Supplementary material

Text S1: Informed priors used in the multi-event mark-recapture model to estimate Steller sea lion vital rates

Here we report means and standard deviations of age-specific survival and pupping probabilities for Steller sea lions estimated in two separate studies and used as informed priors in the estimation of vital rates within the multi-event mark-recapture subcomponent model for the western distinct population segment (Table A1). First, informed priors for age-specific survival were based on the means and standard deviations of estimates from Hastings et al. (2018), who examined survival of Steller sea lions (*n* = 2795) marked in the mid-1990s and early 2000s in Southeast Alaska and resighted over a 21-year study period. Additionally, estimates of age-specific first reproduction for individuals marked in the Kuril and Commander Island chains in the late 1990s and early 2000s in the Commander Islands (A. Altukhov *unpublished data*) were used here as informed priors for first-time pupping probability for individuals age 4-6.

Table S1. Mean and standard deviation of Steller sea lion vital rates for each sex and age estimated in previous research ([*]Hastings et al. 2018, [+]Altukhov *unpublished data*) and used in this study as informed priors for the estimation of survival and pupping probabilities in the multi-event subcomponent model.

Rate	Sex	Age	Mean	Standard deviation
Survival[*]	F	P	0.62	0.03
	M		0.58	0.03
	F	1	0.81	0.02
	M		0.75	0.02
	F	2	0.89	0.01
	M		0.84	0.01
	F	3	0.93	0.01
	M		0.88	0.01
	F	4	0.95	0.01
	M		0.90	0.01
	F	5	0.96	0.01
	M		0.91	0.01
	F	Adult	0.95	0.01
	M		0.82	0.02
Pupping[+]	F	4	0.20	0.01
		5	0.60	0.01
		6	0.40	0.10

Text S2: Age- and sex-specific demography and sensitivity of population growth to demographic parameters in an integrated population model and viability analysis for Steller sea lions

This supplementary material contains additional information pertaining to age- and sex-specific demographic rates, age structure, and the effects of environmental conditions on Steller sea lions in the six management subregions of the wDPS in Alaska.

Using an integrated population modeling (IPM) framework with mark-resight and count survey data, we estimated age- and sex-specific vital rates as functions of fixed effects of natal subregion and random effects of time with varying levels of complexity depending on the vital rate of interest (see main text). Our results showed that male and female vital rates were similar to each other for each age, but varied by region (Figure S1).

In addition to examining population structure in terms of the $\frac{N_{\mathrm{Tot}}}{N_{\mathrm{pup}}}$ ratio, we also here show a more complex age structure that compares estimated age structure within each subregion and range-wide (Figure S2). This more nuanced view provides additional insight into the deviations in the $\frac{N_{\mathrm{Tot}}}{N_{\mathrm{pup}}}$ ratio in the subregions with declining abundance trends. Specifically, we estimated a higher proportion of pups (and therefore female breeders) in the central AI subregion, where pup and yearling survival were notably lower than the range-wide average. Additionally, in the western AI subregion, the proportion of non-breeding females was high while that of female breeders was low, but pup survival was high. These differences provide insights into the different maternal investment strategies that may exist in these two subregions, where survival and pupping probabilities are likely influenced by pup mass, weaning age, maternal body condition, and environmental conditions.

In terms of the effects of environmental conditions on vital rates of Steller sea lions, as noted in the main text, sea surface temperature and warm-phase North Pacific Gyre Oscillation were positively correlated with survival and pupping probabilities, though credible intervals overlapped zero (Figure S3). In considering how these or other environmental variables may affect population dynamics, it is important to examine the sensitivity of population growth rates to changes in demographic rates. As noted in the main text but illustrated in more detail here, population growth rates were most consistently and strongly correlated with female breeder survival and repeat pupping probabilities (Figure S4), though the strength of and uncertainty in the correlation varied across subregions (Figure S5).

