 (Table 1; NMFS 2008; NMML unpublished). In addition, over the 25-year period from 1977 to 2002, non-pup counts at the two Oregon rookeries increased at 3.7% y^{-1} ($P<0.001$; 2.9%-4.6% y^{-1} ; Table 2 and Figure 2; Pitcher et al. 2007). At the three rookeries in California (Año Nuevo Island, Sugarloaf/Cape Mendocino, and St. George Reef), pup production increased at 5.3% y^{-1} ($P=0.018$; 1.2%-9.4% y^{-1} ; Table 1 and Figure 1) between 1996 and 2009. Non-pup counts at three trend California sites in California (Año Nuevo Island, Farallon Islands, and St. George Reef) were stable between 1990 and 2009 (0.6% y^{-1} ; $P=0.418$); at four trend sites (adding Sugarloaf/Cape Mendocino), non-pup counts were stable (-0.9% y^{-1} ; $P=0.157$; Table 2

and Figure 2) between 1996 and 2009 (NMFS 2008; NMML, unpublished). However, sea lion abundance in central California (Año Nuevo and the Farallon Islands) in the 2000s has been only about 15-20% of that recorded in the period from the 1920s through the 1960s (Pitcher et al. 2007; NMFS, unpublished; Table 2).

Eastern DPS overall

Pitcher et al. (2007) estimated that the overall abundance of the eastern DPS of Steller sea lion increased at a rate of 3.1% per year for the 25-year period between 1977 and 2002. Between 2002 and 2009, NMFS and Fisheries and Oceans Canada conducted additional surveys (NMML, unpublished; Olesiuk 2008). Reanalysis of count data collected through 2009 yields overall rates of increase of 3.7% y^{-1} for pups and 2.5% y^{-1} for non-pups. Most of the overall improvement is due to increases in the northern portion of the range in southeast Alaska and British Columbia, but the smaller population in the south (Washington, Oregon and California) has also significantly increased in abundance.

Pitcher et al. (2007) described the northward shift in the breeding population of Steller sea lions within the eastern DPS that has occurred over the last 80 years. This shift began at the southern end of the range in the 1930s with the decline of the southern California rookery on San Miguel Island and continued in the 1960s and 1970s when the central California population declined (Pitcher et al. 2007). At the northern end of the range, Steller sea lions established rookeries in southeast Alaska on Forrester Island in the 1950s, Hazy Island in the 1980s, and on White Sisters, Biali Rock and Graves Rock in the 1990s. In the 1920s, the center of the breeding population was at approximately 46°N (Washington-Oregon border), but by 2002, it had moved northward over 400 miles to the central British Columbia coast. However, the northward shift in the center of the eastern DPS breeding population is not entirely due to movement of eastern DPS animals. Based on genetic analyses, about half of the pups born on White Sisters and about 70% of those on Graves Rock had mtDNA haplotypes previously found only in the western DPS. During 1996-2009 the regional distribution of pup production within the eastern DPS changed only slightly: in 1996, 79% of all eastern DPS pups were born on northern rookeries in southeast Alaska and British Columbia, while the remaining 21% were born on southern rookeries in Oregon and California; in 2009, northern rookeries produced 83% and the southern rookeries 17%. Consequently, it appears that most of the northern shift in the distribution of pup production within the eastern DPS occurred during the period from the 1930s through the early 1990s. Since the mid-1990s, pup production in both the northern and southern portions of the eastern DPS has increased significantly.

B & C. Estimating eDPS Trends

The Steller Sea Lion Recovery Plan (NMFS 2008) identified two criteria that must be met in order to delist the eDPS. The first criteria stated that, “the population has increased at an average annual growth rate of 3% per year for 30 years”. Therefore, the AKR requested the AFSC provide an accounting of the trend for the last 30 years to address this requirement. Because not all sites were surveyed every year or in the same years, a simple trend line that connected and summed the counts was not possible. Therefore, a model was created to estimate what the count would have been in the missing years. This was done for each region separately, as well as for the total DPS, to allow for different rates of growth and volatility.

