Long-term changes in the breeding seasonality of Peruvian seabirds and regime shifts in the Northern Humboldt Current System

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Supplement 1. Seabird data

Table S1. Data of presence and absence of breeders for Guanay cormorant (*Phalacrocorax bougainvillii*) from 1952 to 2014 in Isla Pescadores.

Year	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1952	1	1	0	0	0	0	1	1	1	0	1	1
1953	1	1	0	0	0	0	0	0	1	1	1	1
1954	1	1	1	0	0	1	1	1	1	1	1	1
1955	1	1	1	0	0	0	1	1	1	1	1	1
1956	1	1	1	0	0	0	0	0	0	1	1	1
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	1	0	0	0	0	0	0	0	0	0	1	1
1959	0	0	0	0	0	0	1	1	1	1	0	1
1960	1	0	0	0	0	1	1	0	0	0	0	0
1961	1	0	0	1	1	1	1	1	1	1	1	1
1962	1	1	1	0	0	1	0	0	1	1	1	1
1963	1	0	0	0	0	0	0	0	0	1	1	1
1964	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
1965	1	1	1	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1968	NA	0	0	0	0	0	1	1	1	1	0	0
1977	NA	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	1	1	1	0	0	0	0
1980	0	0	0	0	0	1	1	0	0	1	1	0
1981	0	0	0	0	0	1	1	1	0	0	0	0
1982	0	0	0	0	1	1	1	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	1	1	0	0	0	0
1989	0	0	0	0	0	0	1	0	0	1	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0

Year												
2003	1	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	1	NA
2005	NA	NA	NA	NA	NA	NA	0	NA	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	NA	0	1	1	1	1	1	1	1
2008	1	1	0	0	NA	0	0	0	1	1	1	1
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1
2010	0	0	0	0	0	1	1	1	1	1	1	1
2011	1	1	0	0	1	1	1	1	1	1	1	1
2012	1	0	0	0	0	0	1	1	0	1	1	0
2013	0	0	0	0	0	1	1	1	1	1	1	1
2014	1	1	0	1	0	0	1	1	1	NA	NA	NA

Table S2. Data of presence and absence of breeders for Peruvian booby (*Sula variegata*) from 1952 to 2014 in Isla Pescadores.

	Months											
Year	J	F	M	A	M	J	J	A	S	O	N	D
1952	0	0	0	0	0	0	1	1	1	0	1	1
1953	1	1	0	0	0	0	0	0	1	1	1	1
1954	1	1	0	0	0	1	1	1	1	1	1	1
1955	1	1	1	0	0	0	0	1	1	0	1	1
1956	1	1	0	0	0	0	0	0	0	1	1	1
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	1	1
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	1	0	0	0	1	1	1	1	1	1	1	1
1962	1	0	0	0	0	1	0	0	1	1	1	1
1963	1	0	0	0	0	0	0	0	0	1	1	1
1964	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
1965	1	1	1	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
1967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1968	1	1	1	0	0	0	0	1	1	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	1	0
1978	0	0	0	0	0	0	0	0	1	0	0	0
1979	0	0	0	0	0	1	1	1	0	1	1	0
1980	0	0	0	0	1	1	1	1	1	1	1	0
1981	0	0	0	0	1	1	1	1	0	0	0	0
1982	0	0	0	0	1	1	1	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	1	0	0	0	0	0	0	1	1	0
1985	0	0	0	0	0	1	1	1	0	0	0	0
1986	1	0	0	0	0	0	0	0	0	1	0	0
1987	0	0	0	0	0	0	0	0	0	1	0	0
1988	0	0	0	0	0	0	1	1	0	0	0	1
1989	1	1	1	1	0	0	1	0	0	1	1	1
1990	0	0	0	0	0	0	0	0	1	1	1	0
2003	1	0	0	0	0	0	0	0	0	0	1	1
2004	0	0	0	0	0	1	0	0	1	1	1	NA
2005	NA	NA	NA	NA	NA	NA	1	NA	1	1	1	0

Year	J	F	M	A	M	J	J	A	S	O	N	D
2006	0	0	0	0	0	0	0	0	0	1	0	1
2007	0	0	0	NA	1	1	0	0	0	1	1	0
2008	0	0	0	0	NA	0	0	0	1	1	1	1
2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	1	0	0
2013	0	0	0	0	0	0	0	1	1	1	0	0
2014	0	0	0	0	0	0	0	0	0	NA	NA	NA

Table S3. Data of presence and absence of breeders for Peruvian pelican (*Pelecanus thagus*) from 1952 to 2014 in Isla Pescadores.