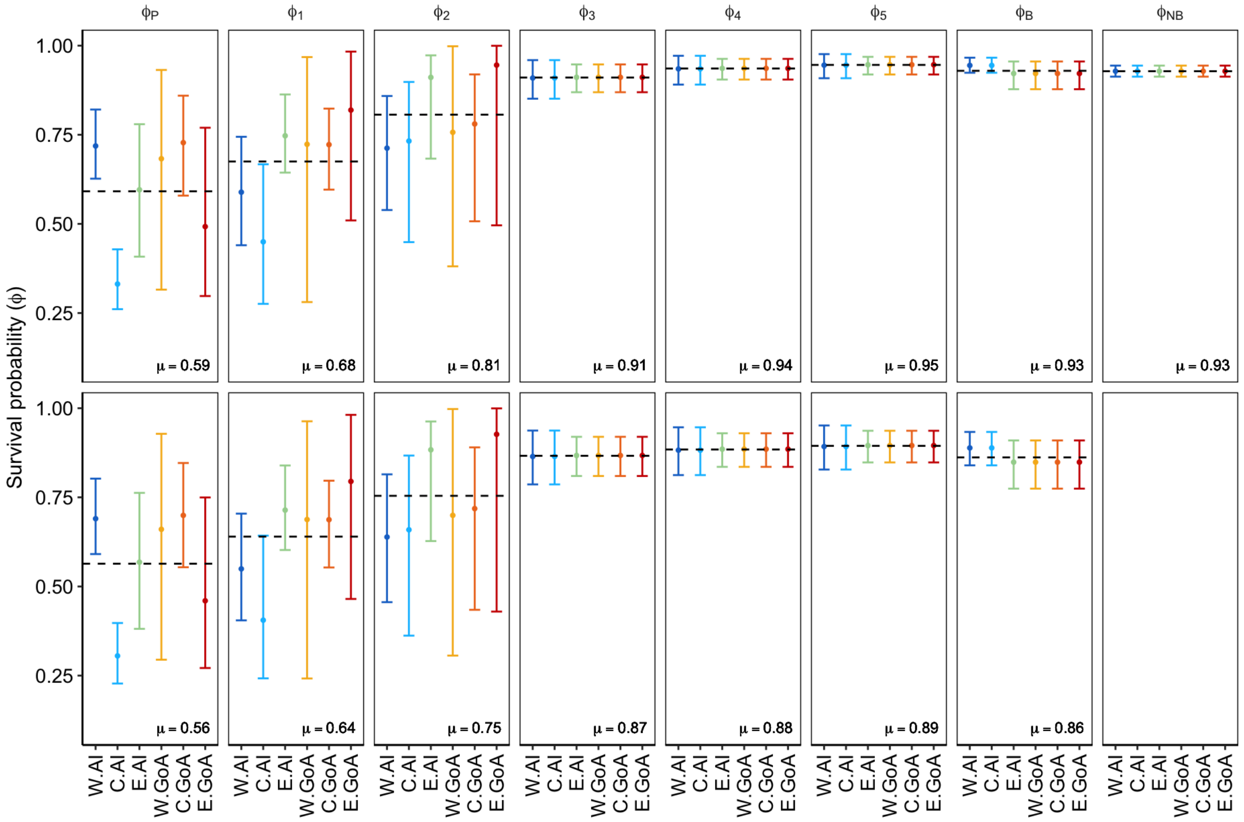

Figure S1: Posterior mean and 95% credible intervals for Steller sea lion age-specific survival ($\phi_{P,1:5,\,B,\,NB}$) across the six western distinct population segment subregions (including the western Aleutians, W.AI; central Aleutians, C.AI; eastern Aleutians, E.AI; western Gulf of Alaska, W.GoA; central Gulf of Alaska, C.GoA; eastern Gulf of Alaska, E.GoA) compared to the range-wide mean represented by the dashed line and corresponding μ.

