Supporting Information

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Wandering Albatross Breeding Cycle

The breeding cycle of wandering albatross, *Diomedea exulans*, lasts a full year. Birds that successfully fledge a chick breed every 2 years. Birds that lose their egg or lose their chick during the early stages of chick-rearing engage in a new breeding attempt the following year (1). Sexual maturity is acquired at 8–10 years on average (2). Wandering albatrosses are long-lived birds (age 50 years+) that show a progressive increase in breeding success in relation to breeding experience between 8–9 and 25–30 years of age (3, 4). Breeding success decreases after six or seven breeding attempts, corresponding to birds age >25–30 years, suggesting senescence at older age. Thus, wandering albatrosses provide an excellent study system for exploring relationships between breeding performance and age-related declines in physiology and foraging behavior.

The incubation period in wandering albatrosses is about 78 days, and laying at the Crozet Islands occurs on January 1 on average (5). The male and the female forage alternately at sea while the other partner fasts on the nest. Only one adult can forage at a time, because the egg needs to be permanently attended lest it become rapidly predated. Thus, during pelagic foraging trips that typically last 5–15 days, albatrosses need to gain mass rapidly to restore body condition and accumulate energy to use during the next fast at the nest. Birds that do not accumulate sufficient energy during a foraging trip risk failing to complete the subsequent incubation shift. Conversely, if a bird remains at sea for too long, then the partner's prolonged fast can lead to nest desertion and breeding failure (6). Thus, the incubation stage represents a conflict between egg care and self-maintenance, and birds need to allocate time and energy between incubating (i.e., fasting) and self-feeding. The resolution of this conflict might be challenging for old, potentially energy-challenged individuals. Incubating albatrosses provide an excellent study system for exploring relationships among foraging performance, foraging behavior, somatic maintenance, and age-related breeding performance. Previous studies that detected age-related patterns in wandering albatrosses focused on incubation period (4, 7).

Choice of Parameter: Age or Experience?

Two parameters are of potential interest when examining senescence patterns: age and previous breeding experience. Both age (4, 5) and experience (7) have been successfully used in studies on wandering albatrosses. The "experience hypothesis" states that over the course of their lives, individuals progressively gain competence in behavioral traits that improve reproductive performance (8). The rates of these processes might differ among individuals. Individual quality has been found to interact with age in determining some senescence patterns (9). In long-lived seabirds, the breeding experience is potentially highly variable between individuals of the same age, because birds often skip reproduction (10), and also because the age at first reproduction varies (7). Some recent studies found that reproductive experience explained these differences more accurately than did age per se (11). Thus, although wandering albatrosses usually do not skip breeding opportunities, it is a priori crucial to consider experience when designing the experiment.

In the study colony (Possession Island, one of the Crozet Islands; 46.8 °S, 51.8 °E), experience has been monitored on an annual basis since 1965. The database provides information on age at first reproduction and number of breeding attempts. Given the ongoing debate in the literature on whether costs of reproduction early in life might affect senescence (i.e., "reproduce now, pay later") (12, 13), we controlled the age of birds at first reproduction when designing the experiment. We excluded the few birds with an "unusual" early life (e.g., birds with delayed age at first reproduction) from the design before starting the field work. In the study sample, age at first breeding attempt was remarkably constant in males (9.8 ± 1.8 years;, $n = 49$) and females (9.1 ± 1.7 years; $n = 45$). Age and breeding experience (i.e., number of total breeding attempts before the study season) were highly correlated in males ($n = 56$, Pearson's product-moment correlation = 0.95, $df = 54$, $t = 22.8$, $P < 0.001$) and females ($n = 50$, Pearson's product-moment correlation = 0.94, $df = 48$, $t = 18.3$, $P < 0.001$). Thus, we could not include breeding experience as a covariate when modeling phenotypic markers with age and date. Age was preferred over experience for empirical reasons, described below.

Previous studies on wandering albatrosses used birds nesting in accessible and carefully monitored parts of the colony (7). In the present study, to increase the sample size, we included a number of remote birds for which the monitoring of breeding experience might be underestimated even though their age is not. Indeed, birds that nest far from paths could be missed during controls, depending on observational effort and empirical constraints. Because albatrosses typically return to the same nesting places from one breeding cycle to the next, the cumulative number of chicks recorded in remote birds might be influenced by their geographical position. Importantly, because the oldest birds were ringed as adults in the early part of the long-term study, their exact experience was unknown. For these old birds (which are of prime interest when studying senescence), it was possible to calculate a minimum age from the year of banding, as well as a minimum age at first breeding in the species. It was not possible to calculate an accurate "minimum experience"—only the reproductive attempts that had been monitored since the year of banding could be considered. Thus, when analyzing our data, it was more relevant to focus on the age of the birds.

