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BREEDING BIOLOGY OF THE SOUTHERN GIANT PETREL (*MACRONECTES GIGANTEUS*) IN PATAGONIA, ARGENTINA

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Resumen. – Biología reproductiva del Petrel Gigante del Sur (*Macronetes giganteus*) en la Patagonia, Argentina. – El Petrel Gigante del Sur (*Macronectes giganteus*) es un procellariiforme considerado Cercano a la Amenaza según criterios de la UICN. El Acuerdo Internacional para la Conservación de Albatros y Petreles (ACAP) impulsa la investigación sobre la biología reproductiva de las especies amenazadas listadas en el acuerdo tales como los petreles gigantes. El conocimiento de aspectos de la biología reproductiva de esta especie contribuirá al desarrollo de herramientas de conservación. Entre el 2001 al 2005 se estudiaron aspectos de la biología reproductiva del Petrel Gigante del Sur en colonias del norte de la Patagonia, Argentina. Los adultos reproductores arribaron a las colonias durante la primera semana de Octubre y la puesta de huevos comenzó tres semanas más tarde. La eclosión fue sincrónica y tuvo lugar durante la tercera semana de Diciembre. Los pichones comenzaron a independizarse durante la segunda semana de marzo hasta fines de Abril. El éxito reproductivo fue alto y no se encontraron diferencias significativas entre estaciones (> 88%). La supervivencia de pichones fue del 100% a partir de los 45 días de vida. La proporción de sexos a la independencia no se desvió de la paridad durante el periodo de estudio. El dimorfismo sexual, con los machos más grandes que las hembras, fue aparente para el peso, largo de pico y tarso y ancho de pico. Las tasas de crecimiento fueron similares entre sexos para el largo de pico, tarso y ala y ancho de pico. Sin embargo, los valores asintóticos para dichas variables fueron diferentes entre sexos (excepto para el largo de ala). El alto éxito reproductivo y la supervivencia de pichones, la similitud en las tasas de crecimiento entre sexos y la igualdad en la proporción de sexos a la independencia, sugieren que las fuentes de alimento no fueron un recurso limitante para la reproducción en las colonias norte de Patagonia durante el periodo de estudio.

Abstract. – The Southern Giant Petrel (*Macronectes giganteus*) is a wide ranging procellariiform considered Near Threatened under IUCN criterion. The Agreement for the Conservation of Albatrosses and Petrels (ACAP) encourages the research on the breeding biology of listed threatened species such as the giant petrels. Better understanding of this issue will help in the development of conservation tools. From 2001 to 2005 we studied aspects of the breeding biology of the Southern Giant Petrel from north colonies of Patagonia, Argentina. Breeding adults arrived at the colonies during the first week of October and egg-laying began three weeks later. Hatching was synchronous and took place primarily during the third week of December. Chicks started to fledge during the second week of March through late April. Breeding success was high, with no differences between seasons (> 88%). Chick survival was 100% from age 45 days onward. The sex ratio at fledging did not differ from parity over the study period. Sexual dimorphism (with males larger than females) was apparent for body mass, bill and tarsus lengths, and bill depth. Growth rates were similar between sexes for bill, tarsus and wing lengths, and bill depth. However, the asymptotic values of these variables were different between sexes (except for wing length). The high breeding success and chick survival, the similarity in growth rates between sexes, and the evenness in the sex ratio at fledging, suggested that food resources were not a constraint in the reproduction of this species in north Patagonian colonies during the study period. *Accepted 27 June 2009.*

Key words: *Macronectes giganteus*, Southern Giant Petrel, breeding biology, Patagonia.

