Range-wide reproductive consequences of ocean climate variability

IG. 1. Monthly values (mean 6

 ϵ SD) of (a) lay dates, (b) breeding success for first attenption for first attenption for all attenptio and the masses (unscaled) for each population. Triangle Island values are depicted as black triangles, SE Fara
Triangles, SE Farallon values are depicted as black triangles, SE Farallon values are depicted as SE Farallon Is a gray square in the San Benito Island as open circles. As open circles in \mathcal{B}

 \mathbf{D} masses different among populations on \mathbf{D} some years (F[population]

$\begin{array}{ccc} & U & \\ & U & \\ \end{array}$

t ivity years during the cooler-water La Nina-like \mathcal{L} \bar{u} and \bar{u} in 2001–2001–2002 when auklets reared nearly real \bar{u} twice as many chicks as did the British Columbia and northern Mexico populations, to a catastrophic year of the catastrophic year of the catastrophic year of the c
The catastrophic year of the catastrophic year of the catastrophic year of the catastrophic year of the catast \Box unduring failure during the unusual the unusual terms of unusual oceanographic event in $\mathcal{L}=\mathcal{L}=\mathcal{L}$ $\mathbb D$ breeding parameters, we have param detected strong covariation in time \mathcal{L} northern populations and in breeding success and in breeding success and in breeding success all μ

 p appear to be linked to be linked to be linked to covariance in the linked to covariance in the linked to covariance in Π ocean conditions across sites and to consistent across sites and to consistent and to consistent and to consistent and to consistent across sites and to consistent across sites and to consistent across sites and to consis relationships between ocean climate conditions and \mathcal{L} $\mathcal D$

Timing of breeding and ocean climate

÷ \mathbf{C} Auklets in the British Columbia and central \mathcal{L} ω and conditions, since auklets, since auklets, since auklets, since auklets, since auklets, since auklets, since au ω on average laid earlier in years with lower March–April earlier in ω sea surface heights that indicate colder with \overline{B} with more variable with more variable with more variable with more variable with \overline{B} upwelling. Our results are consistent with previous \overline{H} findings from the central California population that \overline{V} auklets began egg-laying earlier in \mathcal{Q} mean spring sea surface temperatures (Abraham and \overline{B} are thought to rely on \overline{B} are thought to rely on \overline{B} proximal cues from their marine foraging environment \overline{D} with peaks in previous in previo ω multiple studies in seasonal environments in seasonal environments in seasonal environments in seasonal environments in ω $\mathbf{v} = \mathbf{v} = \mathbf{u} = \mathbf{u}$ between spring search s \Box surface temperature and seabird breeding phenology \Box $\frac{1}{2}$ (Jaquemet et al. 2007). Our results suggest that the theoretical that the theoretical theor probability in spring oceanographic condition in spring of \mathcal{D} tions at the northern and central current sites μ $c_{\mu\nu}$ to time breeding with periods of the breeding with periods of the breeding with periods of the breeding μ increased productivity that allow adults to reach μ breeding condition and that indicate that prey will be available during the chick-rearing period. In contrast, μ μ and μ relationships between ocean climate μ \overline{D} conditions and time \overline{D} conditions of the northern for $\mathcal{M}(\mathcal{M})$ in an ocean environ- which for an ocean environment that is matter that is matter in upwelling as μ p is a seasonal variability results in the seasonal variability results in the seasonal variability results in U higher unpredictability of optimal ocean conditions and prey peaks, which may favor the lower observed \mathcal{P} seasonality in time in time \mathcal{L} in other time in \mathcal{L} $\mathcal D$ seabird populations that breed in low variability $\mathcal D$ environments (Jaquemet et al. 2007).

Breeding success and ocean climate

 \overline{B} is not that Cassin's Auklet breeding succession \overline{B} $\overline{\mathcal{D}}$ and chief masses were similarly related to the total similar relation $\overline{\mathcal{D}}$ and the total similar relation $\overline{\mathcal{D}}$ same local ocean climate variable (sea surface height) and the vector populations, since we expected that oceanic we expected that oceanic we expected that oceanic we expected that oceanic we expected that \mathcal{L} p rocesses would differentially influence reproductive \mathcal{P} parameters across oceanographically heterogeneous regions of the California Current. However, the strength \overline{u} and shape of relationships between breeding success and $s_{\rm{max}} = \sqrt{M_{\rm{max}}}$ across populations. While we have we have we have we have $N_{\rm{max}}$ μ significant linear relationship between breeding between breeding between breeding breeding between breeding μ \overline{B} success and sea surface height for the northern Mexico \overline{N} \overline{B} first breeding attempts, the relationship attempts, the relationship r