Activity at the Sea Surface

Activity Loggers. To address the question of the timing of activity, we used miniature light-level/immersion loggers (GLS-MK4, 25 × 18 × 7 mm, 4.5 g; British Antarctic Survey) (14). This device incorporates a photoreceptor and two electrodes that function as a saltwater sensor. The logger is configured to record light level and saltwater immersion every 3 s. The information is stored as the proportion of each 10-min period spent on the sea surface (as distinct from flying or on land), with reference to an internal clock/calendar. Given the sampling interval (3 s), the value recorded at the end of each 10-min period ranged from 0 (fully dry: flying or on land activity) to 200 (fully wet: sitting on the water or scavenging activity at the sea surface). Because birds were also fitted with satellite transmitters, it was easy to distinguish flying activity from on-land activity.

Structure of the Activity Data: Diurnal and Nocturnal Patterns and Activity Sequences Table S6 presents a typical example of 24 hours of activity monitoring using a leg-mounted MK4 logger. Activity patterns were similar to those found in previous studies (15, 16). Wandering albatrosses spend most of the night sitting on the sea surface (dark gray area in Table S6). Previous studies using stomach temperature sensors demonstrated that wandering albatrosses generally rest during periods of darkness but actively search for widely spaced prey during the day (17). Prey are detected in flight mostly during the daytime using scent cues

(18) and are caught just after landing (15). Our data show the birds sat on the sea surface for 70%–80% of their nocturnal time on average, and preliminary analyses detected no pattern related to age or sex. Thus, to specifically focus on foraging effort, we eliminated nocturnal activity data and studied only diurnal activity data.

As shown in Table S6, the diurnal activity pattern of wandering albatrosses could easily be described as a series of DASs on the water separated by "flying bouts." A typical DAS is a continuous diurnal series of 10-min intervals with at least 5% of the time spent on the water in each interval (e.g., activity levels of 0, 15, 75, 200, 200, 18, 0, with each value a score reflecting time spent on the water during a 10-min interval, with 0 representing fully dry and 200 representing fully wet). DASs are delimited by long flying bouts (activity levels 0, 0, 0, 0, 0, 0. . . in Table S6), during which birds apparently search for prey or navigate over oceanic areas.

Activity Data Analysis. Activity was analyzed independently for each bird from the date of departure to date of return to the colony during one foraging trip (10.8 ± 6.0 days). We assessed an overall "time budget" by quantifying the proportion of diurnal time spent on the water (Table S2). To further analyze the temporal distribution of activity on the sea surface, we quantified four descriptive variables that exactly depict the activity pattern represented in Table S2: (i) the number of DASs per day, (ii) the percentage of time spent on the water during a DAS, (iii) the mean DAS duration, and (iv) the mean flying time between two DASs (see Table S2 for mean values).

Because the average time spent flying between two DASs was much longer than the recording interval (10 min) in both sexes (males, 1.35 ± 0.51 h; females, 1.06 ± 0.38 h), DASs were easily delimited. Given that the device records the *proportion* of time spent on the water every 10 min, DASs shorter than 10 min are detectable as well (e.g., a 7-min DAS is scored as an activity level of 140/200 = 70). Thus, the exact number of DASs is known.

To describe the "intensity" of activity within a DAS, we quantified the mean proportion of time spent on the water during the DAS. Of note, the mean percentage of time spent on the water during DASs was very high and similar in males (0.94% ± 0.036%) and females (0.96% ± 0.029%), indicating a possible close relationship between the number of DASs and the number of total landings, that is, between the number of DASs and foraging costs.

The MK4 loggers used in the present study record only the proportion of time spent on the water every 10 min, not the exact number of landings or take-offs in a given 10-min interval. Thus, only a minimal number of landings might be inferred from our data. Previous studies recording exact numbers of landings showed a limited number of landings and take-offs during a 10-min period in these large birds (15, 16). We are confident that the number of DASs and number of landings are closely related. We analyzed DAS patterns (which provide exact values) as a proxy for take-off/landing patterns, which are known to be of prime importance to foraging costs in wandering albatrosses (34).

Physiology of Albatrosses

This section provides more detailed information about blood sampling, hormone levels, Δcorticosterone (i.e., variation in corticosterone levels over a foraging trip), immune indices, oxidative stress markers, and antioxidant defense assays.

Blood Sampling. Blood was collected from the tarsus vein with a 1-mL heparinized syringe and a 25-gauge needle. Blood was sampled on two occasions: at the time a bird was about to leave the nest (logger deployment; pre-trip sample) and after it returned from sea (logger recovery; post-trip sample). We collected blood samples from 56 males age 7–47+ years and on 50 females age 6–48+ years. The volume of the blood draws never exceeded 0.05% of the bird's body mass (8–12 kg). Blood samples were collected within 3 min of capture. The blood was centrifuged, and plasma was decanted and stored at −20 °C until it was assayed.

