

## SUPPLEMENTARY INFORMATION

### **Selection against immigrants in wild seabird populations**

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#### **S1: Data collection**

Long-term monitoring of wandering albatross started in 1965 (Fay *et al.* 2018). All chicks born on Ile de la Possession were ringed between mid-September and mid-October each year with a stainless steel band just before fledging from 1965. Each year, from early to mid-December, adults from the eight colonies were checked for bands. From mid-January (just after egg laying is resumed) to mid-February, at least three visits were made every 10 days in all colonies to identify the two members of each pair and to ascertain their breeding status. All unmarked individuals were capture and ringed with a uniquely numbered stainless steel-band. In mid-April, June, and August, all nests were checked and the chick status (alive/dead) recorded. During all visits, non-breeding individuals were searched for and their identities determined (from band numbers) when possible. Sex assignments were based on field observations (i.e., sexual size and plumage dimorphism, mating behaviors) and since 1999 on genetic analyses (Fay *et al.* 2018).

Long-term monitoring of southern fulmars started in 1963 (Jenouvrier *et al.* 2003). All chicks born on Ile des Pétrels were ringed each year with a stainless steel band just before fledging from 1963. Each year towards the end of December (just after egg laying is resumed), at least three visits were made every eight days to identify the two members of each pair and to ascertain their breeding status. All unmarked individuals were captured and ringed

with a uniquely numbered stainless steel-band. In late January all nests were checked and the chick status (alive/dead) recorded. During all visits, non-breeding individuals were searched for and their identities determined (from band numbers) when possible. From mid-March all fledglings were ringed. Individuals were not sexed.

Since 1963, three colonies of snow petrels ( $\approx$  290 nests, hereafter called study colonies) situated on Ile des Pétrels have been monitored annually (Chastel *et al.* 1993). In these colonies all adult individuals were identified and sexed by vocalization (females have higher-pitched calls than males (Barbraud *et al.* 2000)) and their breeding status recorded during three nest visits made during the first half of December (just after egg laying is resumed). All unmarked individuals were ringed with a uniquely numbered stainless steel-band. In mid-January all nests were checked and the chick status (alive/dead) recorded. During all visits, non-breeding individuals were searched for and their identities determined (from band numbers) when possible. From late February to early March all fledglings were ringed. In addition, since 1990, all chicks born on the entire Pointe Géologie archipelago (snow petrels breed on eight islands in total) were ringed each year with a stainless steel band just before fledging.

Barbraud, C., Mariani, A. & Jouventin, P. (2000). Variation in call properties of the snow petrel,

*Pagodroma nivea*, in relation to sex and body size. *Aust. J. Zool.*, 48, 421–430.

Chastel, O., Weimerskirch, H. & Jouventin, P. (1993). High annual variability in reproductive success and survival of an Antarctic seabird, the snow petrel *Pagodroma nivea*. *Oecologia*, 94, 278–285.

Fay, R., Barbraud, C., Delord, K. & Weimerskirch, H. (2018). From early life to senescence:

individual heterogeneity in a long-lived seabird. *Ecol. Monogr.*, 88, 60–73.

Jenouvrier, S., Barbraud, C. & Weimerskirch, H. (2003). Effects of climate variability on the temporal population dynamics of southern fulmars. *J. Anim. Ecol.*, 72, 576–587.

## **S2: Identification of immigrants**

For wandering albatrosses breeding at Ile de la Possession, maximum age at first breeding is 18 years (Weimerskirch 1992). We removed individuals which were unringed at first capture and that returned or recruited in the study population before 1985 so as to avoid including resident individuals born before the start of the monitoring program in the immigrant group, and because breeding status was not systematically ascertained for a number of individuals before 1985.

For southern fulmars breeding at Ile des Pétrels, maximum age at first breeding is 15 years (Jenouvrier *et al.* 2003). We removed individuals which were unringed at first capture and that returned or recruited in the study population before 1985 so as to avoid including resident individuals born before the start of the monitoring program in the immigrant group, and because breeding status was not systematically ascertained for a number of individuals before 1985.

For snow petrels breeding at Ile des Pétrels, maximum age at first breeding is 14 years (Chastel *et al.* 1993). Since all chicks from the archipelago were systematically ringed only since 1990, we removed individuals which were unringed at first capture and that returned or recruited in the three study colonies before 2004, so as to avoid including resident individuals born before the start of the monitoring program in the immigrant group.

Chastel, O., Weimerskirch, H. & Jouventin, P. (1993). High annual variability in reproductive success and survival of an Antarctic seabird, the snow petrel *Pagodroma nivea*. *Oecologia*, 94, 278–285.

Jenouvrier, S., Barbraud, C. & Weimerskirch, H. (2003). Effects of climate variability on the temporal population dynamics of southern fulmars. *J. Anim. Ecol.*, 72, 576–587.

Weimerskirch, H. (1992). Reproductive effort in long-lived birds: age-specific patterns of condition, reproduction and survival in the wandering albatross. *Oikos*, 64, 464–473.