INTRODUCTION

Seabirds, particularly albatrosses and petrels, are becoming increasingly threatened. Hence, for improved management and successful conservation efforts a detailed understanding of their breeding biology, foraging ecology, and pelagic distribution is crucial (Boersma *et al.* 2002, Schreiber & Burger 2002). The Southern Giant Petrel (*Macronectes giganteus*) is a wide-ranging procellarid, with approximately 55,000 breeding pairs and 130 colonies distributed around the Southern Hemisphere (ATCM 2008). This species was considered Vulnerable under IUCN criteria up to 2006 (IUCN 2006), but recently was downgraded to Near Threatened (BirdLife International 2008). However, in Argentina this species is still considered Vulnerable (Lopéz-Lanus *et al.* 2008). Along with other species of Procellariiformes, the Southern Giant Petrel is one of the 26 species listed under the Agreement on the Conservation of Albatrosses and Petrels (ACAP 2004). The Advisory Committee of ACAP has identified the need to fill information gaps for the Southern Giant Petrel and other listed species. In Argentina, approximately 2300 breeding pairs nest at four colonies along the Patagonian coast (Quintana *et al.* 2006). Unlike most Southern Giant Petrel colonies which are surrounded by Sub-Antarctic waters, Arce and Gran Robredo islands are located in temperate waters at the northern limit of their breeding range. Better understanding of the breeding biology of the Southern Giant Petrel will help in the development of management and conservation tools. The knowledge about the breeding biology of this species is limited and restricted to a few Sub-Antarctic (Warham 1962, Hunter 1984, Voisin 1988, Peter *et al.* 1991, Cooper *et al.* 2001) and Antarctic colonies (Mougin 1968, Conroy 1972). Here we describe the breeding biology of birds from colonies on Arce and Gran Robredo Islands, Patagonia, Argentina (Fig. 1), presenting data on chronology, breeding parameters, and nesting habitats.

METHODS

Breeding habitat. We estimated the colony area, nest density, and height above sea level at Arce Island (45°00'S, 65°29'W) and Gran Robredo Island (45°08'S, 66°04'W), Patagonia, Argentina (Fig. 1) during 2001 and 2005, respectively. The boundaries of the colonies were mapped using a hand-held global positioning system (GPS) unit, and locations were taken every 10 s. The colony boundaries were derived from the most peripheral nests. The entire surface area of each island was calculated using pre-existing digitalized images. The area of the colonies and the islands were calculated using the Xtools extension (version 6/1/2001) in the ArcView GIS 3.2 package. The nest density (number of nests /100 m^2) was determined using the circular plots method (Bibby *et al.* 1992). We established 33 plots along five transects separated by 15 m. The mean altitude of each colony was calculated by taking the height at several random points in the colony, using the GPS unit that had been calibrated to zero at the sea level.

Timing and breeding success. The Southern Giant Petrel is extremely sensitive to human disturbance in the colonies. Adults will desert nests more quickly than any other procellariids (Warham 1962, Peter *et al.* 1991, Chupin

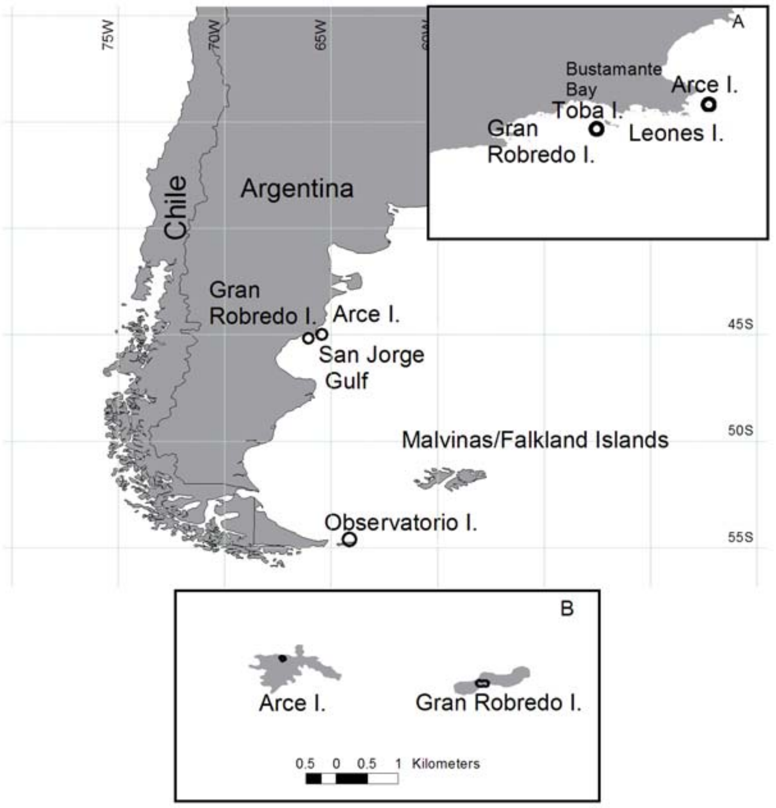

FIG. 1: Study area, detailed for north of San Jorge Gulf (A) and location of the Southern Giant Petrel colonies (black outlines) at Arce and Gran Robredo islands (B).