 \mathbb{R}^n and first chicks chief first chicks chief first chicks chief first chicks chief \mathbb{R}^n \mathcal{L} during anomalous ocean climate conditions in 2005. $H(H) = H$ and the British for t \overline{D} and central California populations when all \overline{C} \Box breeding at the second broods) were discussed by \Box considered. Relationships between seabird demography and ecosystem fluctuations are commonly though to be computed to be \mathcal{A} \overline{B} and characterized by threshold effects (Cairns and characterized by threshold effects (Cairns and Cairns and Cair $\mathbf{p} = \mathbf{p}$ seasonally productive environments of the theorem is the theorem in the theorem is th

central and northern California Current, Cassinia Current, C $A^{\mu\nu}$ achieve relatively constant chick product product product production in first attempts when oceanographic conditions are \overline{u} favorable and when they time breeding time b c peak productivity, leading to non-linear productivity, leading to non-linear productivity, leading to non-linear productivity, H relationships between chick production and \overline{u} climate conditions, where chick production declines only in the worst \mathbf{u} in the worst \mathbf{u} in the worst \mathbf{u} from relays and second broods would further increase μ success in the success in years when ocean climate μ \Box continued to be favorable throughout through the breeding throughout the breeding \Box season, leading to the linear relationships observed for μ

all breeding attempts. In the more aseasonal oceano graphic environment in \mathbf{w} in \mathbf{w} and \mathbf{w} are \mathbf{w} R and Dan Dan Doak for Helpful insights, and Dave for \mathcal{D} Follow from the NOAA \mathbb{R}^2 from the NOAA \mathbb{R}^2 \Box . The altimeter products were produ duced by Ssaltonian by Aviso with support \mathbf{D} and distributed by Aviso with support \mathbf{D} for the cones of the cones fellowships from the National Science H and H and H and H $E = \overline{D}$ Foundation, and the Center for the Center for the Dynamics of the Center for the Dynamics of the Dynamics of the Dynamics of the Dynamics of the D \overline{u} and \overline{v} interface. The Land–Sea Interfa

ITERATURE ITED \overline{M} and \overline{M} and \overline{M} and \overline{M} and \overline{M} even and auklet nestings and auklet nestings and auklet nestings and auklet nestings and annual trends and annual trends and auklet nestings and automatical trends and automatical trends and automatical trends and automat variation in phenology, diet, and growth of a planktic structure of a plankti

\mathcal{L} Ptychoramphus aleuticus. Į.

 \mathbf{A} and C. \mathbf{B} and C. S. H. Morrel, and C. S. S. H. Morrel, and C. S. H. Morrel, and Strong. 1990. Cassing. In \Box Auklet. In D. G. Ainley and R. J. Ain $B \rightarrow B$ boekelheide, editors. Seabirds of the Farallon Islands. Seabirds of the Farallon Islands. Seabirds. Seabirds. B \mathbb{D} Stanford, \mathbb{D} Stanford, California, \mathbb{D} $B = \mathbf{A}$. A. Harfenist, and B. D. Smith. 2005. Oceanical distribution of B . Smith. 2005. Oceanical distribution of B . Ocea \mathcal{L} from upwelling and downwelling domains of British Colum- $\mathbf{D} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 &$ 2841–2853. \overline{B} and \overline{B} and \overline{B} and \overline{B} and \overline{B} and \overline{B} and \overline{B} ω seasonal variation and experimental variation and ecosystem and consequences. Progress in Oceanography 49:283–307. $\mathbf{B} = \mathbf{B} \mathbf{B}$ and $\mathbf{B} = \mathbf{B} \mathbf{B}$ and $\mathbf{B} = \mathbf{B} \mathbf{B}$ $S_{\rm eff}$ and D. F. Bertram. 2008. Variation in marine in mari distributions of \overline{u} and \overline{u} at Triangle Island, \overline{u} at Triangle Island, \overline{u} British Columbia. Auk 125:158–166. $\begin{array}{ccc} \downarrow & & \downarrow & \downarrow \end{array}$ of marine food marine food