	Months											
Year	J	F	M	A	M	J	J	A	S	O	N	D
1952	0	0	0	0	0	0	0	0	0	0	1	1
1953	1	1	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	1	1
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	1	0	0	0	0	0	0	0	0	1	1	1
1962	1	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	1	0
1964		NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	1
1966	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	
1967	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1968	NA	0	1	0	0	0	0	0	0	0	0	0
1977	NA	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	1	1	0
1981	0	0	0	0	0	0	0	0	0	1	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	1	0	0	0	0	0	0	0	0	0	1
1989	0	0	0	0	0	0	1	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	1	1	NA
2005	NA	NA	NA	NA	NA	NA	0	NA	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	1	0	0
2007	0	0	0	NA	0	0	0	0	0	0	0	0
2008	0	0	0	0	NA	0	0	0	0	1	1	1

2009	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	1
2010	0	0	0	0	0	0	0	0	0	0	1	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	1	1	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	NA	NA	NA

Supplement 2. <u>Oceanographic data</u>

The oceanographic covariates were acquired from both international cruises available in the World Ocean Database 2013 (https://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html) of the National Oceanographic Data Center (NODC) and national research vessels belonging to the Consejo de Investigaciones Hidrobiologicas (CIHB, 1952-1959), the Instituto de Investigacion de los Recursos Marinos (IREMAR, 1960-1963), the Instituto del Mar del Peru (IMARPE, 1964 until now). Over the years, the monitoring of the oceanographic conditions along the Peruvian coast consisted