1997), and the abandonment of Southern Giant Petrel colonies close to research stations may have been due to human disturbance (Micol & Jouventin 2001, Nel *et al.* 2002). In addition, the presence of Brown Skuas (*Catharacta antarctica*) at both Arce and Gran Robredo, increased the risk of egg and chick loss when adults are flushed from the colony. Consequently, we were careful when approaching the breeding birds and we did not handle adults, eggs, or chicks during the most critical period (i.e., during incubation and the first weeks of rearing). This decision limited the breeding parameters studied.

Data on the timing and breeding success were collected only at Arce, due to logistic problems. We visited the Arce colony 33 times over four breeding seasons (2001–2004) to determine the timing of laying, hatching, and fledging. The breeding success (fledglings / hatched eggs x 100) was determined without disturbance by following nests from the sixth or seventh week of incubation. During every visit to the colony, nests were mapped by digital pictures and identified from a blind located between 30–50 m from the colony. We followed 86 and 77 nests during the 2001 and 2002 breeding season, respectively, over a period of 75 days. In 2002, we selected a subsample of nests (n = 21) that were clearly visible from a distance by using a spotting scope, and followed them carefully to more accurately determine hatching dates, brooding period and fledging time.

Morphometric measurements and chick growth. In 2002, we measured and weighed 21 chicks (11 males and 10 females) on Arce every 10 days. To reduce disturbance (see above), we collected data from the end of the brooding period (~ 15 days old) (Hunter 1984) until the chicks fledged. The age of the chicks was estimated by determining the hatching date of those eggs studied from a distance (see Methods). We took five body measurements: bill length (BL, exposed culmen), bill depth (BD, depth at the nostril), tarsus length (TL, from the middle of midtarsal joint to the distal end of tarsometatarsus), wing length (WL, from the carpal joint to the tip of the longest primary), and body mass. Wing and tarsus measurements were always taken on the right side of the body. Wing length was measured using a stopped ruler (nearest 1 mm), and bill depth, and bill and tarsus lengths were measured using a digital caliper (nearest 0.01 mm). The body mass was determined using spring balances (nearest 10 and 100 g).

Mass and sex ratio at fledging. During five breeding seasons (1999 and 2001 to 2004), at the end of the breeding season (when the chicks were almost 90 days old) we calculated body mass and sex ratio of the birds just prior to fledging. We weighed a total of 184 chicks from Arce and Gran Robredo (84 females and 100 males), using spring scales (nearest 25 and 100 g). Over the five seasons, the sex of 1595 chicks was determined by molecular techniques or discriminant functions (Copello *et al.* 2006).

Statistical analyses. Differences in breeding success between seasons were determined using the χ^2 test whereas differences in morphometric variables, body mass of fledglings, and the parameters of the mass growth models (see below) were evaluated using non-parametric statistics (Mann-Whitney or Kruskall-Wallis test) and multiple comparison (Duncan's test). Sex ratio deviations from parity were assessed using Generalized Linear Models with a binomial distribution and a logistic link function (McCullagh & Nelder 1989, Wilson & Hardy 2002). To analyze chick growth patterns, we fitted the Richards model, which includes other functions as special cases (Richards 1959). Body mass data were fitted according to the Huin & Prince (2000) model for each bird and by sex. This model takes into account the loss of mass after fledging, broadly observed in chicks of Procellariiformes (Warham 1990). Based on this model, we calculated four coefficients: 1) peak mass, 2) time at which the curve reaches its maximum, 3) mass growth rate and 4) loss rate (see Huin & Prince 2000). The estimation of the coefficients was performed using a maximum log-likelihood function. The confidence intervals for the *m* parameter (which determines the shape of the Richards curve) were calculated using likelihood profiles. The differences in the curves by sex were compared using the likelihood ratio test (Hilborn & Mangel 1997). Loglikelihood functions with log-normal error were used to fit the body mass model due to the multiplicative error structure of data (variability increases as a function of the chick age). The percentage of sexual dimorphism was calculated as:

$$\left[(\bar{x}_m - \bar{x}_f)/\bar{x}_f\right] \text{ x } 100,$$

with $\bar{x}_m$ and $\bar{x}_f$ as means of males and females, respectively (Weidinger & van Franeker 1998). Sex ratio was calculated as:

$$\sum males/(\sum males + \sum females).$$

RESULTS

Breeding habitat. Arce and Gran Robredo Islands support the only two Southern Giant Petrel colonies in northern Patagonia, Argentina. Both islands are farther from the coast (7 and 14 km, respectively) than all of the other 40 islands located in the northern part of the San Jorge Gulf. Arce is located in the northeast of Cabo Dos Bahías (Fig. 1). It is an outcrop with a maximum altitude of 30 m a.s.l. and a surface area of 0.558 km^2. It is poorly vegetated, supporting mostly grasses and herbs, such as *Bromus* sp. (Poaceae), *Chenopodium scabricaule* (Chenopodiaceae), *Erodium cicutarium* (Geraniaceae), and *Sonchus oleraceus* (Asteraceae).

Gran Robredo is located to the southeast of Tova Island (Fig. 1). It is a rocky plateau of about 30 m a.s.l. with a surface area of 0.179 km^2. The vegetation consists of isolated bushes of *Atriplex* sp., which are restricted to crevices and the northern beach. On both islands, the nests of the Southern Giant Petrels were located only on rocky substrate, free of vegetation, and the colonies were limited to the south and the west of Arce and Gran Robredo islands, respectively (Fig. 1). On Arce, the nesting area covered about 1% of the island and averaged 13 m a.s.l. (range 5–19 m), while the Gran Robredo colony comprised approximately 7% of the islands' surface, and nests were located on average 22 m a.s.l. (range 7–28 m).

Timing and breeding success. Breeding adults began to arrive at the colonies during the first week of October, and egg-laying began approximately three weeks later; this pattern was repeated in all years studied. During 2001 and 2002, all surveyed nests contained a single egg (n = 163 nests). Overall mean nest density was 9 nests/100 m^2 (range: 2–25 nests/100 m^2). Hatching was synchronous and took place primarily during the fourth week of December (range: 20–29 December, n = 21 nests, see Methods). The brooding period lasted approximately two weeks with 70% of chicks (n = 21) found alone in the nests following the third week of January. Chicks started to fledge during the second week of March through late April. The minimum age of fledging recorded was 86 days old (n = 21 chicks). Breeding success was quite high with no significant differences between seasons (93% in 2001 vs 88% in 2002, cf. Table 1; n = 163, $\chi^2_1 = 0.9$, $P > 0.1$). Chick survival rate was 100% from age 45 days onward.

Body mass and sex ratio of fledglings. Chick fledging mass did not differ between colonies ($P > 0.1$ for both sexes) so we pooled the data. Throughout all years, the mean mass of males was greater than that of females (Fig. 2, Table 1, $P < 0.01$). However, the mean mass of males differed between years ($H = 14.1$, $P < 0.01$), being smaller in 2002 than in 2003 or 2004 (Fig. 2, Table 1, Duncan's test MS = 0.5, $P < 0.05$ for both cases) and similar in 2001 (Fig. 2, Table 1, Duncan's test MS = 0.5, $P > 0.1$). The body mass of the females did not differ between years (Fig. 2, Table 1, $H = 2.5$, $P > 0.1$).

The sex ratio at fledging fluctuated between 0.43 and 0.69. The proportion did not differ from parity over the study period, nor between colonies (Table 1, GLM, $\chi^2_3 = 0.04$, $P > 0.1$, GLM, $\chi^2_3 = 7.8$, $P > 0.05$, at Arce and Gran Robredo, respectively, and GLM, $\chi^2_4 = 3.6$, $P > 0.1$ for both colonies).

Morphometric measurements and chick growth. Sexual dimorphism (with males larger than females) was apparent for three of the five body measurements taken (BL, BD, and TL) (Fig. 3, $P < 0.01$). Males had bills that were significantly longer and deeper than in females from six weeks of age onward (Fig. 3, $P < 0.01$) and the TL was significantly different from the eighth week of life on (Fig. 3, $P < 0.01$). In contrast, WL was similar between sexes during the entire growth period (Fig. 3, $P > 0.05$). Males were heavier than females from the eighth week of age onward although there was a considerable overlap, and differences were not significant (Fig. 3, $P > 0.1$).