Two methods were used. The first method, outlined in Section B in this memo, involved a geometric Brownian motion model that estimated the annual growth rate of the eDPS between 1979 – 2009 was 4.3% (90% CI = 1.9% – 7.3%). The best available abundance estimate for this DPS in 1979, based on this analysis, was 18,040 animals; while the best available estimate for 2009 was 63,488 animals. A description of this analysis was sent in a memo to the AKR on 17 Feb. 2012 and was used in one of the first Draft versions. After some internal review at AFSC, we decided that it would be appropriate to use a method more closely related to the standard regression method commonly used to estimate population growth. That method is detailed in Section C. The dataset generated from this model (Section C) used an additional year of survey data from British Columbia. This second method produced an estimated growth rate slightly less than the previous model (4.1%) but with a much narrower confidence interval (90% CI = 3.4% - 5.5%). Both methods used the multiplier of 4.5 (Calkins and Pitcher 1982) to calculate a total population for an area based on the number of pups counted.

B. Trend Analysis for eDPS Steller sea lion population (Originally sent to D. Seagars on Feb. 17, 2012)

1. Data

The data used are those described in Section I.E. (Eastern DPS Status and Trend) of the 2008 revision of “Recovery Plan for The Steller Sea Lion” (<http://www.alaskafisheries.noaa.gov/protectedresources/stellers/recovery/sslrpfinalrev030408.pdf>) augmented with the 2009 survey data from the southeast Alaska, California, and Oregon regions, as well as 2006 data for British Columbia.

2. Abundance model

In each region (SEAK, BC, OR, CA) a geometric Brownian motion (GBM) model was fitted. The GBM model is described by the stochastic differential equation

$$dN_t = \mu dt + \sigma dW_t,$$

where N_t is the population size at time t , μ is the growth parameter, σ is a volatility parameter, and W_t is a Brownian motion process. The resulting solution given an initial population of size N_0 is

$$N_t = N_0 e^{\mu t + \sigma W_t}.$$

The median value of N_t is $N_0 e^{\mu t}$, so, $\lambda = e^\mu$ is the annual growth rate.

3. Statistical inference

In order to estimate parameters for the GBM model we make use of the following relationship

$$\ln N_{t+1} \sim \text{Gau}(\ln N_t + \mu \Delta_t, \sigma^2 \Delta_t),$$

where $\text{Gau}(\cdot, \cdot)$ represents a normal distribution and Δ_t is the time difference between N_{t+1} and N_t . In addition, all the Y are independent. So, the negative log-likelihood is given by

$$\ell(\mu, \sigma; \mathbf{y}) = \sum_r \sum_t \left[\ln \sigma_r \sqrt{\Delta_{r,t}} + \frac{\{y_{r,t} - \mu_{r,t} \Delta_{r,t}\}^2}{2\sigma_{r,t}^2 \Delta_{r,t}} \right],$$

where $y_{r,t}$ are the observed values of Y_t . The log-likelihood can then be maximized with respect to the μ and σ parameters. However, in this case I chose to use Bayesian inference and the model was fitted via MCMC. In order to estimate an overall trend for the entire eDPS, I made use of the following relationship:

$$\sum_r N_{t+1}^{(r)} \approx \frac{\sum_r \lambda^{(r)} N_t^{(r)}}{\sum_r N_t^{(r)}},$$

where $N_t^{(r)}$ is the population size in the r th region at time t and $\lambda^{(r)}$ is the growth rate of the region. Thus,

$$\lambda_t = \sum_r \lambda^{(r)} P_t^{(r)}$$

is the population wide growth rate and $P_t^{(r)}$ is the relative size of the population in the r th region. I estimated relative size to be

$$P_t^{(r)} = \frac{N_0^{(r)} e^{-\mu_r t}}{\sum_r N_0^{(r)} e^{-\mu_r t}}.$$

The overall average growth rate is the geometric mean

$$\bar{\lambda} = e^{\frac{1}{T} \sum_t \ln \lambda_t}$$

4. Results

Total eDPS population--

In order to estimate growth rates for the total population of the eDPS stock I used the multiplier, 4.5 animals/pup (Calkins and Pitcher, 1982) times the recorded pup counts in each

region. The estimated regional growth rates and 90% CIs for the eDPS population from 1979 – 2009 (30 yrs) were

BC: **4.2%** (-1.6.0% – 12.0%)

SE AK: **4.0%** (1.3% – 6.5%)

OR: **3.1%** (-1.6% – 7.0%)

CA: **2.6%** (-5.8% – 11.1%)

Based on the best available population data over the period 1979-2009, I estimate the eDPS of Steller sea lions has increased at an average growth rate of $\bar{\lambda} = 4.3\%$ (1.9% – 7.3%) per year for 30 years. Moreover, given the observed data, the probability that the overall growth rate for the population exceeded 3.0% was 0.84.