supplies. Biological Oceanography 5:261–271. Cheal, A. J., S. Delean, H. Sweatman, and A. A. Thompson. $\mathcal{P} = \mathcal{P} = \mathcal$ influence of climate. Ecology 88:158–169. Coulson, T., E. A. Catchpole, S. D. Albon, J. T. Morgan, J. M. Pemberton, T. H. Clutton-Brock, M. J. Crawley, and B. T. μ and μ and μ and μ and μ and μ population crashes in Soay sheep. Science 292:1528–1531. For an extension of M controls and E. Posts. 2004. Using large-scale M \Box \mathbb{F}_p and \mathbb{F}_p a

 \mathcal{L} and annual variation in Black-legged Kittiwake \mathcal{L} $\mathfrak n$ breeding to sea surface temperature. The sea surface temperature temperature temperature. The sea surface temperature $\mathfrak n$ Frederiksen, M., M. P. Harris, and S. Wanless. 2005. Inter $p \longrightarrow q$

 \Box $J = \begin{pmatrix} 1 & \cdots & \cdots & 1000 & \cdots & \cdots & 1000$ $r = \nu$ \mathbf{t} the National Academy of Sciences (USA) 100:9377–9382. G rosbois, V., P. Henry, J. Blondel, P. Perret, J. Perret, J. Perret, J. D. Lebreton, J. D. \mathcal{D} and \mathcal{D} impacts on M investigation between Blue Tit survival: an investigation between M across seasons and spatial scales. Global Change Biology 12: \mathbf{A}

Grotan, V., B. E. Sæther, S. Engen, E. J. Solberg, J. D. C. \Box Climate causes large-scale spatial synchrony in population fluctuations of a temperate herbivore. Ecology 86:1472–1482. $H = \frac{1}{2}$ large-scale climate indices seem to process-seem to predict ecological process-seem to process-seem to processes better than local weather. Nature 430:71–75.

 $H_1 = \frac{1}{2}$ F. Middley, and D. Millar, change-integrated conservation strategies. Global Ecology \overline{u} + Huyer, A. 1983. Coastal upwelling in the California Current

System. Progress in Oceanography 12:259–284.

 $H_1 = \frac{1}{2}$ and $H_2 = \frac{1}{2}$ and $H_3 = \frac{1}{2}$ and $H_4 = \frac{1}{2}$ and $H_5 = \frac{1}{2}$ seabird communities of the southern California Current Curren System (1987–98): response at multiple temporal scales. Deep-Sea Research II 50:2537–2565. \bar{B} and \bar{B}

control of the breeding regime of the Sooty Tern in the southwest Indian Ocean. Deep-Sea Research I 54:130–142. $\begin{array}{ccc}\n\frac{D}{2} & - & \frac{D}{2} \\
\vdots & \vdots & \ddots & \vdots\n\end{array}$ Ptychodemography of the planktivorous Cassin's Auklet Ptycho r amphus aleuticus off northern \mathcal{C} normalizations for \mathcal{C}

population change. Journal of Animal Ecology 76:337–347. L egaard, L and L . And A. C. Thomas. 2006. Spatial patterns in the A. C. Thomas. 200 seasonal and interaction of chlorophyll and seasonal variability of chlorophyll and seasonal μ surface temperature in the California Current. Journal of $G_{\rm eff}$ (Research $R_{\rm eff}$) and $R_{\rm eff}$ (Research). Coefficient μ M and D and D and D becomes conservative con \mathbf{t} theory and probability of population via biology and population via biology \mathbf{t} analysis. Sinauer Associates, Sunderland, Massachusetts, Sunderland, Sunderla P armesan, C. 2006. Ecological and evolutionary responses to D

recent climate change. Annual Review of Ecology, Evolution, \overline{B} Perez-Brunius, P., M. Lopez, and J. Pineda. 2006. Hydro graphic conditions near the coast of near the coast of near the coast of near the coast of \mathbf{A}

California Current System, 1969–1997. Progress in Ocean ography 49:309–329. $V_{\rm eff} = \frac{1}{2} \left(\frac{1}{2} \left(\frac{1}{2} \right) \right)$, $\frac{1}{2} \left(\frac{1}{2} \right)$, \overline{D} and subarctic influences view for dominates view for dominates view \overline{D} nance. California Cooperative Fisheries Investigations Report 44:28–60.