in regular and repetitive sampling along parallel cross-shore transects of ~100 nautical miles long and ~15 nautical miles inter-transect distance from 3°30' to 18°20'°S. However, to build climatologies of the environmental conditions, we only considered in-situ data between 8°-15°S because this region encompasses the main nesting sites of the three seabird species considered here. Furthermore only data from the coast to 100 km offshore were retained because maximum-recorded foraging ranges of seabirds during breeding are: $\approx$60 km for cormorants (S. Bertrand, unpublished data), $\approx$90 km for boobies and $\approx$80 km for pelicans (Zavalaga *et al.* 2011; Bertrand *et al.* 2012). Oceanographic data for this area were available for the three interdecadal periods (1952-1968, 1977-1990 and 2003-2014) for SST and $Z_{2\ ml\ l^{-1}}$ but only for the two most recent periods for Chlo. Moreover, in order to study the interdecadal modulation of the seasonal variations we filtered out periods strongly influenced by interannual El Niño or La Niña events (Trenberth 1997; Trasmonte & Silva 2008).
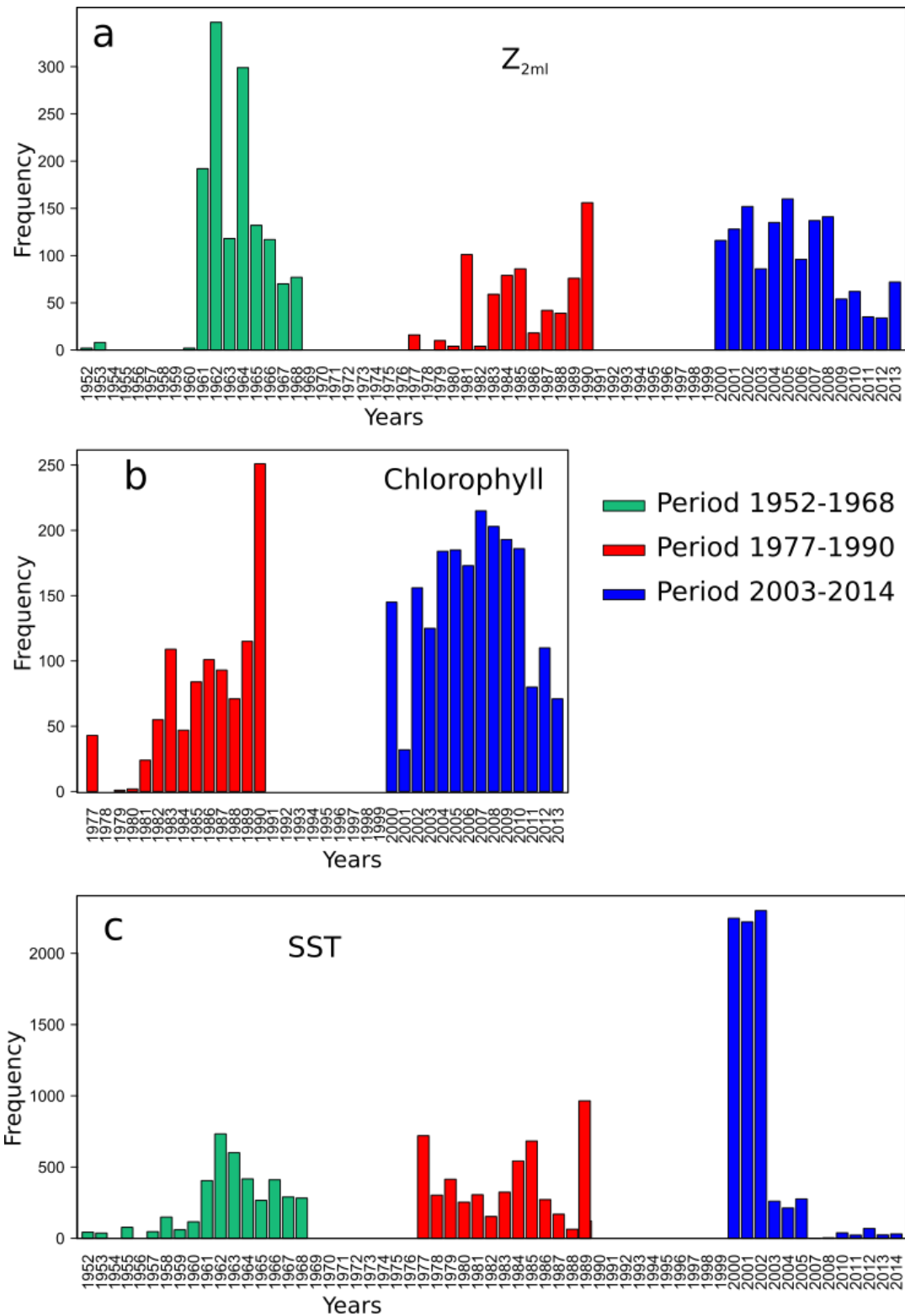
Figure S2. Barplots of data available among the years for a) $Z_{2mll^{-1}}$, b)Chlorophyll and c)SST. Data are classified by periods: green 1952-1968, red 1977-1990 and blue 2000-2012. For the most recent period we use oceanographic data since 2000 because it corresponded to the same regime and allowed us to build a stronger climatology.
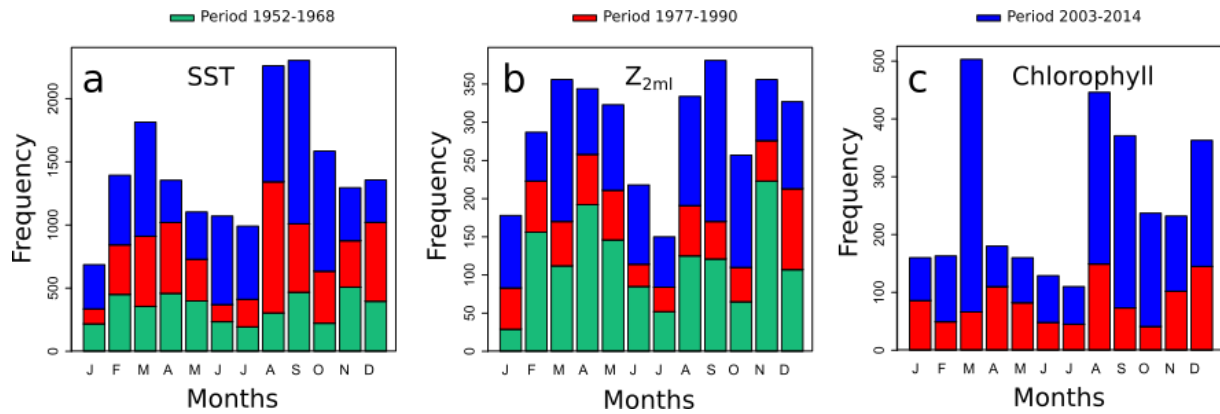
Figure S3 Barplots of data available of a) SST, b) $Z_{2mll}{-1}$ and c) Chlorophyll for each month during the periods: 1952-1968 (green), 1977-1990 (red) and 2003-2014 (blue).