TABLE 1. Breeding success (%), sex ratio at fledging, sexual dimorphism in mass at fledging (%), and body mass (kg, mean ± SD) for the Southern Giant Petrel at northern colonies of Patagonia, Argentina. N/D = no data; differences between seasons: * = $P < 0.005$, ns = non significant.

		1999	2001	2002	2003	2004	Test
Breeding success (%)		N/D	93	88	N/D	N/D	ns
Sex ratio	Arce	N/D	0.51	0.51	0.51	0.50	ns
	Gran Robredo	0.60	S/D	0.69	0.43	0.51	ns
	Total	0.60	0.51	0.57	0.47	0.50	ns
Mass dimorphism (%)		N/D	23.7	12.5	21.9	25.0	
Mass (kg)	Males	N/D	4.7 ± 0.6	4.5 ± 0.4	5.0 ± 0.6	5.0 ± 0.9	*
	Females	4.2 ± 0.3	3.8 ± 0.6	4.0 ± 0.5	4.1 ± 0.5	4.0 ± 0.6	ns

The percentage of dimorphism in bill size fluctuated between 2 and 12% for BL, and between 6 and 14% for BD. The degree of sexual dimorphism for each of these variables increased linearly with age ($r_s = 1$ and 0.7, and $P < 0.05$ for BL and BD, respectively).

The BL and TL growth rates were greater than those of BD and WL (Table 2). Consequently, chicks reached the BL and TL asymptotic values sooner than they did in the other variables (80 ± 10 and 70 ± 10 days, respectively). BD reached its asymptotic value at the age of 100 ± 10 days and the WL asymptote had not been reached by the time the chicks fledged (Fig. 3). Growth rates were similar between sexes for all the linear measures (Table 2, LRT < 3.1, $P > 0.05$). However, the asymptotic values of BL, BD, and TL were different between sexes (Table 2, LRT < 88.0, $P < 0.01$). The mean maximum body mass was similar between males and females (4.2 ± 0.5 kg for males and 4.0 ± 0.5 kg for females; $U = 43$, $P > 0.05$) as well as the mean age for reaching peak mass (96 ± 21.8 and 102 ± 10.7 days old for males and females, respectively; $U = 29$, $P > 0.1$). The maximum mass reached by the chicks represented for both sexes 117 and 148% of the mean adult body mass (for males and females, respectively). The gain rate was similar between sexes (48.8 ± 10.2 and 46.5 ± 5.5 $g \times d^{-1}$ for males and females, respectively; $U = 49$, $P > 0.1$), as was the rate of mass loss (25.2 ± 19.6 and 95.0 ± 92.6 $g \times d^{-1}$ for males and females respectively, $U = 32$, $P > 0.1$).

The observed data fitted well with both the logistic and the Gompertz models, and both could be used to describe the growth of BL, TL, and WL. BD was also consistent with the von Bertalanffy model. The *m* parameter was similar between sexes (Table 2, LRT < 28.6, $P > 0.05$). In addition, the growth model for body mass also clearly fitted with the observed values. However, the estimations of the mass loss rate should be taken with caution due to the few data obtained during the study period.

DISCUSSION

Breeding habitat. Most Southern Giant Petrel colonies are located in grass-covered habitats without tall vegetation and/or in areas with a low density of shrubs (Carboneras 1992). In contrast, the north Patagonian colonies on Arce and Gran Robredo Islands are situated on rocky substrates with a limited vegetation cover. Rocky substrates have been reported from some Antarctic colonies, such as those on South Shetland Islands (Coria 2006). The northern Patagonian colonies were characterized by high nest densities, similar to the colonies at Malvinas (Falkland) and Macquarie