Hormone Assays: Corticosterone, Prolactin, and ΔCorticosterone. Corticosterone (the "stress" hormone) and prolactin (the "parental" hormone) levels were measured in frozen plasma (pre-trip blood samples) using RIA techniques developed at the Centre d'Etudes Biologiques de Chizé (7, 19). All samples were run in a single assay for both hormones (intra-assay variation: corticosterone, 5.1%; prolactin, 7.4%; n = 5 duplicates). Because blood samples were collected within 3 min of capture, they were considered to reflect baseline corticosterone levels (20). No variation was found between the time of handling and prolactin levels (which did not vary until 10 min); thus, prolactin levels were considered to reflect baseline levels of prolactin. Baseline corticosterone levels were not influenced by meteorologic conditions at the time of sample collection (nebulosity/rain index: $F_{2,85} = 0.05$, $P = 0.95$; wind index: $F_{2,68} = 0.62$, $P = 0.55$), or by temperature ($F_{1,61} = 0.13$, $P = 0.72$) or meteorologic conditions in the 6 hours before sampling ($F_{3,81} = 0.82$, $P = 0.82$). Mean corticosterone and prolactin baseline levels in males and females (Table S1) were consistent with results from a previous study of the same colony (7).

We computed ΔCorticosterone, the relative decrement in baseline level of corticosterone over a foraging trip [i.e., (corticosterone pre-trip level − corticosterone post-trip level)/corticosterone pre-trip level × 100], as a hormonal proxy of foraging success (see *Discussion* and ref. 21). High ΔCorticosterone values indicate high foraging success, whereas low Δ Corticosterone values reflect low foraging success. Although quantifying mass change would provide a direct indication of foraging effort, weighing such a large bird (up to 12 kg) could be stressful for individuals and thus affects hormonal status, activity at sea, and eventually reproductive success, one of the crucial parameters in our study.

Humoral Immunity, Oxidative Stress, Antioxidant Defenses. Seven indices were selected to probe various immune and oxidative stress markers. The assays were performed on frozen plasma or RBCs, using aliquots from the same pre-trip blood sample used for hormone measures. Because of ethical considerations, all tests were performed in vitro. Thus, immune indices rely on innate humoral immunity; albatrosses were not challenged.

Plasma antibacterial activity. Plasma antibacterial activity was assessed using a modified growth-inhibition test (22). We used a bacterial strain of *Escherichia coli* resistant to tetracycline (CIP 103410; Institut Pasteur). Bacteria were cultured in standard LB medium [10 g of bactotryptone, 5 g of yeast extract, 10 g of NaCl, and 1 L of dH_2O (pH 7.0)] at 37 °C in a shaking incubator. Bacteria were washed with PBS buffer, and the concentration was evaluated under a microscope using a counting chamber (Neubauer Improved) and set at 8.10^4 bacterium/mL. For the experiment, 200 μL of LB medium was mixed with 10 μL of the *E. coli* suspension and 50 μL of plasma. Samples were incubated for 30 min at 37 °C, after which 50 μL was spread on Petri dishes with agar containing 20 μg/mL of tetracycline. The Petri dishes were incubated overnight at 37 °C, and colony-forming units were counted. Antibacterial activity was expressed as the percent inhibition compared with controls; the fewer colonies developing compared with controls, the greater the antibacterial activity.

Lysis and agglutination scores. Innate humoral immune status was assessed by HHA as described previously (23–25). Lysis reflects the interaction of lytic enzymes (complement) and natural antibodies (NAbs), whereas agglutination results only from NAbs. The assay was carried out in 96-well (8 rows × 12 columns) U-bottomed assay plates. First, 50 μL of plasma samples was pipetted into the first column of the plate, and then 50 μL of 0.01 M PBS (Sigma-Aldrich) was added to columns 2–12. The samples were serially diluted (1:2) through column 11 on the first line and through column 11 on the second line, with 22 wells

used for each plasma sample. This resulted in dilutions ranging from 1 to $4.7{\cdot}10^{-7}$. After 25 μL of a 2% rabbit blood cell suspension was added to all wells, each plate was vortexed for 15 s before being incubated at 39 °C. Plates were digitized after 90 and 120 min of incubation. Agglutination and lysis were scored from the first scan and the second scan, respectively. Assays were randomized and run blindly with respect to sample. Both lysis and agglutination were computed as the negative log2 of the last plasma dilution exhibiting each function (i.e., a dilution of 1:16 is scored as 4). Preliminary analyses with 20 μL of plasma and a 1% rabbit blood cell suspension (1–3) were not conclusive. Thus, we adapted the assay, using 50 μL of plasma and a 2% rabbit blood cell suspension.

Lysis scores were very low in our study (males, 2 ± 2; females, 1 ± 1). This result is consistent with a previous study (23) in which no lysis was observed in the waved albatross, *Phoebastria irrorata*, contrary to other bird species in included in the dataset. Agglutination scores of birds range from 0 to 12 in the literature (24). In our study on wandering albatross, the mean agglutination score (males, 9 ± 1; females, 8 ± 1) was close to that reported in the waved albatross (6 ± 1; $n = 14, 25$).