### **S3: Multi-state capture-mark-recapture model structure**

Models were parameterized in terms of survival probability ( $\Phi$ ), return probability given survival ( $\rho$ , only for wandering albatross), breeding probability given (return and) survival ( $\beta$ ), hatching probability given (return and) survival and breeding ( $\delta$ ), and fledging probability given (return and) survival and breeding and hatching ( $\gamma$ ). Transition probabilities ( $\psi$ ) between state  $s$  in year  $t$  and state  $r$  in year  $t+1$  were modelled with a five-step procedure for wandering albatross where survival, return, breeding, hatching and fledging were considered as five successive steps in transition matrices (i.e.  $\psi = \Phi \times \rho \times \beta \times \delta \times \gamma$ ). For other species, transition probabilities were modelled with a four-step procedure (i.e.  $\psi = \Phi \times \beta \times \delta \times \gamma$ ).

Figure S1 and S2 present multinomial tree diagrams describing the probability structure for multistate observations and parameters of the models defined above for the three species. The state dead being explicitly included in the models but being never encountered implied several constraints (initial encounter probability was fixed to 0, transition probabilities from the state dead to the other states were fixed to 0, and recapture probability was fixed to 0). States were defined as follows: FBE = failed breeder at the egg stage, FBC = failed breeder at the chick stage, SB = successful breeder, NB = non-breeder, PFB = post-failed breeder, PSB = post-successful breeder, PNB = post-non-breeder, Dead = dead. For wandering albatrosses the probability of seeing individuals in unobservable states and transitions between unobservable states were constrained to zero.

For the wandering albatross the MSCMR models were parameterised by the initial state probabilities vector:

$$\mathbf{\Pi} = \begin{pmatrix} \pi_{FBE} & \pi_{FBC} & \pi_{SB} & 1 - \pi_{FBE} - \pi_{FBC} - \pi_{SB} & 0 & 0 & 0 \end{pmatrix},$$

the transition probabilities matrix  $\Psi$ :

$$\begin{array}{cccccccc} & FBE & FBC & SB & NB & PFB & PSB & PNB & Dead \\ \left( \begin{array}{cccccccc} \phi_{FBE}\rho_{FBE}\beta_{FBE}(1-\delta_{FBE}) & \phi_{FBE}\rho_{FBE}\beta_{FBE}\delta_{FBE}(1-\gamma_{FBE}) & \phi_{FBE}\rho_{FBE}\beta_{FBE}\delta_{FBE}\gamma_{FBE} & \phi_{FBE}\rho_{FBE}(1-\beta_{FBE}) & \phi_{FBE}(1-\rho_{FBE}) & 0 & 0 & 1-\phi_{FBE} \\ \phi_{FBC}\rho_{FBC}\beta_{FBC}(1-\delta_{FBC}) & \phi_{FBC}\rho_{FBC}\beta_{FBC}\delta_{FBC}(1-\gamma_{FBC}) & \phi_{FBC}\rho_{FBC}\beta_{FBC}\delta_{FBC}\gamma_{FBC} & \phi_{FBC}\rho_{FBC}(1-\beta_{FBC}) & \phi_{FBC}(1-\rho_{FBC}) & 0 & 0 & 1-\phi_{FBC} \\ \phi_{SB}\rho_{SB}\beta_{SB}(1-\delta_{SB}) & \phi_{SB}\rho_{SB}\beta_{SB}\delta_{SB}(1-\gamma_{SB}) & \phi_{SB}\rho_{SB}\beta_{SB}\delta_{SB}\gamma_{SB} & \phi_{SB}\rho_{SB}(1-\beta_{SB}) & 0 & \phi_{SB}(1-\rho_{SB}) & 0 & 1-\phi_{SB} \\ \phi_{NB}\rho_{NB}\beta_{NB}(1-\delta_{NB}) & \phi_{NB}\rho_{NB}\beta_{NB}\delta_{NB}(1-\gamma_{NB}) & \phi_{NB}\rho_{NB}\beta_{NB}\delta_{NB}\gamma_{NB} & \phi_{NB}\rho_{NB}(1-\beta_{NB}) & 0 & 0 & \phi_{NB}(1-\rho_{NB}) & 1-\phi_{NB} \\ \phi_{PFB}\rho_{PFB}\beta_{PFB}(1-\delta_{PFB}) & \phi_{PFB}\rho_{PFB}\beta_{PFB}\delta_{PFB}(1-\gamma_{PFB}) & \phi_{PFB}\rho_{PFB}\beta_{PFB}\delta_{PFB}\gamma_{PFB} & \phi_{PFB}\rho_{PFB}(1-\beta_{PFB}) & \phi_{PFB}(1-\rho_{PFB}) & 0 & 0 & 1-\phi_{PFB} \\ \phi_{PSB}\rho_{PSB}\beta_{PSB}(1-\delta_{PSB}) & \phi_{PSB}\rho_{PSB}\beta_{PSB}\delta_{PSB}(1-\gamma_{PSB}) & \phi_{PSB}\rho_{PSB}\beta_{PSB}\delta_{PSB}\gamma_{PSB} & \phi_{PSB}\rho_{PSB}(1-\beta_{PSB}) & 0 & \phi_{PSB}(1-\rho_{PSB}) & 0 & 1-\phi_{PSB} \\ \phi_{PNB}\rho_{PNB}\beta_{PNB}(1-\delta_{PNB}) & \phi_{PNB}\rho_{PNB}\beta_{PNB}\delta_{PNB}(1-\gamma_{PNB}) & \phi_{PNB}\rho_{PNB}\beta_{PNB}\delta_{PNB}\gamma_{PNB} & \phi_{PNB}\rho_{PNB}(1-\beta_{PNB}) & 0 & 0 & \phi_{PNB}(1-\rho_{PNB}) & 1-\phi_{PNB} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right) \end{array} \begin{array}{l} FBE \\ FBC \\ SB \\ NB \\ PFB \\ PSB \\ PNB \\ Dead \end{array}$$