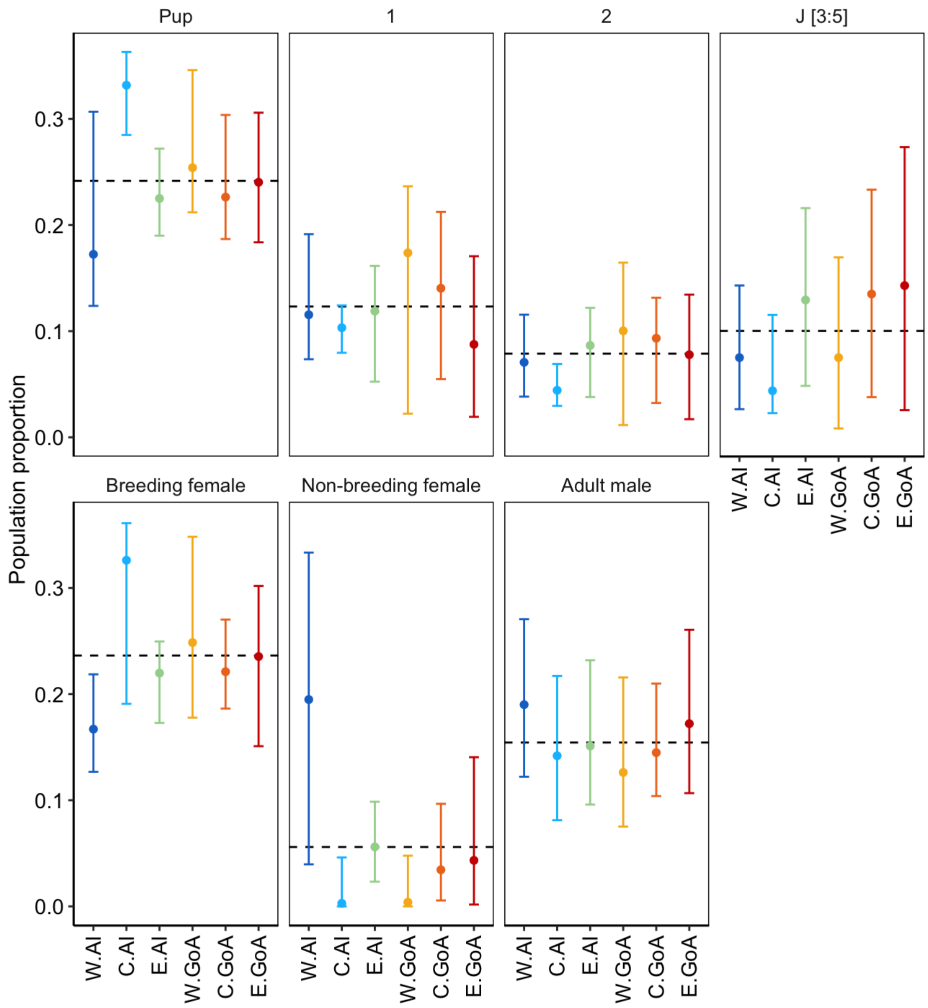

Figure S2: Posterior mean and 95% credible intervals of population age structure (proportion of each age class from pups, young sea lions age 1-2, juveniles age 3-5, and female and male adults that comprise total abundance) in each of the six western distinct population segment subregions (colors; including the western Aleutians, W.AI; central Aleutians, C.AI; eastern Aleutians, E.AI; western Gulf of Alaska, W.GoA; central Gulf of Alaska, C.GoA; eastern Gulf of Alaska, E.GoA) compared with the estimated mean range-wide age structure (black dashed line).