Haptoglobin. Haptoglobin, a well-known acute-phase protein that indicates an ongoing inflammatory response, is found in a wide range of taxa, including birds (26). Haptoglobin normally circulates at low levels, but concentrations increase during inflammatory responses. Haptoglobin was quantified in plasma following the instructions provided with a commercially available assay kit based on hemoglobin-binding reaction (Tri-Delta Diagnostics). Mean haptoglobin levels (Table S2) were close to the levels measured previously in insular birds (25).

Antioxidant capacity of plasma. Oxidative stress refers to the imbalance between pro-oxidant substances and the level of antioxidant defenses, leading to the generation of oxidative damage. The oxidative stress theory of aging proposes that age-related loss of function is the result of accumulated oxidative damage throughout life (27). Recent studies found that levels of pro-oxidants and antioxidants also may have relevant ecological and evolutionary roles and may provide insight into functional interactions among life history traits (28). A common test of antioxidant capability, measurement of the total antioxidant capacity of plasma, was recently used in captive birds and yielded detectable age-related patterns (29). Plasma samples were incubated with a chromogen [metmyoglobin and 2,2-azinodi-[3-ethylbenzthiazoline sulphonate] (ABTS)]. After the addition of hydrogen peroxide, the samples were incubated for 2 min, inducing production of the radical cation ABTS, the concentration of which was determined by spectrophotometry at 600 nm (blue). Any extracellular antioxidant in the plasma sample (e.g., vitamins E and C, carotenoids) causes suppression of the blue color to a degree proportional to its concentration. Results are given as millimoles per liter of total antioxidants in plasma.

Level of lipid peroxidation. The level of lipid peroxidation is a major indicator of oxidative damage (28). Lipid peroxidation in plasma was estimated by quantifying malondialdehyde, a plasmatic by-product of lipid peroxydation, using a commercially available kit (TBARS Assay kit; Cayman Chemical). Levels of peroxidized lipids were expressed as nanomoles of MDA per milliliter of blood.

Superoxide dismutase activity. The activity of superoxide dismutase (an intracellular enzyme involved in antioxidant defense) in RBCs was assessed using the Superoxide Dismutase Assay Kit (Cayman Chemical). This assay kit uses a tetrazolium salt for detecting superoxide radicals generated by xanthine oxidase and hypoxanthine. Ten microliters of RBCs was lysed in 40 μL of Milli-Q water and centrifuged (13,725 × *g* at 4 °C for 15 min). Assays were performed on the supernatant.

Impact of the Experiment

To assess the potential impact of the experiment on reproductive performance, we compared the reproductive success of pairs in the study group (constituting pairs in which at least one of the two partners was handled; $n = 77$ pairs) with the reproductive success of pairs in the control group (pairs in which no bird was handled; $n = 283$ pairs) during the 2008 breeding season. Specifically, we monitored the hatching success (i.e., the probability of each pair successfully incubating the egg until hatching), as well as the overall breeding success (i.e., the probability of each pair successfully raising a chick until fledging at the end of the 2008 breeding season). Hatching success did not differ between the study group (0.83, $n = 72$ nests) and the control group (0.82, $n = 266$ nests; $\chi^2 = 0.0004$, $P = 0.98$). Breeding success also did not differ between the study group (0.73, $n = 77$ nests) and the control group (0.72, $n = 283$ nests; $\chi^2 = 0.0024$, $P = 0.96$). Thus, there was no detectable impact of the experiment on the reproductive success of albatrosses.

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Table S1. Modeling foraging behavior parameters of male and female wandering albatrosses