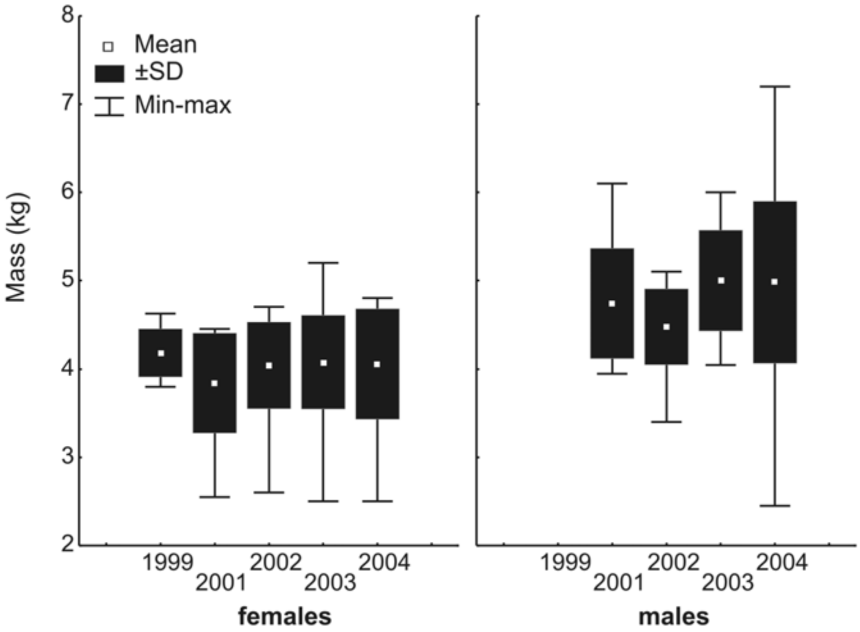

FIG. 2. Mean body mass (SD and range) of males and females fledglings in northern colonies (Arce Island and Gran Robredo I.) of Patagonia, Argentina, during the 1999 and 2001–2004 breeding seasons.

islands (Warham 1962, Voisin 1982, Reid & Huin 2008). In contrast, the colonies on Observatorio Island, southern Patagonia, Argentina (Fig. 1), have a markedly lower nest density, with more than 70 groups of nests (mean group size = 5.6 nests, range 2–22) covering all the surface of the island (Quintana *et al.* 2005). In addition, the substrates of the southern nesting sites were also different from those found in the northern Patagonia colonies. Nests on Observatorio I. were located over Magellanic moorland, comprised primarily of graminoid bogs intermingled with shrubs (Schiavini *et al.* 1999).

Timing and breeding success. Initiations of the egg-laying (October) and fledging periods (March) observed for the Southern Giant Petrel in northern Patagonia were similar to those reported for Antarctic and sub-Antarctic colonies (Warham 1962, Conroy 1972, Hunter 1984) as well as colonies of lower latitudes (Cooper *et al.* 2001). However, in northern Patagonia, the laying period started two weeks later than on Macquarie Island (Warham 1962) and one week earlier than on South Georgia Island (Hunter 1984). In addition, the duration of the hatching period was shorter (10 vs 15–20 days) than observed at other colonies (Warham 1962, Hunter 1984, Cooper *et al.* 2001). These chronological differences could be due to interannual variations in the food availability and/or different oceanographic conditions of the marine environment around the colonies.

Although the hatching success could not be accurately quantified due to methodological restrictions, our results - restricted to the final stage of the incubation period (i.e., from the sixth week onward) - showed a high hatching success (81 and 78% for 2001 and 2002, respectively). Certainly, the calculated values may overestimate the overall hatching success (i.e., from the start of the laying