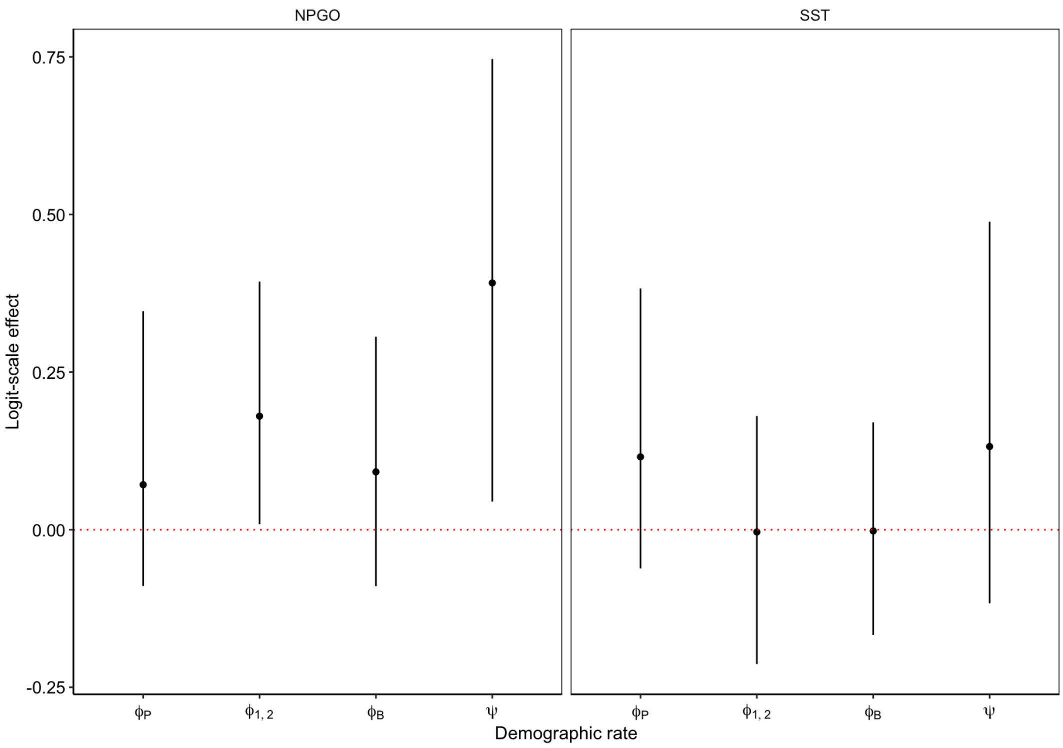

Figure S3: Mean and 95% credible intervals of logit-scale effects of sea surface temperature (SST) and the North Pacific Gyre Oscillation (NPGO) conditions on the survival of male and female pups (ϕ_P) and young individuals age 1-2 ($\phi_{1:2}$), breeding females (ϕ_B), and pupping probability (ψ).

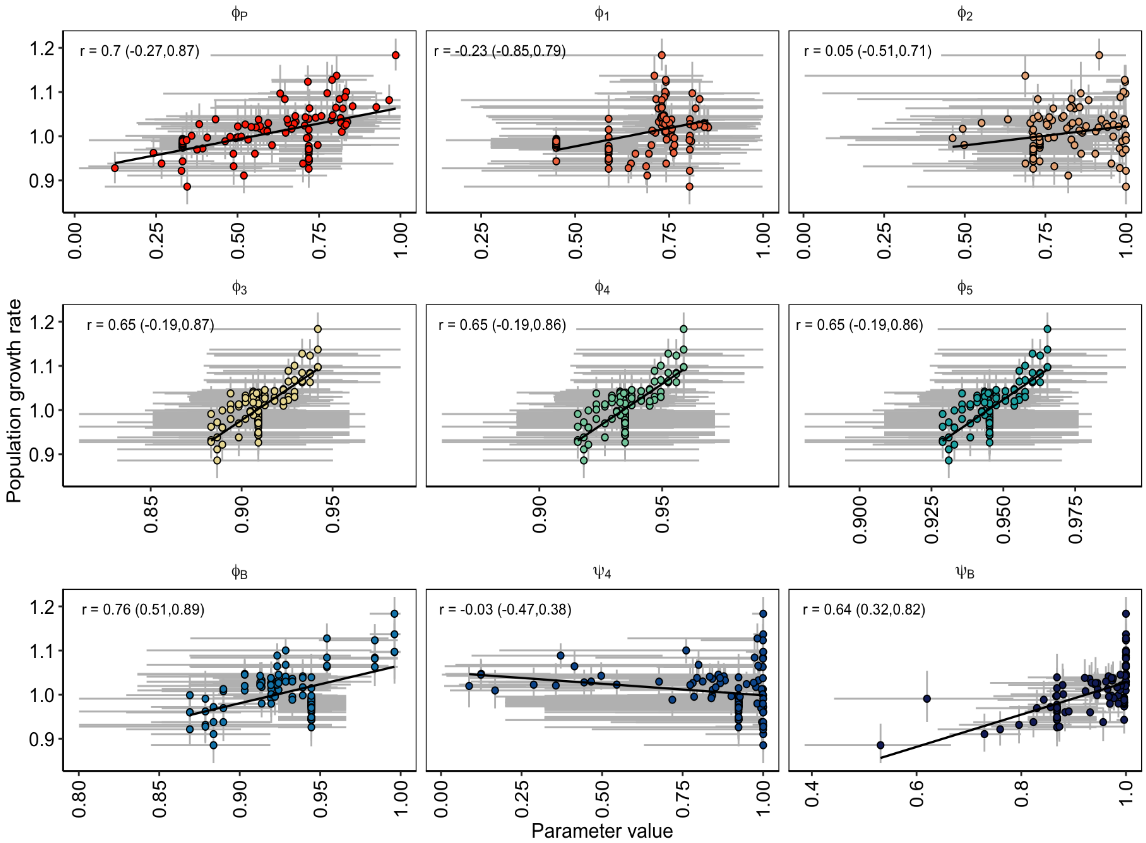

Figure S4: Posterior means (colored dots) of range-wide annual population growth rates (*y*-axis) plotted against posterior means of female Steller sea lion demographic rates (*x*-axes), along with 95% credible intervals (grey lines). Demographic rates include time-varying survival probabilities for pups (ϕ_P), 1 to 5-year-olds (ϕ_1 to ϕ_5), and breeders (ϕ_B); first-time pupping probability for age-4 individuals (ψ_4); and repeat pupping (ψ_B) probabilities. Also shown are regression lines (black) quantifying the correlation between the parameters shown in each facet, with the mean and 95% credible interval for each correlation coefficient *r* printed in each facet.