Independent variables and models	Males				Females		
	k	AIC_c	ΔAIC_c	w_i	AIC_c	ΔAIC_c	w_i
Total distance traveled (log, 24 males, 24 females)							
~ age	3	**465.2**	**0**	**59.5**	453.9	2.6	16.9
~ intercept	2	467.5	2.4	18.2	**451.3**	**0**	**62.4**
~ age + date	4	467.6	2.5	17.4	456.8	5.5	3.9
~ date	3	470.2	5	4.9	453.9	2.6	16.8
Foraging range (log, 24 males, 24 females)							
~ age	3	**398.5**	**0**	**57.9**	393.2	2.6	16.7
~ intercept	2	400.6	2.1	20.1	**390.5**	**0**	**62**
~ age + date	4	401.2	2.8	14.5	395.9	5.4	4.2
~ date	3	402.6	4.1	7.4	393.1	2.6	17.1
Latitude at maximum range (24 males, 24 females)							
~ age	4	**157.8**	**0**	**68.7**	160.5	0.8	31.9
~ age + date	3	160.1	2.3	22	163.1	3.4	8.7
~ intercept	2	162.4	4.6	7	**159.8**	**0**	**46.5**
~ date	3	164.7	6.8	2.3	162.3	2.6	12.9
Duration of trip (24 males, 24 females)							
~ intercept	4	**323.7**	**0**	**36.4**	291.8	0.3	36
~ age	3	323.9	0.3	32.1	294.1	2.6	11.6
~ date	2	325.1	1.4	17.7	**291.5**	**0**	**41.9**
~ age + date	3	325.6	2	13.7	294.3	2.8	10.4
Percentage of diurnal time spent on water (18 males, 22 females)							
~ intercept	2	**143.9**	**0**	**58.8**	**171.5**	**0**	**42.1**
~ date	3	146.2	2.3	18.4	172.5	0.9	26.4
~ age	3	146.3	2.4	17.3	172.7	1.1	24.1
~ age + date	4	148.6	4.7	5.5	175	3.5	7.4
Number of DASs per day (18 males, 22 females)							
~ date	3	**53.6**	**0**	**72.2**	76.6	4.9	5.7
~ age + date	4	56.5	2.9	16.8	74.6	3	15
~ intercept	2	58.2	4.6	7.2	**71.6**	**0**	**66.6**
~ age	3	59.4	5.9	3.8	75	3.3	12.7
Percentage of time spent on water within DAS (18 males, 22 females)							
~ age	3	**92.7**	**0**	**33.8**	124.1	2.2	19.6
~ age + date	4	93.1	0.3	28.8	126.6	4.6	5.8
~ intercept	2	93.1	0.4	27.5	**121.9**	**0**	**58.8**
~ date	3	95.2	2.4	10	124.6	2.6	15.8
Mean DAS duration (18 males, 22 females)							
~ intercept	2	**30.7**	**0**	**51.2**	**21.1**	**0**	**62.3**
~ age	3	32.6	1.8	20.4	23.8	2.7	16.5
~ date	3	32.8	2	18.6	25.9	4.8	5.7
~ age + date	4	34.1	3.3	9.7	23.9	2.8	15.5
Flying time between two DASs (18 males, 22 females)							
~ age	3	**32.7**	**0**	**56.3**	38.7	0	38.8
~ intercept	2	34.9	2.1	19.5	**38.7**	**0**	**39.5**
~ age + date	4	35.5	2.8	13.9	41.2	2.5	11.1
~ date	3	36.1	3.4	10.2	41.3	2.6	10.5
Variation of stress hormone level over a foraging trip (Δ Corticosterone) (19 males, 21 females)							
~ age	3	**116.5**	**0**	**76**	144.6	2.7	16.5
~ age + date	4	119	2.5	21.6	147.7	5.8	3.5
~ intercept	2	123.9	7.4	1.8	**141.9**	**0**	**63.7**
~ date	3	126.6	10.1	0.5	144.6	2.7	16.2

AICc (AIC corrected for small sample size) was used to compare each set of models. Δ *AICc* is the difference between the model and the model with lowest *AICc* value, or the most parsimonious model (in bold type). *wi* is the *AICc* weight, which provides a measure of the relative likelihood of a given model to be the best among the models fitted. *k* is the number of estimated parameters. Date refers to Julian date of departure (foraging trips). Models were ranked according to *AICc* value in males.

Table S2. Modeling of immune indices, oxidative stress markers, antioxidant defenses, and baseline hormone levels in male and female wandering albatrosses

		Males			Females		
Independent variables and models	*k*	AIC_c	ΔAIC_c	w_i	AIC_c	ΔAIC_c	w_i
Total antioxidant capacity of plasma (52 males, 47 females)							
~ intercept	2	**−56.9**	**0**	**39.7**	-7.2	7.2	1.9
~ date	3	−55.9	1	23.7	**-14.4**	**0**	**69.1**
~ age	3	−55.4	1.5	19	-6.6	7.8	1.4
~ age + date	4	−55.3	1.6	17.6	-12.6	1.8	27.6
Lipid peroxidation (53 males, 48 females)							
~ intercept	2	**463.3**	**0**	**57.1**	476.5	4.3	7.8
~ date	3	465.5	2.2	18.6	**472.1**	**0**	**68.1**
~ age	3	465.5	2.2	18.5	478.1	6	3.4
~ age + date	4	467.9	4.6	5.8	474.5	2.4	20.8
Haptoglobin (51 males, 37 females)							
~ intercept	2	**−97.2**	**0**	**34.2**	**−108.4**	**0**	**41.6**
~ age	3	−96.7	0.5	26.8	−108.1	0.3	35.2
~ date	3	−96.7	0.5	26.1	−106.1	2.3	12.9
~ age + date	4	−95.2	2	12.9	−105.7	2.8	10.4
Bactericidal activity (22 males, 22 females)							
~ intercept	2	**−14.7**	**0**	**53.7**	−4.9	1.9	21.1
~ date	3	−12.8	1.9	20.3	**−6.8**	**0**	**54.0**
~ age	3	−12.6	2.1	19.2	−3.8	3.0	12.1
~ age + date	4	−10.6	4.1	6.8	−3.9	2.9	12.8
HHA agglutination score (22 males, 22 females)							
~ intercept	2	**64.4**	**0**	**53.5**	88.7	3.6	11.0
~ date	3	65.9	1.5	24.8	**85.1**	**0**	**66.3**
~ age	3	66.9	2.4	15.7	91.0	5.9	3.5
~ age + date	4	68.8	4.4	5.9	87.6	2.5	19.2
HHA lysis score (22 males, 22 females)							
~ intercept	2	**0**	**52.6**	**−30.2**	**43.3**	**0**	**45.1**
~ date	3	1.7	22.5	−29.6	46.7	3.4	8.3
~ age	3	2.2	17.5	−29.9	45.5	2.2	14.8
~ age + date	4	3.9	7.4	−29.0	44.0	0.7	31.8
Corticosterone baseline level (55 males, 49 males)							
~ intercept	2	**252.9**	**0**	**52.2**	**206.9**	**0**	**54.4**
~ date	3	254.6	1.7	22.8	209	2	19.6
~ age	3	255.1	2.2	17.3	209	2	19.5
~ age + date	4	256.8	3.8	7.7	211.2	4.3	6.4
Prolactine baseline level (55 males, 47 females)							
~ age + date	4	**528**	**0**	**41.8**	455.5	2.2	17.4
~ date	3	529.4	1.3	21.6	**453.3**	**0**	**53.6**
~ intercept	2	529.5	1.5	20.1	455.1	1.8	21.9
~ age	3	529.9	1.9	16.5	457.3	4.1	7.1