Nonpups--

The estimated average individual region growth rates and 90% CIs for 1981 – 2010 (29 yrs) were

BC: **5.1%** (4.2% – 6.1%)

SE AK: **1.0%** (-4.0% – 5.8%)

OR: **3.8%** (-2.1% – 9.5%)

CA: **-1.0%** (-5.7% – 5.1%)

The overall growth rate for the eDPS nonpups data was 3.1% (1.7% – 5.6%). Moreover, given the observed data, the probability that the overall growth rate was >3.0% was 0.68.

C. Analyzing eDPS Steller Sea Lion Population Trends Using Subpopulation Surveys II

Here we present a second method for analyzing growth trends of the abundance of an entire population when censuses have been conducted at disparate times on subpopulations with possibly differing annual rates of growth (or decline). The method involves modeling growth of each subpopulations abundance using a semi-parametric approach to obtain posterior distributions of counts for missing years. The population total can then be calculated from the subpopulation posterior counts for every year. Standard regression can then be performed on the posterior log counts to obtain average growth rates. The benefit of this method compared to the previous version of 17 February 2012 (Section B) is that the analysis is consistent in that if all sites were observed in all years, the method would converge to standard regression methods for estimating population growth. The method is demonstrated on the eDPS population of Steller sea lions. There are four generally recognized populations: Southeast Alaska (SEAK), British Columbia, Canada (BC), Oregon (OR), and California (CA).

Since the late 1970s these populations have been counted at various times depending upon the funding and ability of the local agencies responsible for management (Table 1). The eDPS has generally been growing over the past 32 years and is currently being petitioned for delisting from its ESA status. The criterion for delisting is that the entire population has been growing at an average rate of 3% per year for the last 30 years. This presents a statistical inference problem in that the required parameter describes the growth of the *sum* of the subpopulations, but these populations were generally not surveyed in the same years. Each individual subpopulation can be analyzed well enough. But, this does not satisfy the delisting criterion.

Therefore, the following method was developed for estimating the population-wide growth rate from each of the four subpopulations

1. Statistical method

First, assume that the abundance of each subpopulation, say j , can be modeled with a semiparametric integrated Ornstein-Uhlenbeck (IOU) model

$$\ln N_{t+1}^{(j)} = \ln N_t^{(j)} + \int_t^{t+1} \nu^{(j)}(u) du$$

where $\nu^{(j)}(u)$ is a continuous-time Ornstein-Uhlenbeck stochastic process with mean $\gamma^{(j)}$, autocorrelation $\beta^{(j)}$, and volatility $\tau^{(j)}$ that represents instantaneous growth rates. Using this model we can draw from posterior distribution $[N_1, \dots, N_T | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}]$, where $\mathbf{N}_{obs}^{(j)}$ is a vector of those $N_t^{(j)}$ that were observed. Johnson et al. (2008) describe how this can be done in the context of animal movement. After drawing a sample from $[N_1, \dots, N_T | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}]$ for each j , we can sum to obtain a draw from the population total posterior distribution $[N_1, \dots, N_T | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}]$ using

$$N_t = \sum_j N_t^{(j)}$$

If N_t were known for all $t=1, \dots, T$, to estimate annual growth rate, the simple regression model and subsequent analysis would suffice

$$\ln N_t = \ln N_0 + \lambda t + \varepsilon_t$$

where $\lambda = e^r$ is the average yearly growth rate and $[\varepsilon] = N(0, \sigma^2 \mathbf{I})$. To obtain Bayesian posterior inference for r , the reference prior, $[\ln N_0, r, \sigma] \propto 1/\sigma^2$, can be used which leads to the posterior distribution

$$[r | N_1, \dots, N_T] = SE(\hat{r}) \times t_{T-2} + \hat{r},$$

where \hat{r} is the standard least-squares estimate for r , $SE(\hat{r})$ is the standard LS standard-error estimate, and t_{T-2} is a t random variable with $df = T-2$.