and the event probabilities matrix:

$$\begin{array}{cccc} \text{not seen} & \text{seenFBE} & \text{seenFBC} & \text{seenSB} & \text{seenNB} \\ E = \left( \begin{array}{cccc} 1 - p_{FBE} & p_{FBE} & 0 & 0 & 0 \\ 1 - p_{FBC} & 0 & p_{FBC} & 0 & 0 \\ 1 - p_{SB} & 0 & 0 & p_{SB} & 0 \\ 1 - p_{NB} & 0 & 0 & 0 & p_{NB} \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{array} \right) \begin{array}{l} FBE \\ FBC \\ SB \\ NB \\ PFB \\ PSB \\ PNB \\ Dead \end{array} \end{array}$$

For the other species the MSCMR models were parameterised by the initial state probabilities

vector:

$$\begin{matrix} FBE & FBC & SB & NB \end{matrix}$$

$$\boldsymbol{\Pi} = \left( \pi_{FBE} \quad \pi_{FBC} \quad \pi_{SB} \quad 1 - \pi_{FBE} - \pi_{FBC} - \pi_{SB} \right),$$

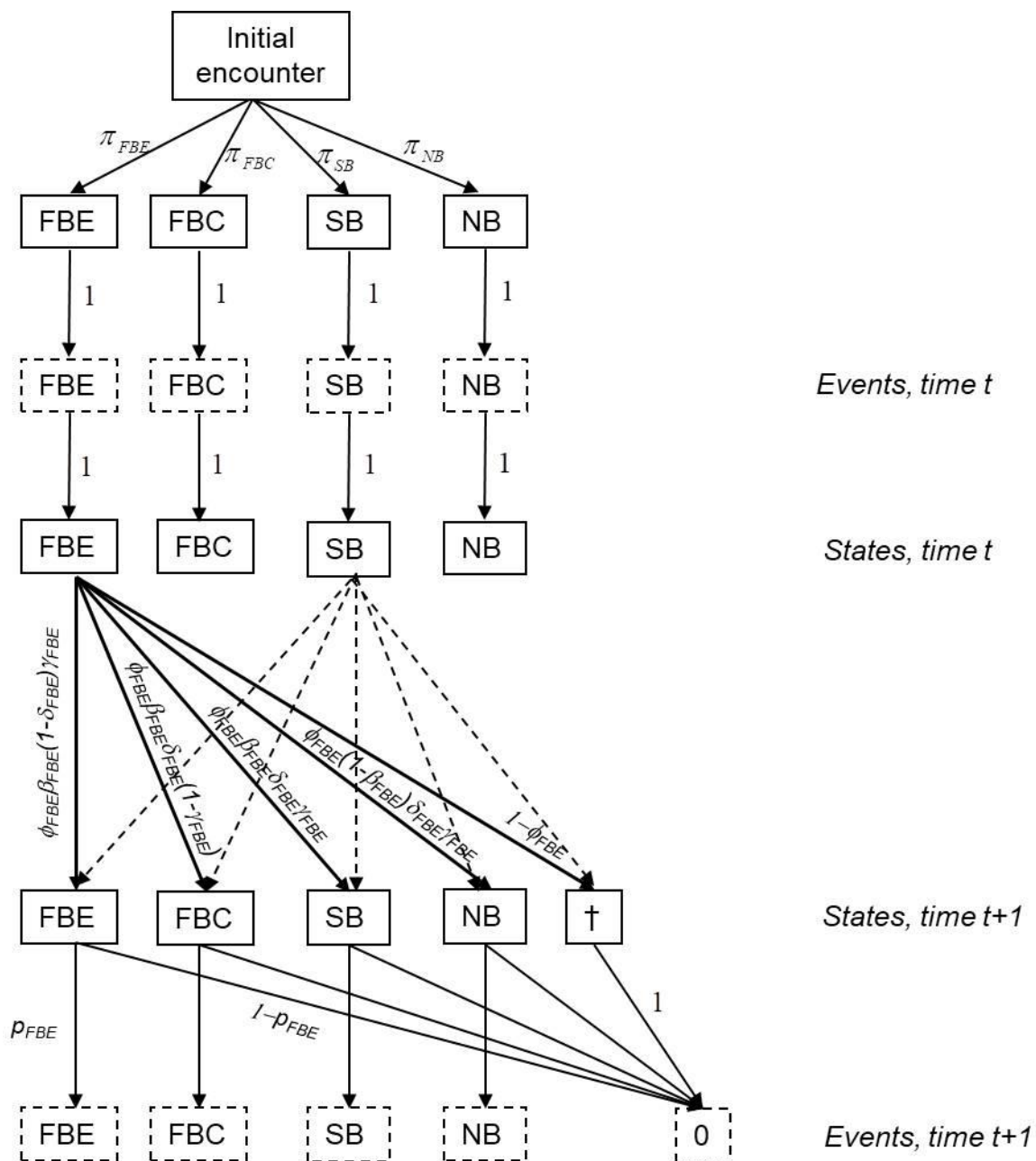
the transition probabilities matrix  $\Psi$ :