Supplement 3. Acoustic data

Acoustic data have been acquired by routine scientific surveys performed along the Peruvian coast by IMARPE to estimate anchovy biomass since 1985.

Surveys were performed two to four times per year and lasted between one and three months. In general, the survey design consisted in parallel cross-shore transects of ~100 nm long and ~15 nm intertransects (Gutiérrez et al. 2007, Simmonds et al. 2009). Surveys were performed by research vessels equipped with hull mounted 38 and 120 kHz Simrad split beam scientific echosounders (EKS, EK500 and/or EK60). The echosounders were calibrated with a standard sphere (Foote et al. 1987). Nautical-area-backscattering coefficients (s_A or NASC) were recorded in each georeferenced elementary distance sampling unit (ESDU = 2 nautical miles during 1985-1993 and 1 nautical miles from 1994-2011) (Simmonds and Maclennan 2005). The volume-backscattering strengths were thresholded at -65 dB. The identification of records of anchovy and other species before 1999 was performed by the results of fishing hauls and the characteristics of the records; after 1999 the identification was performed using Echoview software.

Only acoustic data between 8ºS and 15ºS were retained and as a measure of abundance of anchovy we used 3 distinct metrics: i) the seasonal average of s_A (nautical-area-backscattering coefficient) per ESDU (georeferenced elementary distance sampling unit) representing a regional abundance of anchovy, ii) the seasonal average of s_A per ESDU only when anchovy was present (s_A+) representing local density of anchovy and iii) the seasonal spatial occupation index (ISO) computed as the percentage of ESDU with presence of anchovy, that represents the spatial distribution of anchovy. We calculated these metrics for two periods: during 1985-1990 (associated with the 1977-1990 period) and 2000-2011 (associated with the 2003-2014 period). We also calculated by period the average depth and height of schools of anchovy during day and night from acoustic data into the sub sampled area (100 km, 8ºS and 15ºS).

Supplement 4. <u>Tests of prior sensitivities and estimation of hyperparameters in informative priors</u>

Informative priors add a priori knowledge about output posteriors. The use of informative priors is advised to increase precision of posterior estimates when sample size is small (Morris et al. 2015). Since our data sample was small (17 years was the longest period) we used three different priors to test sensitivity: uninformative priors as Uniform and Jeffrey's prior, and informative priors. Informative priors (Gelman et al. 2003) came from our previous work on modelling breeding seasonality of seabirds of the NHCS (Passuni et al. 2016, Figure S4 and Table S4).
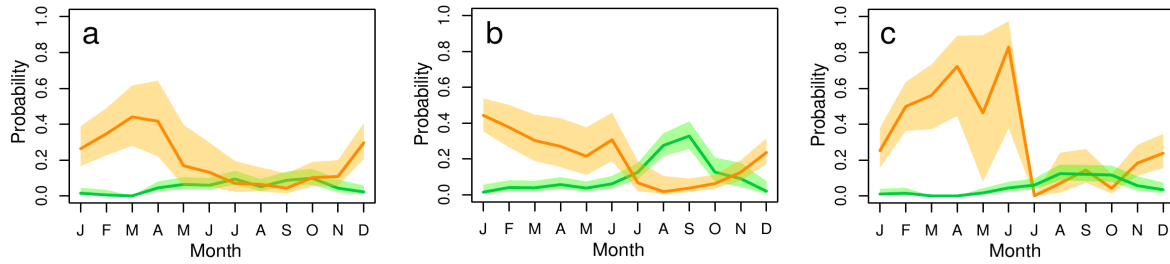
Figure S4. Estimates of monthly probabilities of onset of breeding (green solid line) and termination of breeding (orange solid line) at the breeding sites for (a) cormorants, (b) boobies and (c) pelicans in the Northern Humboldt Current System for the period 2003-2012 from Passuni et al. (2016). Shaded areas correspond to 95% confidence intervals.

Table S4. Mean (μ), variance (σ^2) and enlarged variance (σ^2 used) of the onset and termination of breeding for the cormorants, boobies and pelicans from 2003-2012 of 31 breeding sites in the Peruvian coast obtained from Passuni et al. (2016). Enlarged variance (maximum for onset 0.01 and termination 0.02), the hyperparameters α and β of the beta distribution were calculated for the three species. β and α hyperparameters for informative prior distribution were calculated from mean and enlarged variance.

Species	Onset					Termination				
	μ	σ^2	σ^2 used	α	β	μ	σ^2	σ^2 used	α	β
Cormorants	0.05	0.00	0.01	0.18	3.44	0.20	0.02	0.02	1.45	5.67
Boobies	0.10	0.01	0.01	0.82	7.27	0.20	0.02	0.02	1.46	5.68
Pelicans	0.05	0.00	0.01	0.19	3.54	0.33	0.08	0.02	3.38	6.74

To homogenize the distribution of the three priors and make them comparable, we use conjugate priors. Conjugate priors are used when the posterior distribution $f(\gamma \mid z)$ is in the same family as the prior probability distribution $f(\gamma)$. In our case, probability of onset and termination followed a Bernoulli distribution and its conjugate prior distribution was a beta distribution [Beta (α, β)]. Conjugate priors for a Uniform prior was Beta (1, 1) and for Jeffrey's prior Beta (0.5, 0.5). In the case of informative priors mean and variance could be

$$\mu = \frac{\alpha}{\alpha + \beta} \quad \text{and} \quad \sigma^2 = \frac{\alpha\beta}{(\alpha + \beta)^2 (\alpha + \beta + 1)}$$

expressed in terms of α and β such as .
So we can solve these equations for the parameters α and β of the prior distribution in terms of μ and σ^2:

$$\alpha = \mu \left(\frac{\mu(1 - \mu)}{\sigma^2} - 1 \right) \quad \text{and} \quad \beta = (1 - \mu) \left(\frac{\mu(1 - \mu)}{\sigma^2} - 1 \right) .$$

We used the largest variances of the probabilities of onset and termination of breeding obtained in Passuni et al. (2016, Figure S4 and Table S2) to estimate α and β parameters of the beta distribution.