We do not observe N_1, \dots, N_T , however, thus we need to make our inference using the posterior distribution

$$[r | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}] = \int_{N_1} \dots \int_{N_T} [r | N_1, \dots, N_T] [N_1, \dots, N_T | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}] dN_1 \dots dN_T$$

Using the fact that we can draw values from $[N_1, \dots, N_T | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}]$ using the IOU models and for any function, $f(\cdot)$, posterior expectations and variances from $[r | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}]$ can be obtained via

$$E[f(r) | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}] = E\{E[f(r) | N_1, \dots, N_T]\}$$

and

$$Var[f(r) | \mathbf{N}_{obs}^{(1)}, \dots, \mathbf{N}_{obs}^{(j)}] = Var\{E[f(r) | N_1, \dots, N_T]\} + E\{Var[f(r) | N_1, \dots, N_T]\}$$

In addition if we are interested in posterior credible intervals, i.e., a 90% CI, we simply choose L and U such that

$$E\{\Pr[L < r < U | N_1, \dots, N_T]\}$$

This can be done with numerical optimization methods.

2. eDPS population analysis

Details

The data used for analysis is given in Table 3. The pup count was multiplied by 4.5 to estimate the total number of animals in each subpopulation when it was surveyed (Calkins and Pitcher, 1982). Markov Chain Monte Carlo (MCMC) was used to draw $N_t^{(j)}$ for missing surveys, hence, the total population size, N_t . Parameter prior distributions used for the analysis were

$\gamma^{(j)} \sim N(0, 0.01)$, $\tau^{(j)} \sim N(0, 1)$, and $\beta^{(j)} \sim N(0, 1)$. A seemingly informative prior was used for $\gamma^{(j)}$ because it was assumed that subpopulations would not be growing (declining) at a rate $> 20\%$ (-20%) per year in the long term. In addition I constrained the counts in CA and OR previous to the first count to be less than twice the observed first count. Other indicators including nonpup counts indicate that the CA and OR populations had been growing since before 1979 (R. DeLong, NMML, pers. comm.). Therefore, twice the first count is a generous bound and keeps the population from exploding and making the results nonsensical.

Results

The estimated growth rate (posterior mode) from 1979-2010 for the eDPS population of Steller sea lions was $\lambda = 4.1\%$ with a 90% CI = (3.4% - 5.5%). The probability that the growth rate exceeded 3% was 0.98. Figure 3 illustrates the estimated abundance in each region ($N_t^{(j)}$), as well as the total abundance for the eDPS (N_t) and the fitted growth rate curve.

D. 2002 pup counts for White Sisters and Biali Rocks

The AKR requested an estimate of the pup counts at two rookeries in the eDPS in 2002. From Table 1 we note that there were 403 pups at the White Sisters and 59 pups at Biali Rocks.

Literature Cited

- Calkins, D. G. and K. W. Pitcher (1982) Population assessment, ecology, and trophic relationships of Steller sea lions in the Gulf of Alaska. Pages 447-456, in Environmental assessment of the Alaskan continental shelf. U. S. Dept. of Comm. and U.S. Dept. of Int., Final Rep. Principal Investigators, 19:1-565.
- DeMaster, D. 2009. Aerial Survey of Steller Sea Lions in Alaska, June-July 2009 and Update on the Status of the Western Stock in Alaska. Memorandum to D. Mecum, Director Alaska Region, and K. Brix and L. Rotterman, Alaska Region Protected Resources. 2 December 2009, 30 p. <http://www.afsc.noaa.gov/nmml/PDF/SSL-Survey-09-memo-11-30-09.pdf>.
- Fisheries and Oceans Canada. 2010. Management Plan for the Steller Sea Lion (*Eumetopias jubatus*) in Canada [Final]. *Species at Risk Act* Management Plan Series. Fisheries and Oceans Canada, Ottawa. vi + 69 pp.
- Fritz, L., and T. Gelatt. 2010. Surveys of Steller sea lions in Alaska, June-July 2010. Memorandum to the Record. 31 January 2011, 31 p. <http://www.afsc.noaa.gov/nmml/PDF/SSL-Survey-memo-2010.pdf>

- NMFS (National Marine Fisheries Service). 2008. Steller sea lion recovery plan, eastern and western distinct population segments (*Eumetopias jubatus*). Revision. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, MD. 325 pages.
- Olesiuk, P.F. 2008. Abundance of Steller sea lions (*Eumetopias jubatus*) in British Columbia. Canadian Science Advisory Secretariat Research Document. 2007/063.
- Pitcher, K.W., P.F. Olesiuk, R.F. Brown, M.S. Lowry, S.J. Jeffries, J.L. Sease, W.L. Perryman, C.E. Stinchcomb, and L.F. Lowry. 2007. Abundance and distribution of the eastern North Pacific Steller sea lion (*Eumetopias jubatus*) population. Fishery Bulletin 107: 102-115.
- Stewart, B. S., P. K. Yokum, R. L. DeLong, and G. A. Antonelis. 1993. Trends in abundance and status of pinnipeds on the southern California Channel Islands. In Third California Islands symposium: recent advances in research on the California islands (E. Hochberg, ed.), p. 501–516. Santa Barbara Museum of Natural History, Santa Barbara, CA.