<i>FBE</i>	<i>FBC</i>	<i>SB</i>	<i>NB</i>	<i>Dead</i>	
$\phi_{FBE}\rho_{FBE}\beta_{FBE}(1-\delta_{FBE})$	$\phi_{FBE}\rho_{FBE}\beta_{FBE}\delta_{FBE}(1-\gamma_{FBE})$	$\phi_{FBE}\rho_{FBE}\beta_{FBE}\delta_{FBE}\gamma_{FBE}$	$\phi_{FBE}\rho_{FBE}(1-\beta_{FBE})$	$1-\phi_{FBE}$	<i>FBE</i>
$\phi_{FBC}\rho_{FBC}\beta_{FBC}(1-\delta_{FBC})$	$\phi_{FBC}\rho_{FBC}\beta_{FBC}\delta_{FBC}(1-\gamma_{FBC})$	$\phi_{FBC}\rho_{FBC}\beta_{FBC}\delta_{FBC}\gamma_{FBC}$	$\phi_{FBC}\rho_{FBC}(1-\beta_{FBC})$	$1-\phi_{FBC}$	<i>FBC</i>
$\phi_{SB}\rho_{SB}\beta_{SB}(1-\delta_{SB})$	$\phi_{SB}\rho_{SB}\beta_{SB}\delta_{SB}(1-\gamma_{SB})$	$\phi_{SB}\rho_{SB}\beta_{SB}\delta_{SB}\gamma_{SB}$	$\phi_{SB}\rho_{SB}(1-\beta_{SB})$	$1-\phi_{SB}$	<i>SB</i>
$\phi_{NB}\rho_{NB}\beta_{NB}(1-\delta_{NB})$	$\phi_{NB}\rho_{NB}\beta_{NB}\delta_{NB}(1-\gamma_{NB})$	$\phi_{NB}\rho_{NB}\beta_{NB}\delta_{NB}\gamma_{NB}$	$\phi_{NB}\rho_{NB}(1-\beta_{NB})$	$1-\phi_{NB}$	<i>NB</i>
0	0	0	0	1	<i>Dead</i>

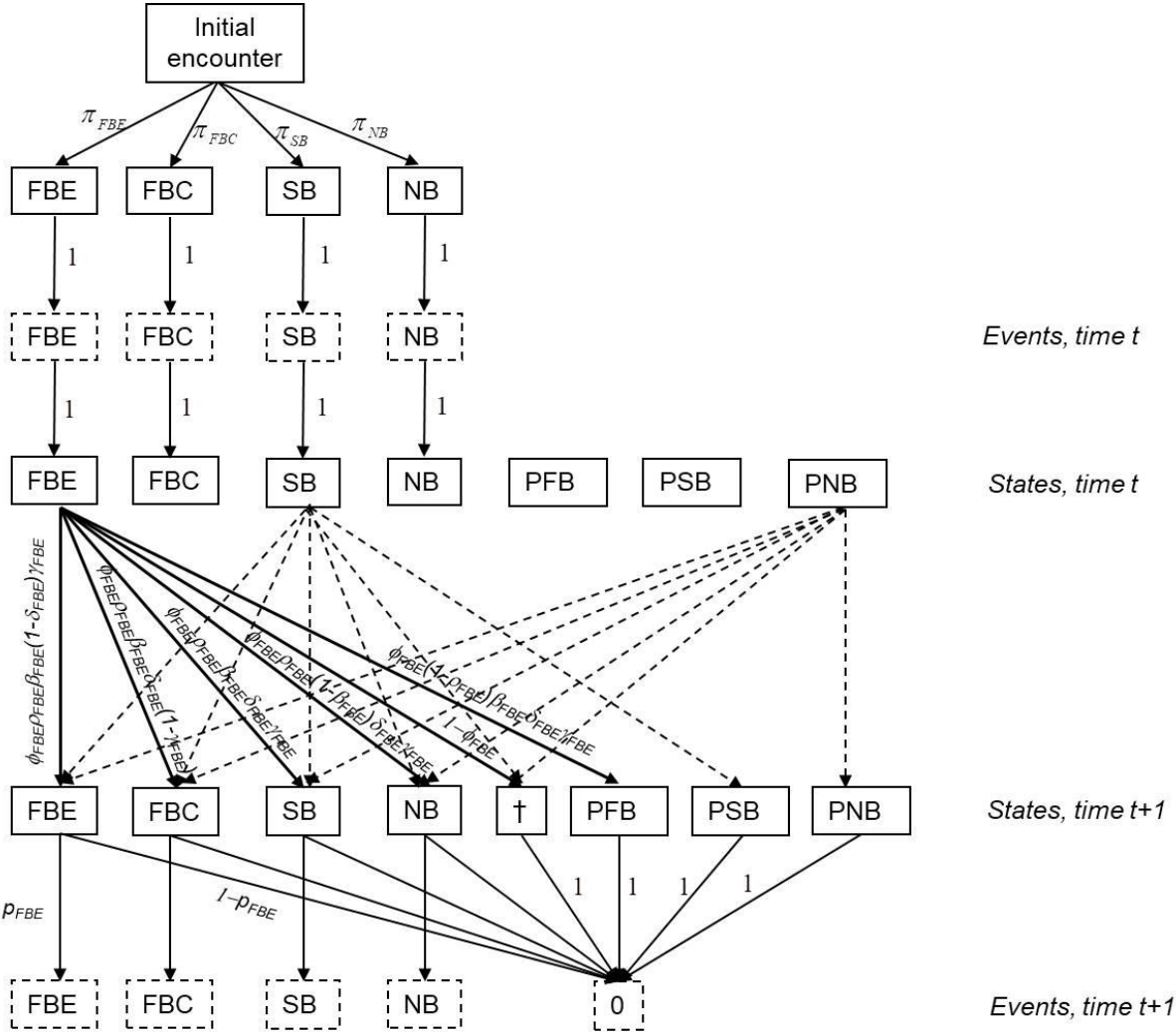
and the event probabilities matrix:

	not seen	seenFBE	seenFBC	seenSB	seenNB	
$E =$	$1 - p_{FBE}$	$p_{FBE}$	0	0	0	<i>FBE</i>
	$1 - p_{FBC}$	0	$p_{FBC}$	0	0	<i>FBC</i>
	$1 - p_{SB}$	0	0	$p_{SB}$	0	<i>SB</i>
	$1 - p_{NB}$	0	0	0	$p_{NB}$	<i>NB</i>
	1	0	0	0	0	<i>Dead</i>

**Figure S1** A multinomial tree diagram describing the probability structure for multistate observations for the southern fulmar and the snow petrel. Solid boxes marked FBE, FBC, SB, NB and † indicate possible states (alive in state FBE, FBC, SB, NB or dead), while dashed boxes represent possible observations following initial release. Possible observations include FBE (encountered in state failed breeder at the egg stage), FBC (encountered in state failed breeder at the chick stage), SB (encountered in state successful breeder), NB (encounter in state non breeder), and 0 (not encountered). State transition probabilities were decomposed in a four-step process as the product of probabilities of survival  $\phi$ , breeding  $\beta$ , hatching  $\delta$ , and fledging  $\gamma$ . Transition probabilities are only explicitly indicated for the FBE state for clarity. Dashed arrows indicate possible transitions for the SB state for illustration. All possible transitions are not shown for clarity.



**Figure S2** A multinomial tree diagram describing the probability structure for multistate observations for the wandering albatross. Solid boxes marked FBE, FBC, SB, NB, PFB, PSB, PNB and † indicate possible states (alive in state FBE, FBC, SB, NB, PFB, PSB, PNB or dead), while dashed boxes represent possible observations following initial release. Possible observations include FBE (encountered in state failed breeder at the egg stage), FBC (encountered in state failed breeder at the chick stage), SB (encountered in state successful breeder), NB (encounter in state non breeder), and 0 (not encountered). State transition probabilities were decomposed in a five-step process as the product of probabilities of survival  $\phi$ , return  $\rho$ , breeding  $\beta$ , hatching  $\delta$ , and fledging  $\gamma$ . Transition probabilities are only explicitly indicated for the FBE state for clarity. Dashed arrows indicate possible transitions for the SB and PNB states for illustration. All possible transitions are not shown for clarity.





**Table S1** Goodness of fit tests of the JollyMoVe umbrella model for multistate models. Only three tests have biological interpretations: WBWA, tests for a memory effect, i.e. whether individuals tend to stay in the same state from one encounter occasion to the next; 3G.SR, tests for transience; M.ITEC, tests for trap-dependence. WA = wandering albatross, SP = snow petrel, FU = southern fulmar. Values are  $\chi^2$ , df and P-values

	WBWA	3G.SR	3G.Sm	M.ITEC	M.LTEC	Global
WA Male	250.978	51.705	326.461	95.799	33.056	757.999
	206	107	523	46	18	900
	0.018	1	1	<0.001	0.016	0.999
WA Female	174.758	80.394	305.728	118.767	47.57	727.217
	174	122	491	39	23	849
	0.470	0.998	1	<0.001	0.002	0.999
SP Male	14.871	18.638	17.162	21.877	5.85	78.398
	37	24	64	9	2	136
	0.999	0.771	1	0.009	0.054	0.999
SP Female	20.307	24.4	10.386	7.374	0	62.467
	29	27	71	6	0	133
	0.883	0.608	1	0.288	NA	1
FU	65.52	58.562	117.124	31.193	8.042	280.441
	113	91	256	23	4	487
	0.999	0.997	1	0.118	0.090	1
Global	526.434	233.699	776.861	275.01	94.518	1906.522
	559	371	1405	123	47	2505
	0.835	1	1	<0.001	<0.001	1