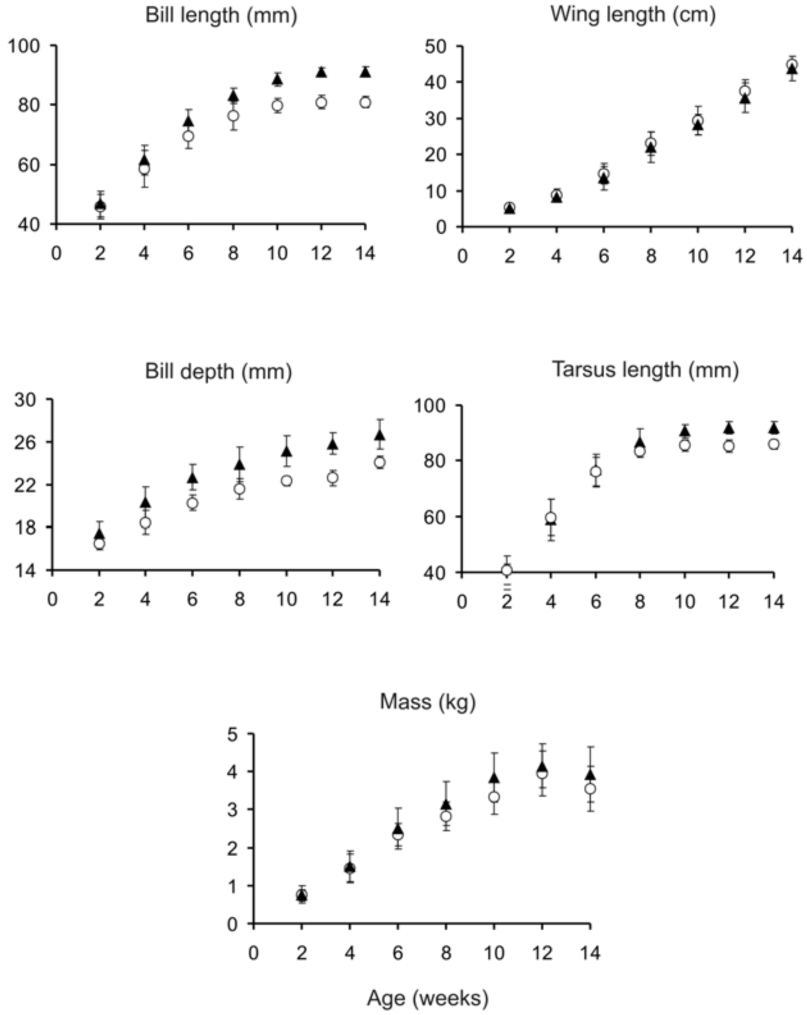

FIG. 3. Growth of bill, tarsus, wing, and mass (means ± SD, CI = 95%) of male (black triangles) and female chicks (empty dots) of Southern Giant Petrels at Arce Island, Argentina, during the 2002 breeding season.

period in late October), as egg loss is generally high during the first incubation phase for most petrel species (Warham 1990). Although we were unable to determine the causes of egg loss with certainty, predation by skuas (*Catharacta antarctica*) on abandoned eggs and harassment of incubating adults were frequent events. Although skuas breed on both islands, they are far more numerous on Arce (136 pairs) than on Gran Robredo (three pairs; Yorio 2005). Predation by skuas has been reported as the main cause of egg loss at other Southern Giant Petrel colonies (Warham 1962, Hunter 1984).

Chick mortality occurred during the first six weeks of life, contrary to reports from elsewhere, such as the South Georgia colonies (Hunter 1984). Breeding success was high and

TABLE 2. Parameters (L_∞, k, and m) of the Richards model fitted to lineal morphometric variables. L_∞ = asymtote, k = constant rate growth, m determined curve's shape. $m = 0$ von Bertalanffy (LVB), $m = 2/3$ LVB isometric, $m = 1$ Gompertz, and $m = 2$ logistic. Likelihood ratio test (LRT) refers to differences between sexes. * = $P < 0.005$ (CI 95%), ns = not significant.

Variable	Sex	k	LRT	P	L_∞	LRT	P	m	LRT	P
Bill length (mm)	M	0.040			93.5			2.7 (1.2 - 4.5)		
	F	0.045	2.8	ns	81.3	88.0	*	3.6 (2.1 - 5.7)	-159.8	ns
Bill depth (mm)	M	0.027			27.8			1.3 (0.0 - 6.3)		
	F	0.025	0.8	ns	24.9	18.0	*	1.3 (0.0 - 5.1)	28.6	ns
Tarsus length (mm)	M	0.054			92.3			2.5 (1.5 - 3.9)		
	F	0.058	3.1	ns	86.0	70.0	*	3.9 (2.7 - 5.4)	-171.6	ns
Wing length (cm)	M	0.034			60.2			1.7 (1.8 - 2.4)		
	F	0.039	0.1	ns	55.8	1.0	ns	1.9 (1.5 - 2.4)	-85.1	ns

similar to that observed at other Antarctic and Sub-Antarctic colonies (Warham 1962, Conroy 1972, Hunter 1984, Voisin 1988). The high breeding success observed at northern Patagonian colonies may either reflect the quality of the foraging areas exploited by the adults during the breeding period or the availability of abundant carrion nearby (see Warham 1990, Brooke 2004). The populations of the Southern Giant Petrels at both colonies we studied have increased over the last decade. Possible reasons for the population growth include 1) close proximity to expanding colonies of penguins, elephant seal and sealions, 2) low bycatch rates by longliners at the Patagonian shelf, and/or 3) the extensive use of offal as an extra food source from a nearby fleet of trawlers and jiggers, which are also expanding in numbers (Quintana *et al.* 2006).