AIC_c was used to compare each set of models. ΔAIC_c is the difference between the model and the model with lowest AIC_c value, or the most parsimonious model (in bold type). w_i is the AIC_c weight which provide a measure of the relative likelihood of a given model to be the best among the models fitted. Estimation of the age parameter is given in Table 1. Date refers to Julian date of departure (foraging trips) or blood sampling date (other parameters). *k* is the number of estimated parameters. Models were ranked according to AIC_c value in males.

Table S3. Modeling laying date and reproductive performance in wandering albatrosses

	Pairs				
Independent variables and models	*K*	*AIC*	Δ *AIC*	w_i	Biological meaning
Laying date (*n* = 116 pairs)					
~ intercept	**2**	**738.0**	**0**	**29.2**	No detectable effect of age of male or female on laying date
~ absolute age difference in pair	3	738.2	0.2	26.4	
~ breeding experience of pair	3	739.9	1.8	11.6	
~ age of female	3	740.0	1.9	11.1	
~ age of male	3	740.1	2.1	10.4	
~ age of female + (age of female)^2	4	740.7	2.7	7.6	
~ age of male + (age of male)^2	4	742.2	4.2	3.6	
Reproductive performance (*n* = 302 pairs with exact known-age males)					
~ age of male + (age of male)^2	**4**	**333.5**	**0**	**82.0**	Quadradic effect of age of male on breeding success of pair (r^2 = 0.43)
~ age of male	3	337.6	4.1	10.7	
~ intercept	2	338.3	4.8	7.3	
Reproductive performance (n = 289 pairs with exact known-age females)					
~ age of female + (age of female)^2	**4**	**326.9**	**0**	**62.8**	Quadradic effect of age of female but weaker model than in males (Δ *AIC* < 2 with intercept model, and r^2 = 0.21)
~ intercept	2	328.7	1.8	26.0	
~ age of female	3	330.4	3.5	11.2	

The *AIC* was used to compare models. Models are ranked according to *AIC* value. Δ*AIC* is the difference between the model and the model with lowest *AIC* value, or the most parsimonious model (in bold type). w_i is the *AIC* weight which provide a measure of the relative likelihood of a given model to be the best among the models fitted. Estimation of the age parameter is given in Table 1. *k* is the number of estimated parameters. Models were ranked according to *AIC* value in males.

Table S4. Mean numerical values of the phenotypic traits measured in male and female wandering albatrosses

	Females				Males			
	n	Mean value	SD	Note	*n*	Mean value	SD	Note
Foraging trip								
Distance traveled, km	24	3,980	2,720	–	24	4,010	3,820	*
Foraging range, km	24	1,190	770	–	24	1,090	950	*
Latitude at maximum range, °	24	−47.6	1.6	–	24	−51.8	6.4	*
Duration of foraging trip, days	24	10.0	4.1	†	24	11.5	7.9	–
Foraging activity								
Diurnal time spent on water, %	22	37.4	11.0	–	18	46.7	11.9	–
Number of DASs per day	22	4.21	2.52	–	18	3.50	2.20	–
Time spent on water during DASs, %	22	93.9	3.6	–	18	94.5	2.9	*
DAS duration, hours	22	1.06	0.38	–	18	1.35	0.51	–
Flying time between 2 DASs, hours	22	1.46	0.54	–	18	1.44	0.57	*
Variation of stress hormone levels over a foraging trip								
Δ Corticosterone, %	21	5.8	6.5	–	19	5.6	5.7	*
Humoral immunity								
Haptoglobin level, mg · mL^{-1}	37	0.34	0.05	–	51	0.33	0.09	–
Bactericidal activity, %	24	24	20	†	23	27	16	–
Agglutination score (no. of wells in HHA)	22	9	1	†	22	8	1	–
Lysis score (no. of wells in HHA)	22	2	2	–	21	1	1	–
Oxidative stress and antioxidant defenses								
Antioxidant capacity of plasma, $mmol.L^{-1}$	47	0.67	0.22	†	52	0.66	0.14	–
Lipid peroxidation, MDA nM · mL^{-1}	48	54.6	33.5	†	53	43.4	18.6	–
Hormone baseline levels								
Stress hormone (corticosterone), ng · mL^{-1}	49	4.7	1.9	–	55	4.9	2.3	–
Parental hormone (prolactine), ng · mL^{-1}	47	40.1	5.7	†	55	30.3	5.5	*,†
Reproduction								
Laying date	116 nests	12/31/07	5.7 days	–	116 nests	–	–	–
Reproductive performance‡	289 females	0.755		*	302 males	0.747		*