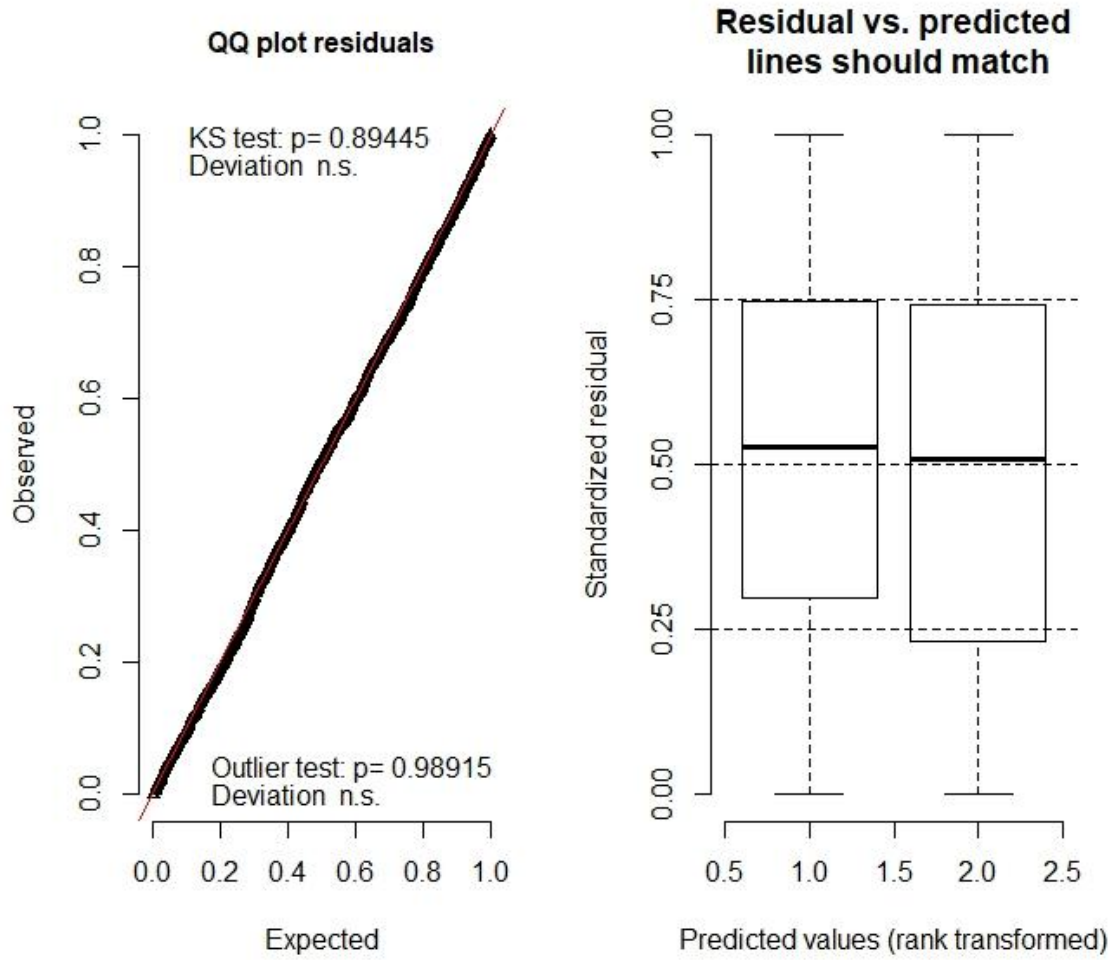
**Table S2** Modelling demographic parameters (recapture probability, fledging probability, hatching probability, breeding probability, return probability, survival probability) of residents and immigrants for wandering albatross, snow petrel and southern fulmar