Body mass and sex ratio of fledglings. As in other albatross and petrel species and also for giant petrels from other colonies (e.g., Hunter 1984, Peter *et al.* 1991, Shaffer *et al.* 2001, González-Solís 2004), the Southern Giant Petrel in northern Patagonia showed clear sexual dimorphism in body mass at the end of the fledgling period. Male chicks were on average one kg heavier than females in all seasons studied. However, similar to other albatross and petrel species (Warham 1990), we also observed high seasonal variability in body mass. During the 2002 breeding season, males were lighter than during 2003 and 2004. Yet, the sex ratio at fledging did not differ from parity over the five seasons, suggesting a lack of sex-biased mortality during the first month of life. Similar results have been reported from other Southern Giant Petrel colonies (Hunter 1984, Cooper *et al.* 2001, González-Solís & Croxall 2005). In seabirds with strong sexual dimorphism, the sex that is larger requires more parental investment during the rearing period than the smaller one (Hunter 1987, Anderson *et al.* 1993, Torres & Drummond 1999, Weimerskirch *et al.* 2000). In the case of Southern Giant Petrels (from South Georgia), the total food intake of male chicks was estimated to be 37% greater than that of females chicks (Hunter 1987). Our results suggest that, at least for our study seasons, food availability and/or quality had no negative impacts on either the growth or the survival of the chicks.

Morphometry and chick growth. Southern Giant Petrel chick growth patterns from northern Patagonia were similar to that observed in other species of Procellariiformes. Except for wing length, there was an exponential increase for all morphometric measurements during the first 60–70 days of life, reaching the asymptotic values after this phase. Growth rates were similar between sexes, although males reached greater asymptotic values than females for bill dimensions and tarsus length. It has been shown that, in birds, growth patterns depend on adult provisioning rates, which are linked to the food availability in the foraging area (Lack 1968). Our results on chick growth agree with this finding, but indicate also the existence and exploitation of abundant and accessible food sources adjacent to the colonies by the parental birds. In general terms, the growth patterns observed for Southern Giant Petrel chicks from Patagonia (Figs. 3, 4) were similar to those reported by Conroy (1972), Hunter (1984), and Cooper (2001). The Richards model showed that three different curves (logistic, Gompertz, and LVB) could be used to describe the mean growth of the chicks, which, in turn, might indicate individual variability in growth perhaps as a result of differences in adult body condition or experience (Cobley *et al.* 1998, Berrow *et al.* 2000).

Similar to other procellariiform species, Southern Giant Petrel chicks exceeded the body mass of their parents (117–148%) although they lost mass prior to fledging (see Warham 1990 for a review). The maximum body mass of chicks from the northern Patagonian colonies was lower than maxima reported from other Sub-Antarctic colonies (Hunter 1984, Cooper *et al.* 2001, Coria 2006). However, the same differences between colonies were also observed in adult body mass (Copello *et al.* 2006).

In summary, this study describes for the first time the breeding biology of the Southern Giant Petrel in northern Patagonia, Argentina. The high breeding success and chick survival, the similarity in growth rates between sexes, and the evenness in the sex ratio suggest that food resources were not a constraint in the reproduction of this species during the study period. Our results may be beneficial to the development of marine protected areas especially against the background of the rapid growth in tourism and related industries in Patagonian coastal areas. Our results may also be important when setting up management plans to regulate colony visitation by tourists. Limiting the extent and timing of disturbance is a crucial issue as it can be a serious threat to seabirds (Yorio *et al.* 2001). Although there is no tourism on Arce and Gran Robredo, there are sport fishing excursions and cruises in the area of Leones Island, ≤ 10 km away from Arce. The coastal areas of San Jorge Gulf, the Cabo Dos Bahías Reserve, and Bustamante Bay receive approximately 7000 visitors each year (Yorio *et al.* 2005). While ecotourism could help to raise the public awareness of species conservation issues, and the revenue generated is an important financial factor for the local community, it is important to develop sound management tools based upon the best scientific information.

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