All data have been quantified on wandering albatross that were incubating an egg during austral summer 2008 at Crozet Island.
*Age of individuals has a statistically significant effect (see Tables S3, S4, S5, and S6 and Table 1 for statistical analysis and Fig. 1 for graphical representation of variation with age).
†Sampling date has an effect (see Tables S3, S4, S5, and S6 and Table 1 for effect analysis).
‡Reproductive performance is the probability to successfully raise a chick.

Table S5. Long-term satellite tracking data of male wandering albatross at Crozet Island, 1989–2008

Year	*n*	Dates	Foraging range, km	Latitudinal range	Antartica foragers	Sub-Antarctica foragers	References
1989	4	1/20 to 3/21	min 610, max 2,550	min 44 °S, max 65 °S	1 male, ≥ 25 years	3 males	6, 30
1990	6	1/14 to 3/16	min 600, max 1,300	min 43 °S, max 58 °S	1 male, ≥ 25 years.	5 males	5
1991	2	1/18 to 2/5	min 680, max 3,300	min 42 °S, max 64 °S	1 male, ≥ 25 years	1 male	5, 31
1992	3	1/2 to 3/14	min 810, max 3,800	min 44 °S, max 62 °S	1 male, ≥ 25 years	2 males	6
1994	4	1/17 to 2/22	min 380, max 3,880	min 40 °S, max 62 °S	1 male, 15 years	3 males	6
1998	12	1/6 to 3/22	min 280, max 1,200	min 39 °S, max 48 °S	0	12 males	32, 33
1999	19	1/1 to 3/10	min 100, max 2,560	min 40 °S, max 60 °S	3 males, ≥ 25 years	16 males	19, 32
2000	2	1/6 to 1/19	min 210, max 1,010	min 45 °S, max 47 °S	0	2 males	34
2001	4	2/8 to 1/29	min 580, max 1,590	min 43 °S, max 49 °S	0	4 males	34
2003	8	1/1 to 2/5	min 860, max 1,280	min 39 °S, max 54 °S	1 male, ≥ 25 years	7 males	Not applicable
2008	24	1/10 to 3/24	min 60, max 3,640	min 38 °S, max 67 °S	5 males, ≥ 25 years	19 males	Present study

n, annual effort of satellite tracking (i.e, number of birds satellite-tracked per year during incubation); foraging range, maximum distance from the colony during a foraging trip; Antarctica foragers, number and age of birds that foraged to Antarctica waters (south of polar front, 53°S); age, age of birds at the time of device deployment; sub-Antarctica foragers, number of birds that foraged to northern, sub-Antarctica waters. This table assess the overall proportion of old birds that forage in remote Antarctica waters, without further analysis of interannual effects. Because females do not forage in Antarctica waters, data for females are not described here.