Model	Hypothesis tested	Structure	Dev	Rank	AICc	$\Delta$ AICc	$w_i$
Male wandering albatross							
M1	Null model	$\Phi_s \rho_s \beta_s \delta_s \gamma_s p_s^t$	36454.3	137	36732.6	0.0	0.255
M2	Different recapture	$p_{s.g}^t$	36346.1	257	36875.2	142.6	0.000
M3	Different fledging	$\gamma_{s.g}$	36453.8	139	36736.2	3.6	0.042
M4	Different hatching	$\delta_{s.g}$	36451.6	139	36734.0	1.4	0.124
M5	Different breeding	$\beta_{s.g}$	36453.6	139	36736.0	3.4	0.046
M6	Different return	$\rho_{s.g}$	36453.2	139	36735.6	3.0	0.057
M7	Different survival	$\Phi_{s.g}$	36451.0	138	36731.3	-1.3	0.476
Female wandering albatross							
M8	Null model	$\Phi_s \rho_s \beta_s \delta_s \gamma_s p_s^t$	33107.9	137	33386.6	0.0	0.164
M9	Different recapture	$p_{s.g}^t$	32994.8	257	33525.7	139.1	0.000
M10	Different fledging	$\gamma_{s.g}$	33107.3	139	33390.2	3.6	0.027
M11	Different hatching	$\delta_{s.g}$	33105.0	139	33387.9	1.3	0.086
M12	Different breeding	$\beta_{s.g}$	33102.2	139	33385.1	-1.5	0.349
M13	Different return	$\rho_{s.g}$	33103.2	139	33386.1	-0.5	0.212
M14	Different survival	$\Phi_{s.g}$	33105.8	138	33386.6	0.0	0.162
Male snow petrel							
M15	Null model	$\Phi_s \beta_s \delta_s \gamma_s p_s^t$	1791.6	59	1928.2	0.0	0.120
M16	Different recapture	$p_{s.g}^t$	1772.3	81	1971.3	43.1	0.000
M17	Different fledging	$\gamma_{s.g}$	1786.5	60	1925.7	-2.5	0.403
M18	Different hatching	$\delta_{s.g}$	1790.3	60	1930.9	2.7	0.030
M19	Different breeding	$\beta_{s.g}$	1787.1	60	1926.4	-1.8	0.294
M20	Different survival	$\Phi_{s.g}$	1788.4	60	1927.7	-0.5	0.153
Female snow petrel							
M21	Null model	$\Phi_s \beta_s \delta_s \gamma_s p_s^t$	1898.8	59	2033.6	0.0	0.121
M22	Different recapture	$p_{s.g}^t$	1871.2	83	2072.3	38.7	0.000
M23	Different fledging	$\gamma_{s.g}$	1898.0	60	2035.5	1.9	0.047
M24	Different hatching	$\delta_{s.g}$	1893.2	60	2030.7	-2.9	0.526
M25	Different breeding	$\beta_{s.g}$	1894.7	60	2032.1	-1.5	0.259
M26	Different survival	$\Phi_{s.g}$	1898.1	60	2035.5	1.9	0.047
Southern fulmar							
M27	Null model	$\Phi_s \beta_s \delta_s \gamma_s p_s^t$	8174.4	137	8470.5	0.0	0.116
M28	Different recapture	$p_{s.g}^t$	8096.4	251	8677.5	207.0	0.000
M29	Different fledging	$\gamma_{s.g}$	8172.6	138	8471.0	0.5	0.090
M30	Different hatching	$\delta_{s.g}$	8171.6	138	8470.0	-0.5	0.146
M31	Different breeding	$\beta_{s.g}$	8168.8	138	8467.2	-3.3	0.609
M32	Different survival	$\Phi_{s.g}$	8174.3	138	8472.7	2.2	0.038

Dev, deviance (=  $-2 \times$  maximized log-likelihood); rank, number of estimated parameters in the model; AICc, Akaike information criterion;  $\Delta$ AICc, difference in AICc between the null model and the model tested;  $w_i$ , Akaike weights. All models are full rank. Structure indicates the model structure with probabilities of survival  $\Phi$ , return  $\rho$ , breeding  $\beta$ , hatching  $\delta$ , fledging

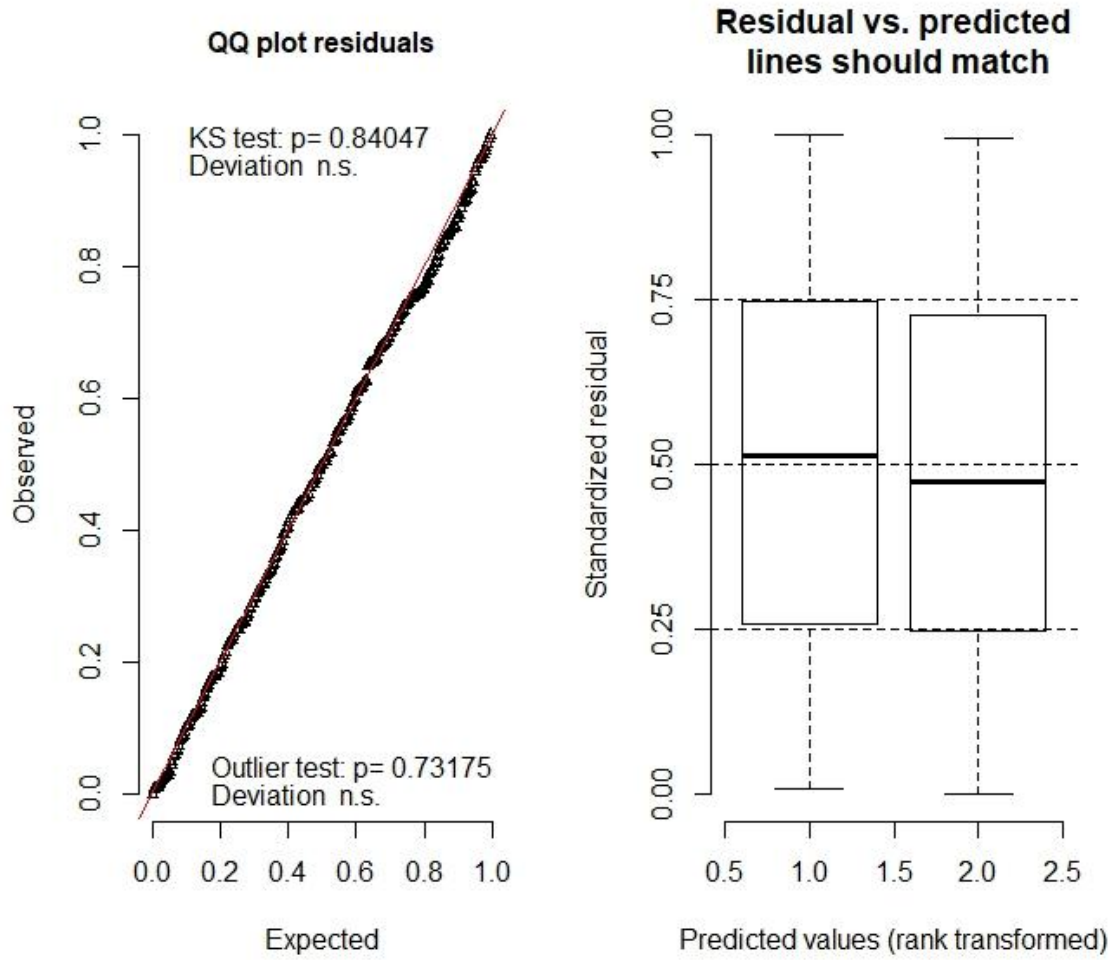
$\gamma$ , and recapture  $p$ ;  $t$ , year;  $s$ , state;  $g$ , group (immigrant, resident). Only the parameter for which the structure differs from the null model is indicated