We compared posteriors calculated using informative and non-informative priors through visual comparison and the deviance information criteria (DIC, Spiegelhalter et al. 2002). DIC is considered as a measure of model complexity and adequacy of posteriors. The model with the smallest DIC was selected as the best and we considered a difference in > 5 units as substantial evidence in favor of the model with the smaller DIC, and a difference in > 10 units as strong evidence (Spiegelhalter et al. 2002).

We obtained similar patterns of occupancy and onset of breeding using either uninformative or informative priors for the three seabird species (Figs S5-7). Therefore posteriors were not sensitive to the prior used. Nevertheless, we preferred using informative priors to estimates posteriors of onset of breeding because they were more coherent with the observed data than estimates obtained using uninformative priors (Table S5). In the case of termination of breeding, there was sensitivity to the use of priors. There were clear differences between posteriors resulting from informative and uninformative priors (Figs S5-7). Uninformative priors resulted in posterior estimates much larger than those observed for months where zero or only one event of termination was observed. Hence the use of informative priors is advised but also it indicates that there was not enough data to make robust inferences. Sensitivity to prior choice has been complemented with identifiability of parameters.

Table S5. Comparison of deviance information criterion (DIC) between the three priors used to model probabilities of occupancy, onset of breeding and termination of breeding: Uniform, Jeffrey and informative for the three species and the three periods. Comparison between models was only done when the dependent variable did not change, i.e. by rows. The lower DIC with a difference of 5 was selected in bold.

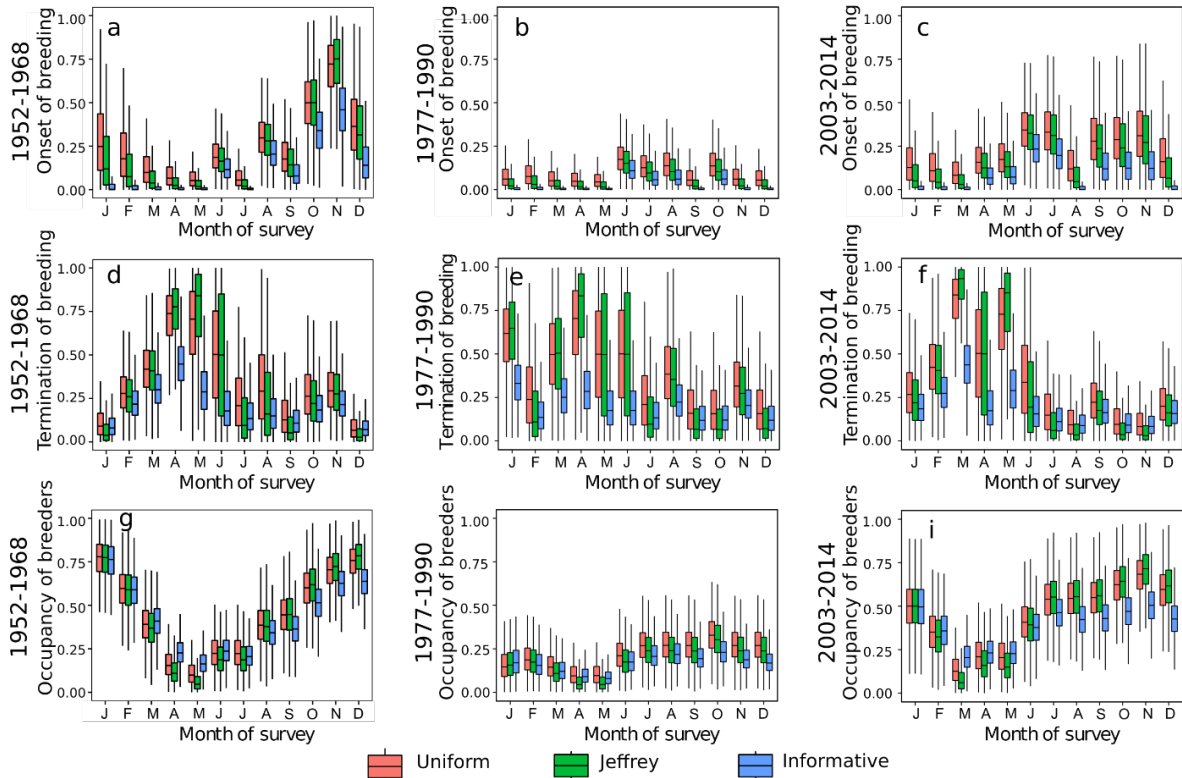| Periods	Species	Uniform DIC	Jeffrey DIC	Informative DIC
1952-1968	Cormorants	158.44	**148.39**	**147.46**
	Boobies	149.41	**135.50**	**137.01**
	Pelicans	111.12	96.73	**84.63**
1977-1990	Cormorants	116.24	100.54	**86.12**
	Boobies	193.17	**188.07**	**188.61**
	Pelicans	77.79	58.15	**43.27**
2003-2014	Cormorants	138.46	**126.77**	**128.14**
	Boobies	114.77	**102.61**	108.58
	Pelicans	86.73	73.16	**63.09**