Table 1. Counts of Steller sea lion pups at rookeries in southeast Alaska (A), British Columbia (B), Oregon (C) and California (D), 1971-2005.

Rookery	1971	1973	1977	1979	1982	1987	1990	1991	1992	1993	1994	1995
A												
Forrester Island				2,187			2,932	3,261			2,757	
Hazy Island				32			638	808			862	
White Sisters							30	95			151	
Graves Rocks												
Biali Rocks												
Total SE Alaska				2,219			3,600	4,164			3,770	
B												
Maggot Island	174	188	147		171	180			107		76	
Sartine Island	163	273	309		409	176			253		62	
Triangle Island	181	189	140		185	305			476		630	
Virgin Rocks	0	0	0		0	2			0		0	
N Danger Rocks	86	93	64		74	54			148		84	
Cape St James	337	272	303		404	367			484		333	
Miscellaneous	0	0	0		2	0			0		1	
Total British Columbia	941	1,015	963		1,245	1,084			1,468		1,186	
C												
Rogue Reef							492					
Orford Reef							298					
Total Oregon							790					
D												
Año Nuevo							312	287	263	230	244	226
Farallons							4	2	4	5	7	
Sugarloaf/Cape Mendocino												
Saint George Reef											115	

Table 1 continued. Counts of Steller sea lion pups at rookeries in southeast Alaska (A), British Columbia (B), Oregon (C) and California (D), 1996-2009.

Rookery	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2009
A												
Forrester Island	2,764	2,798	2,753			3,152	3,057			3,429		4,036
Hazy Island	768	1,157	1,199			1,091	1,248			1,286		1,976
White Sisters	182	205	282			371	403			520		847
Graves Rocks			1			89	99			175		440
Biali Rocks						38	59			100		144
Total SE Alaska	3,714	4,160	4,235			4,741	4,866			5,510		7,443
B												
Maggot Island			72				77				62	
Sartine Island			148				146				178	
Triangle Island			1,211				2,199				2,674	
Virgin Rocks			0				1				55	
N Danger Rocks			144				219				403	
Cape St James			484				635				723	
Miscellaneous			4				4				23	
Total British Columbia			2,063				3,281				4,118	
C												
Rogue Reef	685					600	746					910
Orford Reef	335						382					508
Total Oregon	1,020						1,128					1,418
D												
Año Nuevo	236	210	186	152	184	230	189	226	221			214
Farallons	5			10	4	2	7	13	22			24
Sugarloaf/Cape Mendocino	62		61	86	138	152	150	158	131			161
Saint George Reef	243		256	184	293	338	367	458	444			492
Total California	546			432	619	722	713	855	818			891

Table 2. Counts of Steller sea lion adults and juveniles (non-pups) at trend sites (those consistently surveyed) in southeast Alaska (SE AK), British Columbia (BC), Oregon (OR) and California (CA), 1971-2009. Number of trend sites follows each region name.

Year	SE AK-12	BC-all	OR-2	CA-3	CA-4
1971		4,889			
1973		4,039			
1974					
1977		5,219	1,461		
1979			1,542		
1980			1,632		
1981			2,105		
1982	6,898	4,726	2,604		
1983			2,106		
1984			1,867		
1985			2,210		
1986			2,289		
1987		6,122	2,709		
1988			2,825		
1989			2,183		
1990	7,629		2,414	1,329	
1991	8,641			1,163	
1992	7,555	7,378	3,581	969	
1993			2,838	821	
1994	9,001	8,104	3,293	1,046	
1995			3,837		
1996	8,231		3,205	1,369	1,870
1997			3,897		
1998	8,693	9,818	3,971		
1999			3,275	1,277	1,547
2000	9,892		2,927	1,215	1,704
2001			3,648	1,077	1,817
2002	9,949	12,121	4,169	1,096	1,684
2003				1,193	1,706
2004				1,163	1,578
2006		15,700			
2008	8,748				
2009	11,798			1,236	1,588
2010	9,644				