Table S6. MK4 activity-logger data

Date and time	Light	Activity level	Interpretation	Date and time	Light	Activity level	Interpretation	Date and time	Light	Activity level	Interpretation	Date and time	Light	Activity level	Interpretation
1/3/08 02:44	64	**0**	Flying	1/3/08 07:24	64	**0**	Flying	1/3/08 12:04	64	**0**	Flying	1/3/08 16:34	0	**200**	A/S on water
1/3/08 02:54	64	**0**	Flying	1/3/08 07:34	64	**0**	Flying	1/3/08 12:14	64	**0**	Flying	1/3/08 16:44	0	**200**	A/S on water
1/3/08 03:04	64	**0**	Flying	1/3/08 07:44	64	**0**	Flying	1/3/08 12:24	64	**0**	Flying	1/3/08 16:54	0	**200**	A/S on water
1/3/08 03:14	64	**0**	Flying	1/3/08 07:54	64	**0**	Flying	1/3/08 12:34	64	**0**	Flying	1/3/08 17:04	0	**200**	A/S on water
1/3/08 03:24	64	**0**	Flying	1/3/08 08:04	64	**0**	Flying	1/3/08 12:44	64	**0**	Flying	1/3/08 17:14	0	**200**	A/S on water
1/3/08 03:34	64	**0**	Flying	1/3/08 08:14	64	**15**	Landing on water	1/3/08 12:54	64	**0**	Flying	1/3/08 17:24	0	**200**	A/S on water
1/3/08 03:44	64	**0**	Flying	1/3/08 08:24	64	**75**	A/S on water	1/3/08 13:04	64	**0**	Flying	1/3/08 17:34	0	**200**	A/S on water
1/3/08 03:54	64	**0**	Flying	1/3/08 08:34	64	**200**	A/S on water	1/3/08 13:14	64	**0**	Flying	1/3/08 17:44	0	**200**	A/S on water
1/3/08 04:04	64	**0**	Flying	1/3/08 08:44	64	**200**	A/S on water	1/3/08 13:24	64	**57**	Landing on water	1/3/08 17:54	0	**200**	A/S on water
1/3/08 04:14	64	**0**	Flying	1/3/08 08:54	64	**200**	A/S on water	1/3/08 13:34	64	**200**	A/S on water	1/3/08 18:04	0	**200**	A/S on water
1/3/08 04:24	64	**0**	Flying	1/3/08 09:04	64	**18**	Taking off	1/3/08 13:44	64	**200**	A/S on water	1/3/08 18:14	0	**200**	A/S on water
1/3/08 04:34	64	**0**	Flying	1/3/08 09:14	64	**0**	Flying	1/3/08 13:54	64	**180**	A/S on water	1/3/08 18:24	0	**200**	A/S on water
1/3/08 04:44	64	**0**	Flying	1/3/08 09:24	64	**0**	Flying	1/3/08 14:04	64	**200**	A/S on water	1/3/08 18:34	0	**200**	A/S on water
1/3/08 04:54	64	**0**	Flying	1/3/08 09:34	64	**0**	Flying	1/3/08 14:14	64	**200**	A/S on water	1/3/08 18:44	0	**200**	A/S on water
1/3/08 05:04	64	**0**	Flying	1/3/08 09:44	64	**0**	Flying	1/3/08 14:24	64	**196**	A/S on water	1/3/08 18:54	0	**200**	A/S on water
1/3/08 05:14	64	**37**	Landing on water	1/3/08 09:54	64	**0**	Flying	1/3/08 14:34	64	**200**	A/S on water	1/3/08 19:04	0	**200**	A/S on water
1/3/08 05:24	64	**200**	A/S on water	1/3/08 10:04	64	**0**	Flying	1/3/08 14:44	64	**200**	A/S on water	1/3/08 19:14	0	**174**	Taking off
1/3/08 05:34	64	**200**	A/S on water	1/3/08 10:14	64	**0**	Flying	1/3/08 14:54	64	**145**	Taking off	1/3/08 19:24	0	**197**	Landing on water
1/3/08 05:44	64	**200**	A/S on water	1/3/08 10:24	64	**0**	Flying	1/3/08 15:04	64	**0**	Flying	1/3/08 19:34	0	**200**	A/S on water
1/3/08 05:54	64	**200**	A/S on water	1/3/08 10:34	64	**78**	Landing on water	1/3/08 15:14	64	**0**	Flying	...	...	...	...
1/3/08 06:04	64	**200**	A/S on water	1/3/08 10:44	64	**16**	A/S on water	1/3/08 15:24	64	**0**	Flying	2/3/08 01:24	0	**200**	A/S on water
1/3/08 06:14	64	**200**	A/S on water	1/3/08 10:54	64	**200**	A/S on water	1/3/08 15:34	64	**0**	Flying	2/3/08 01:34	12	105	Taking off
1/3/08 06:24	64	**200**	A/S on water	1/3/08 11:04	64	**180**	A/S on water	1/3/08 15:44	64	**78**	Landing on water	2/3/08 01:44	50	0	Flying
1/3/08 06:34	64	**192**	A/S on water	1/3/08 11:14	64	**200**	A/S on water	1/3/08 15:54	50	**200**	A/S on water	2/3/08 01:54	64	**0**	Flying
1/3/08 06:44	64	**167**	Taking off	1/3/08 11:24	64	**75**	Taking off	1/3/08 16:04	4	**200**	A/S on water	2/3/08 02:04	64	**0**	Flying
1/3/08 06:54	64	**0**	Flying	1/3/08 11:34	64	**0**	Flying	1/3/08 16:04	0	**200**	A/S on water	2/3/08 02:14	64	**0**	Flying
1/3/08 07:04	64	**0**	Flying	1/3/08 11:44	64	**0**	Flying	1/3/08 16:14	0	**200**	A/S on water	2/3/08 02:24	64	**0**	Flying
1/3/08 07:14	64	**0**	Flying	1/3/08 11:54	64	**0**	Flying	1/3/08 16:24	0	**200**	A/S on water	2/3/08 02:34	64	**0**	Flying

Twenty-four hours of activity monitoring in a wandering albatross. Light refers to light level, from 0 (night) to 64 (day). Light gray denotes sunset or sunrise; dark gray denotes night. Given the sampling interval (3 s), the value recorded at the end of each 10-min period ranges from 0 (fully dry) to 200 (fully wet). A/S represents activity on water or sitting. Note that although the logger does not record the exact number of landings on water, the exact number of activity sequences on water can be inferred from the data. The time is Greenwich Mean Time.