DHARMA scaled residual plots



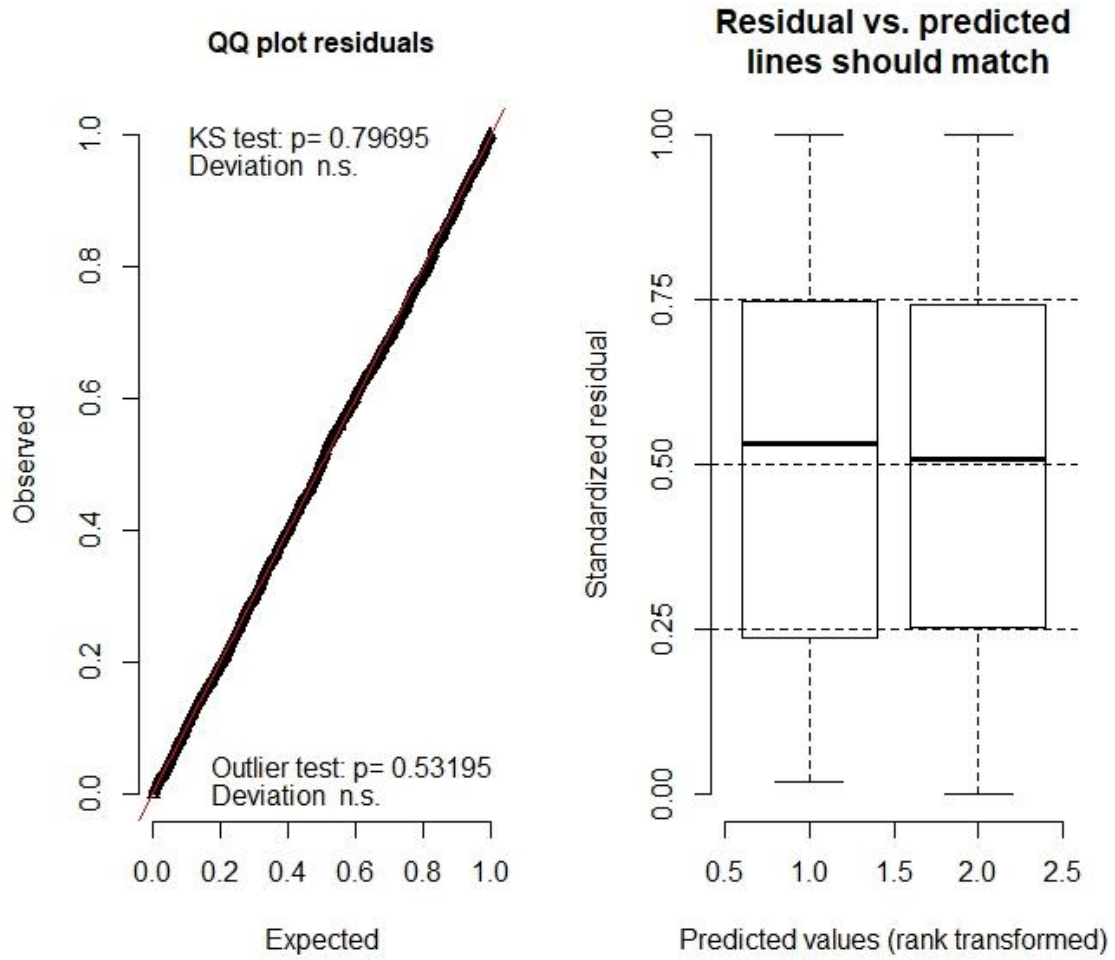
**Figure S3** Residuals of the generalized mixed effect model with number of recruits produced as a response variable for residents and immigrant male wandering albatrosses.

DHARMA scaled residual plots



**Figure S4** Residuals of the generalized mixed effect model with number of recruits produced as a response variable for residents and immigrant female wandering albatrosses.

DHARMA scaled residual plots



**Figure S5** Residuals of the generalized mixed effect model with number of recruits produced as a response variable for residents and immigrant southern fulmars.