Table 3.
*Data used to estimate average yearly growth of the eDPS
 population of Steller sea lion.*

Region	Year	Count
BC	1982	1245
BC	1987	1084
BC	1992	1468
BC	1994	1186
BC	1998	2063
BC	2002	3281
BC	2006	4118
BC	2010	5485
SEAK	1979	2219
SEAK	1990	3600
SEAK	1991	4164
SEAK	1994	3770
SEAK	1996	3714
SEAK	1997	4160
SEAK	1998	4235
SEAK	2001	4741
SEAK	2002	4866
SEAK	2005	5510
SEAK	2009	7443
OR	1990	790
OR	1996	1020
OR	2002	1128
OR	2009	1418
CA	1996	546
CA	1999	432
CA	2000	619
CA	2001	722
CA	2002	713
CA	2003	855
CA	2004	818
CA	2009	891

Figure 1. Counts of Steller sea lion pups at rookeries in southeast Alaska (A), British Columbia (B), Oregon (C) and California (D), 1971-2009 (symbols), and the log-linear regression estimate (line).

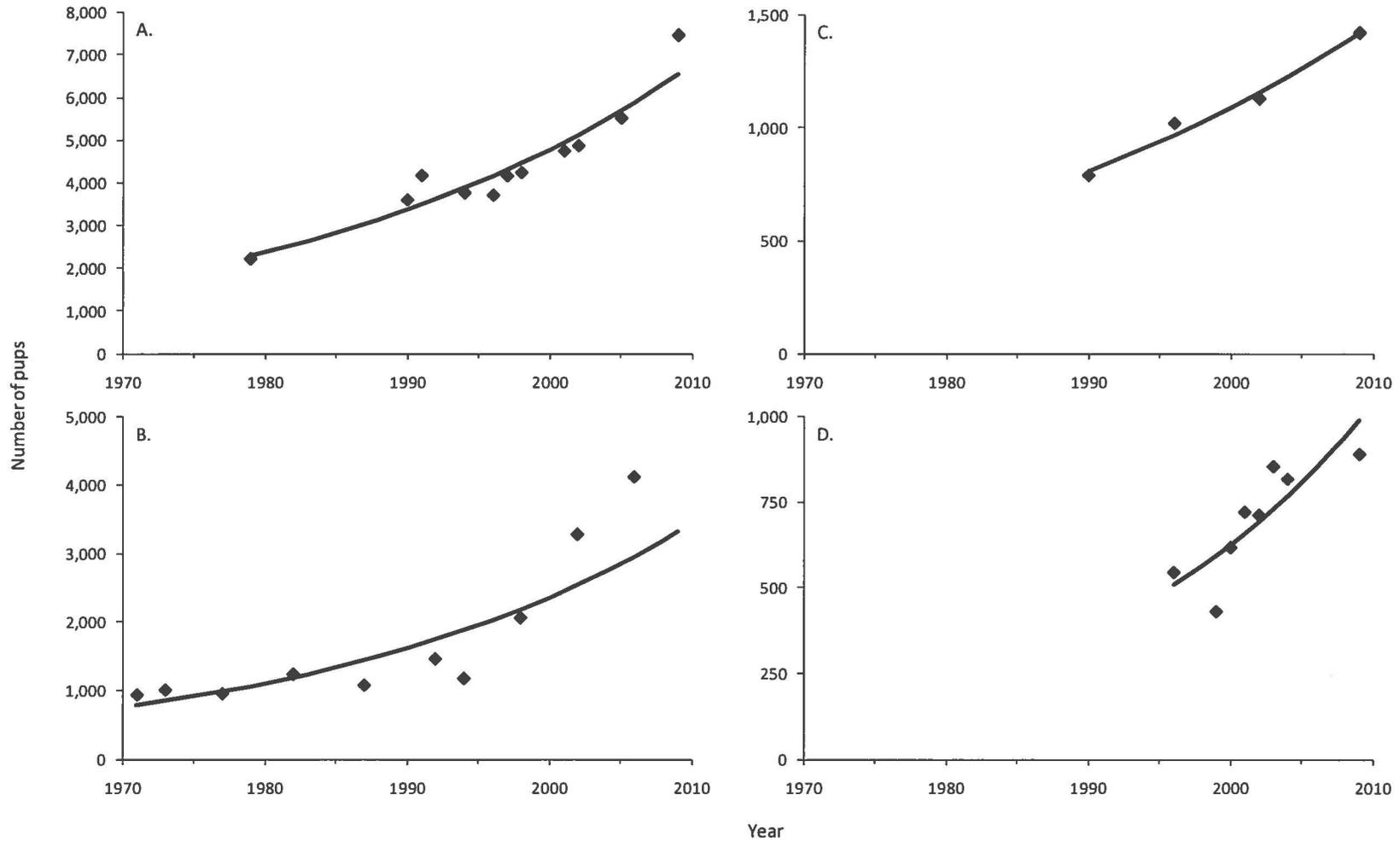
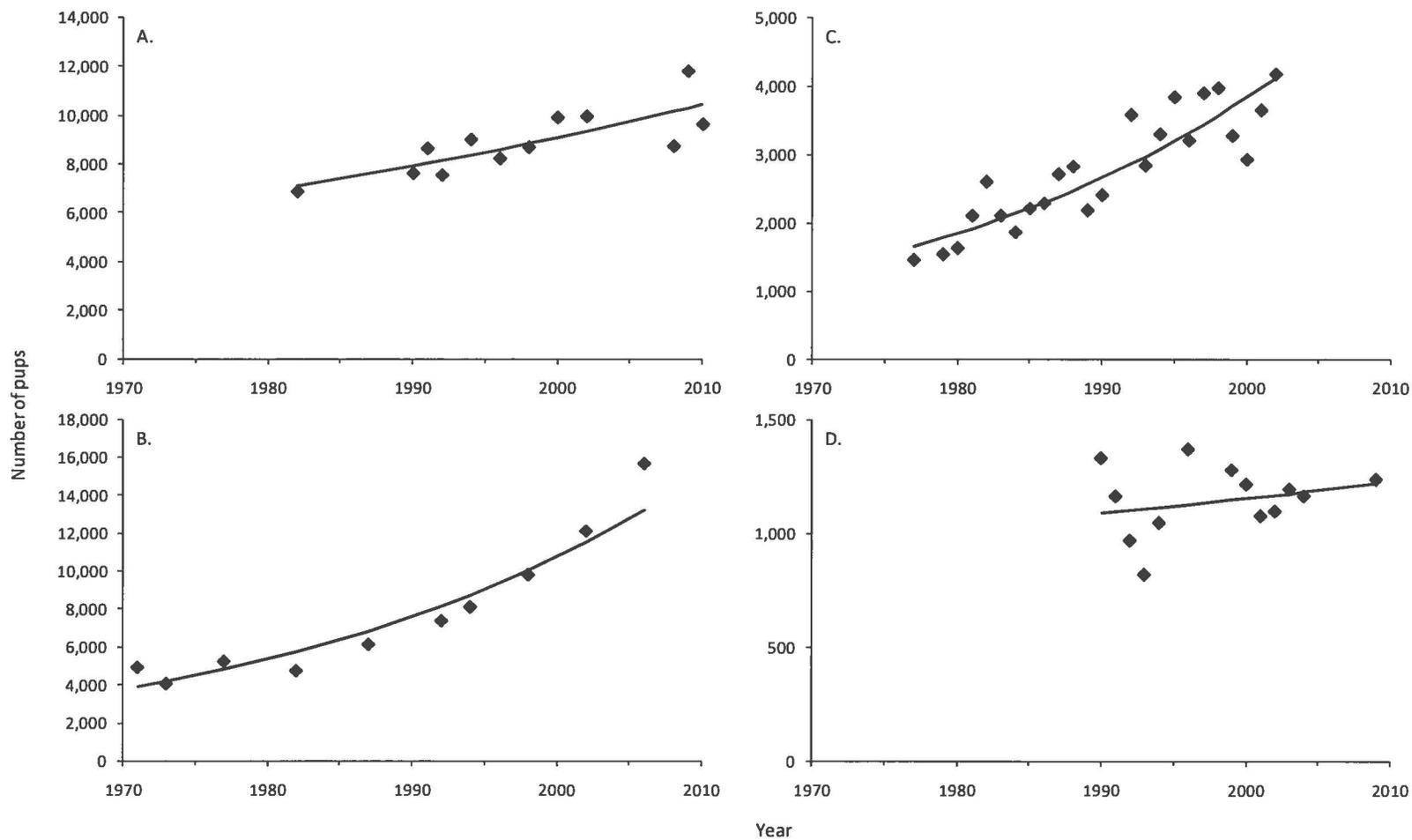


Figure 2. Counts of Steller sea lion adults and juveniles (non-pups) at trend sites in southeast Alaska (A), British Columbia (B), Oregon (C) and California (D), 1971-2009 (symbols), and the log-linear regression estimate (line).