Guanay cormorant

Figure S5. Output of a-c) onset, d-f) termination, and g-i) occupancy of breeding for Guanay cormorants for the periods 1952-1968, 1977-1990 and 2003-2014 with different hyperparameters: Uniform (red boxes), Jeffrey (green boxes) and Informative (blue boxes).
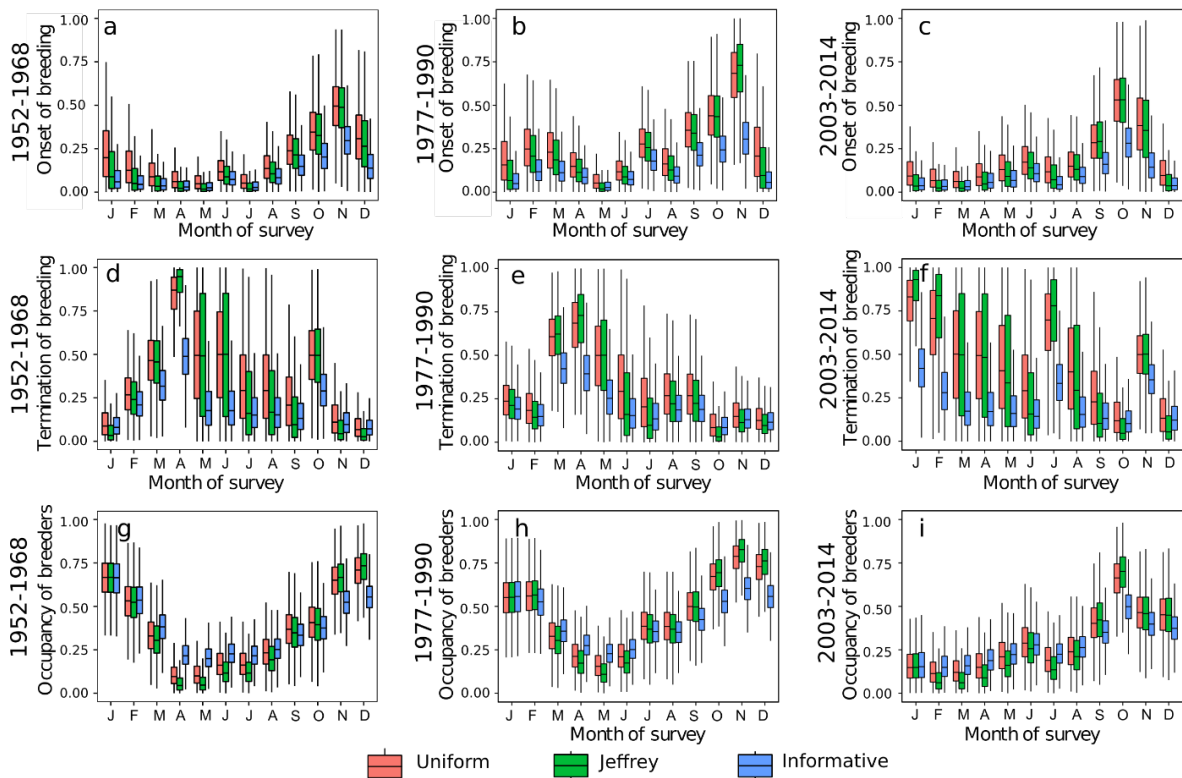
Peruvian booby