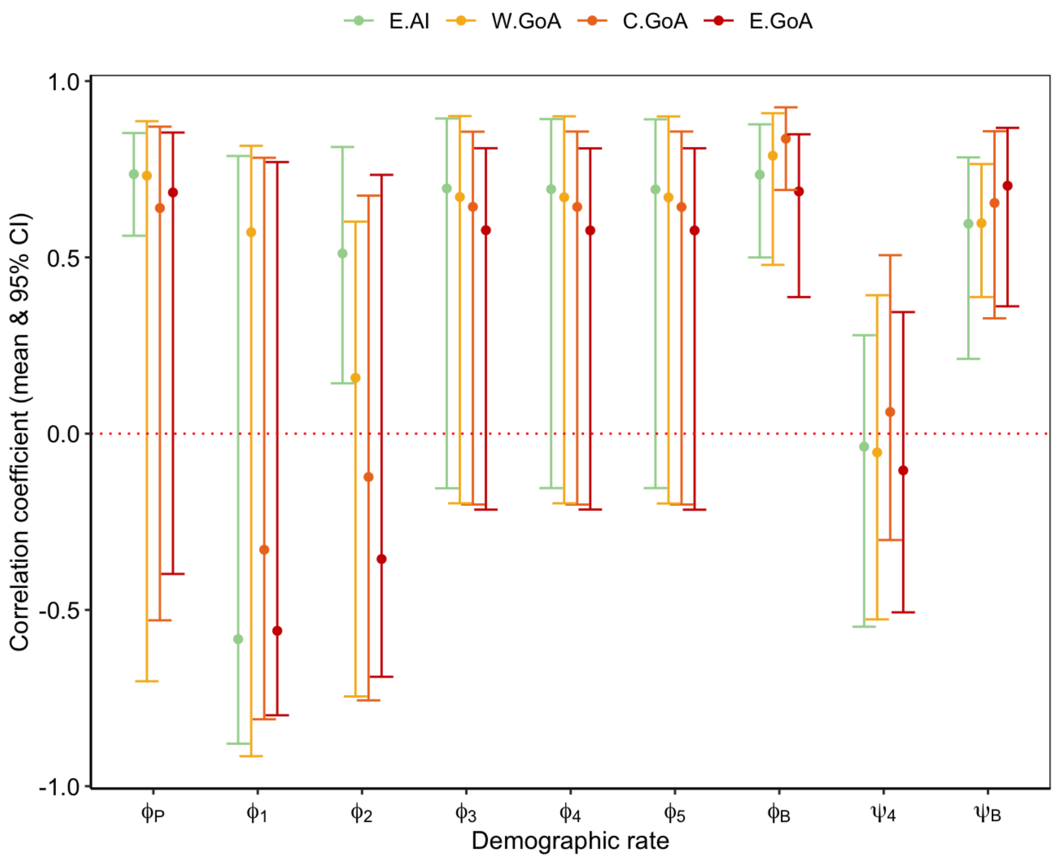

Figure S5: Posterior mean and 95% credible intervals for correlation coefficients *r* between annual population growth rates and female time-varying age-specific survival ($\phi_{P,1:5,B}$) and first-time pupping for age-4 individuals (ψ_4) and repeat (ψ_B) pupping rates across the four wDPS subregions where temporal variance in demographics was estimated: the eastern Aleutians, E.AI; western Gulf of Alaska, W.GoA; central Gulf of Alaska, C.GoA; eastern Gulf of Alaska, E.GoA.

Literature Cited

Hastings KK, Jemison LA, Pendleton GW (2018) Survival of adult Steller sea lions in Alaska: senescence, annual variation and covariation with male reproductive success. R Soc Open Sci 5: 170665 https://doi.org/10.1098/rsos.170665