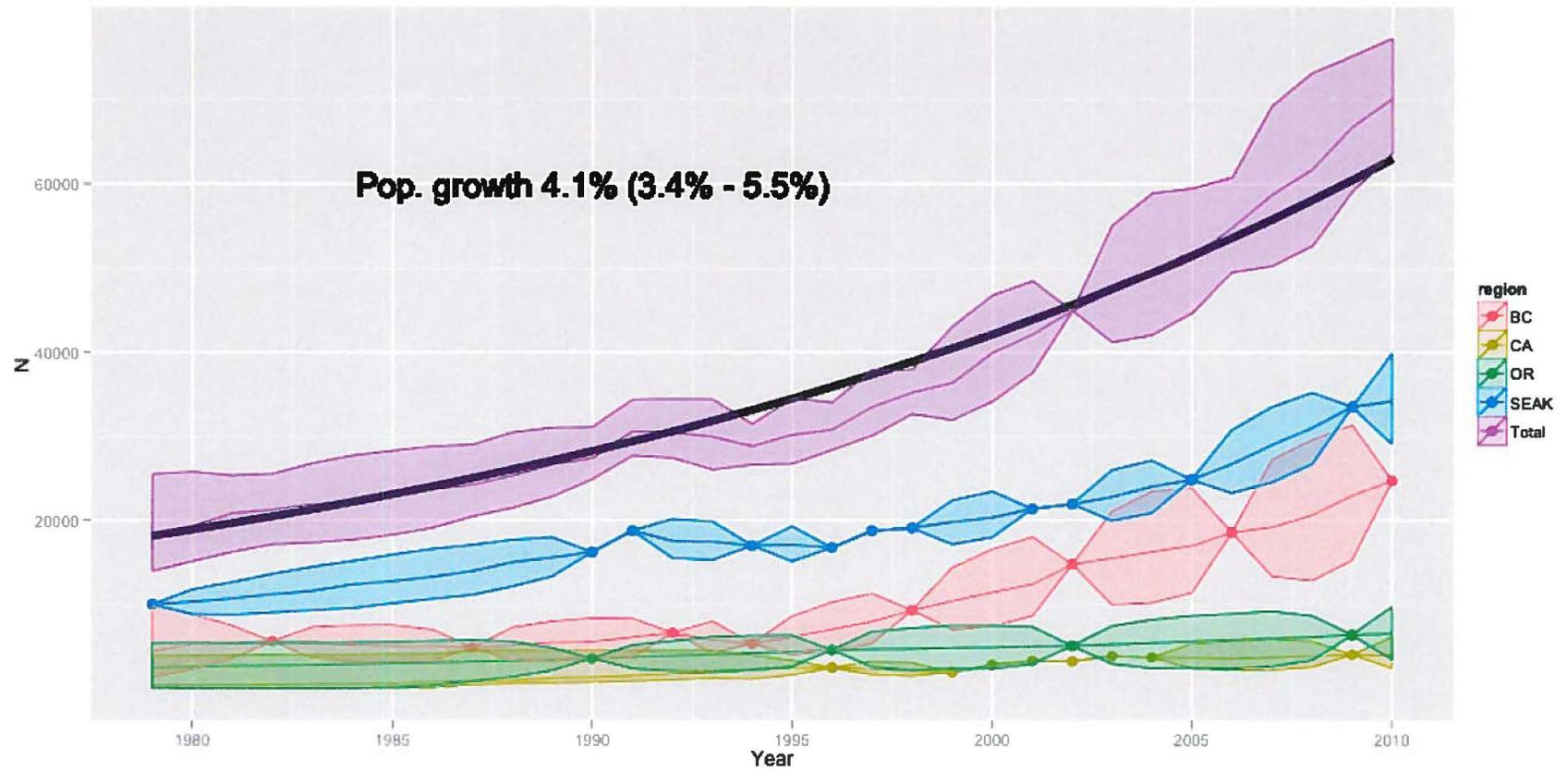


Figure 3. Estimated abundance for the eDPS Steller sea lion. Points represent observed pup counts $\times 4.5$ (Calkins and Pitcher, 1982). Solid lines are posterior median estimates of abundance between surveys and colored envelopes are 90% posterior credible intervals.