Figure S6. Output of a-c) onset, d-f) termination, and g-i) occupancy of breeding for Peruvian boobies for the periods 1952-1968, 1977-1990 and 2003-2014 with different hyperparameters: Uniform (red boxes), Jeffrey (green boxes) and Informative (blue boxes).
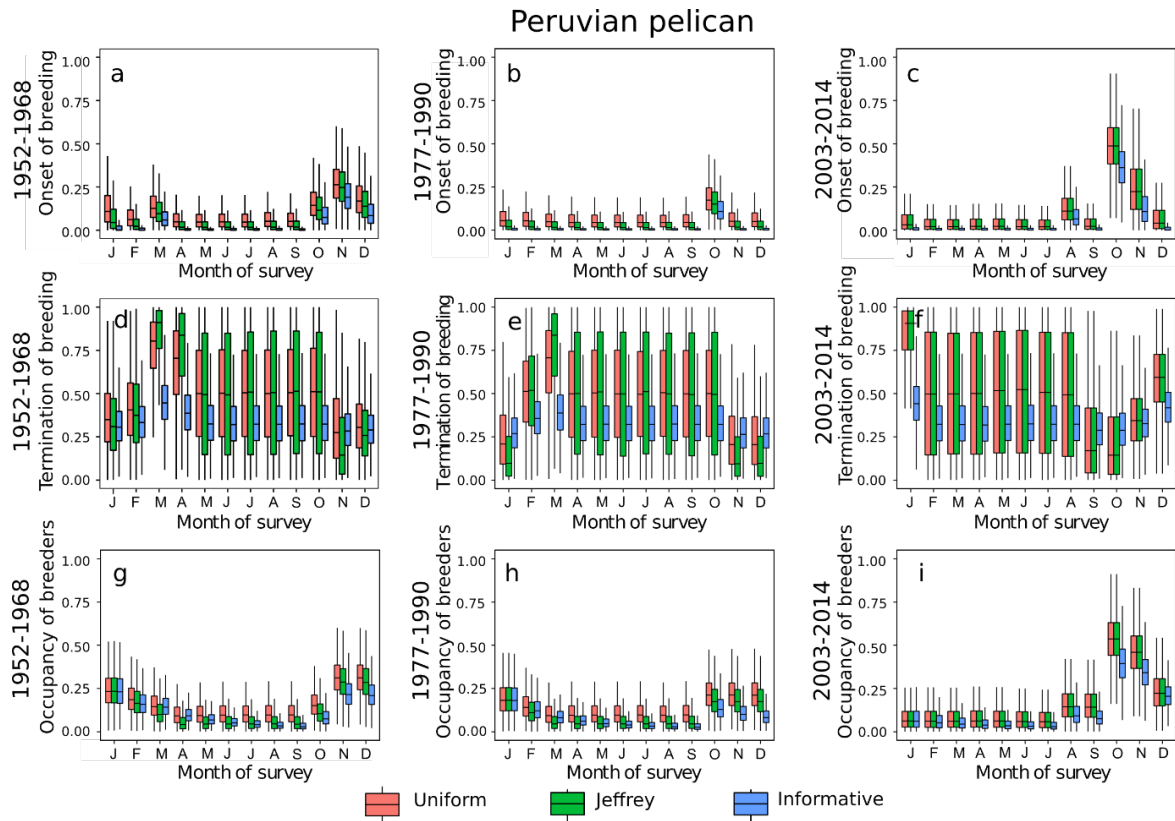
Figure S7. Output of a-c) onset, d-f) termination, and g-i) occupancy of breeding for Peruvian pelicans for the periods 1952-1968, 1977-1990 and 2003-2014 with different hyperparameters: Uniform (red boxes), Jeffrey (green boxes) and Informative (blue boxes).

Supplement 5. <u>Tests of identifiability of parameters</u>

We performed an identifiability test because sample size was limited for the three periods and since the posterior probability mode could be located at one of the extremes of the domain of the parameter space (for example $\gamma_{i,t-1} = 0$ or $\gamma_{i,t-1} = 1$). We tested the identifiability of the parameters γ and ε using the percentage of overlap between uniform prior and posterior distribution (τ), overlaps higher than 35% meant weak identifiability (Gimenez et al. 2009).

Overall, probabilities of onset of breeding were from well to weakly identifiable (mean percentage of overlap between uniform prior and posterior distribution for the three species and the three periods using uniform priors: $\tau'_{\gamma_t} = 39.6 \pm 11.7$), but probabilities of termination of breeding were not identifiable ($\tau'_{\varepsilon_t} = 69 \pm 15.8$). Occupation of breeders, derived from onset and termination, were weakly identified ($\tau'_{\psi_t} = 42.16 \pm 6.21$, Table S4). The low identifiability of termination of breeding could be associated to the fact that events of termination were widespread in time including normal terminations (end of the breeding season) and abandon of nest (almost every month) and therefore the signal was blurred. Consequently, we only considered the parameters onset of breeding (γ) and occupancy of breeders (ψ) for interpretation.

Table S6. Identifiability of onset (τ_γ), termination (τ_ε) and occupancy (τ_ψ) of breeders for the three seabirds during the three periods analyzed. Values indicated with * were considered as not identifiable because the overlap between the prior and posterior distribution was >70%, the average of overlap for the probabilities of termination of breeding.

	Cormorants			Boobies			Pelicans		
Parameter	1952 - 1968	1977- 1990	2003- 2014	1952- 1968	1977- 1990	2003- 2014	1952- 1968	1977- 1990	2003- 2014
τ_{γ_1}	68.88	28.71	47.22	60.83	52.92	35.88	40.28	26.19	33.39
τ_{γ_2}	55.73	29.83	41.69	46.18	56.93	31.44	29.11	26.25	28.01
τ_{γ_3}	39.42	24.74	36.17	36.74	57.05	29.14	36.01	24.12	28.32
τ_{γ_4}	30.23	23.26	42.14	28.05	41.56	34.31	23.74	23.44	28.87
τ_{γ_5}	24.31	23.35	46.34	23.77	25.22	40.30	25.38	23.44	29.11
τ_{γ_6}	41.40	40.62	54.03	35.27	34.47	45.38	24.73	23.82	28.24
τ_{γ_7}	27.34	35.42	61.31	24.46	49.01	39.01	24.00	22.75	27.05
τ_{γ_8}	49.75	38.19	44.12	39.77	43.98	41.61	24.68	22.99	39.57
τ_{γ_9}	47.13	26.77	60.61	48.20	56.36	52.62	25.31	22.03	29.37
$\tau_{\gamma_{10}}$	64.32*	39.17	62.15	58.78	60.96	64.32	39.15	40.82	57.65
$\tau_{\gamma_{11}}$	62.84	29.11	65.88	61.62	64.40	72.82*	49.18	25.95	59.00
$\tau_{\gamma_{12}}$	69.15	26.85	54.00	64.10	60.67	39.83	44.59	25.72	41.66
τ_{ε_1}	35.04	71.68*	59.18	34.99	48.93	54.80	71.29*	59.41	62.79
τ_{ε_2}	52.29	67.29	66.98	52.23	47.36	76.40*	73.75*	80.65*	93.65*
τ_{ε_3}	57.87	79.30*	52.31	61.53	57.03	93.00*	60.14	73.54*	94.19*
τ_{ε_4}	60.56	74.10*	94.04*	46.20	64.79	93.05*	76.35*	93.88*	91.91*
τ_{ε_5}	75.74*	92.57*	74.34*	93.29*	80.73*	89.61*	92.96*	93.36*	93.07*
τ_{ε_6}	93.04*	92.55*	78.57*	92.50*	75.75*	73.58*	93.10*	93.47*	94.08*
τ_{ε_7}	60.49	61.75	48.61	75.58*	60.91	70.93*	92.58*	92.32*	91.21*
τ_{ε_8}	74.40*	74.18*	37.02	75.45*	59.90	86.37*	91.79*	93.32*	92.91*

Parameter	Cormorants			Boobies			Pelicans		
	1952 - 1968	1977-1990	2003-2014	1952-1968	1977-1990	2003-2014	1952-1968	1977-1990	2003-2014
τ_{ε_9}	46.63	53.16	53.43	60.93	61.18	64.90	93.18*	93.30*	76.20*
$\tau_{\varepsilon_{10}}$	60.92	54.64	39.51	72.47*	34.85	43.65	93.20*	93.46*	71.80*
$\tau_{\varepsilon_{11}}$	55.47	65.41	35.09	43.24	42.71	60.35	72.45*	61.78	62.58
$\tau_{\varepsilon_{12}}$	29.91	51.79	49.24	30.69	36.07	49.78	66.14	61.05	66.82
τ_{ψ_1}	45.37	38.43	56.58	49.33	51.83	42.24	47.60	40.80	29.81
τ_{ψ_2}	49.44	38.60	51.51	50.64	49.29	35.95	42.67	34.95	34.16
τ_{ψ_3}	48.28	34.58	35.97	46.21	44.71	36.96	36.04	29.85	34.23
τ_{ψ_4}	37.46	28.61	44.75	30.33	41.58	40.14	29.44	30.21	35.75
τ_{ψ_5}	31.48	29.78	45.76	31.06	36.62	44.11	31.03	29.97	35.79
τ_{ψ_6}	42.66	41.06	51.06	38.47	40.50	49.77	31.76	30.39	35.70
τ_{ψ_7}	43.68	43.79	52.37	38.75	47.64	41.01	31.35	30.99	34.55
τ_{ψ_8}	49.02	43.88	52.71	44.49	47.52	46.54	31.74	30.95	43.08
τ_{ψ_9}	50.33	44.10	51.34	48.55	48.43	50.64	32.90	30.43	42.52
$\tau_{\psi_{10}}$	51.24	45.92	49.78	50.24	44.50	49.45	41.82	41.20	53.42
$\tau_{\psi_{11}}$	45.80	43.81	49.31	48.36	41.69	52.31	46.79	42.06	53.15
$\tau_{\psi_{12}}$	42.78	43.27	52.61	44.90	43.88	53.77	47.86	41.34	47.97

Supplement 6. Seabird life history traits

Table S7. Life history traits of cormorants, boobies and pelicans. K is a growth constant indicating the rate at which asymptotic weight is being achieved (Ricklefs 1973). * indicate approximate values corresponding to family members or similar species. Information is based on Bertrand et al. (2012), Nelson (2005), Ricklefs (1973), Duffy and Ricklefs (1981).

Life history trait	Cormorants	Boobies	Pelicans
Adult weight (kg)	2.12	1.56	5.23
Egg as percentage of female weight [*]	2-3%	5%	3%
Duration of incubation (days)	28	42	37
Rearing of chicks (days)	56	98	80
Post-fledging feeding (days)	30	35	30
Maximum brood size (individuals) [*]	4	3	3
Growth rate of chicks (K)[*]	0.08 - 1.33	0.04 - 0.09	0.07