Revista Brasileira de Ornitologia, 18(3):207-215
Setembro de 2010

Breeding biology of South American Tern *Sterna hirundinacea* (Charadriiformes: Sternidae) on Deserta Island, southern Brazil

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Submetido em: 09/05/2009. Aceito em: 04/07/2010.

RESUMO: Ecologia reprodutiva do trinta-réis-de-bico-vermelho *Sterna hirundinacea* (Charadriiformes: Sternidae) na Ilha Deserta Sul do Brasil. Este trabalho descreve a ecologia reprodutiva do trinta-réis-de-bico-vermelho *Sterna hirundinacea* na ilha Deserta (27°16'S, 48°20'W), Sul do Brasil, incluindo informações sobre o período reprodutivo, o tamanho da população, o número de ovos por ninho, o tamanho dos ovos, o sucesso de eclosão e de criação e o crescimento dos filhotes. A colônia abrigou pelo menos 163 casais na estação reprodutiva de 2006. O estabelecimento dos casais ocorreu em abril. A maioria dos ninhos foi construída em locais cobertos por vegetação baixa e o primeiro ovo foi colocado em maio. A média de ovos por ninho foi 1,55 ± 0,55 (EP) e o tamanho médio foi de 45,5 ± 0,2 cm (comprimento), 33,2 ± 0,1 cm (largura) e 25.56 ± 2,0 cm^3 (volume). O período de incubação foi de 21 dias. O sucesso de eclosão foi de 23% e a maior parte das perdas foi atribuída à predação pelo gaivotão, *Larus dominicanus.* O sucesso de criação foi de 28% e a maior parte das perdas ocorreu na primeira semana de vida dos filhotes e foi provocada provavelmente por inanição. O sucesso reprodutivo total foi de 6%. Os filhotes cresceram de acordo com uma curva logística e os tamanhos assintóticos encontrados ficaram próximos aos tamanhos dos adultos, o que parece ser uma regra entre as Laridae. Os parâmetros das curvas foram os seguintes: Massa corpórea – A = 125 g e k = 0,186; Tarso – A = 2,514 cm e k = 0,076; e Cúlmen exposto – A = 2,832 cm e k = 0,082. A massa, em função da sua variabilidade, fornece informações potencialmente importantes sobre as condições de forrageio dos pais e sobre as taxas de alimentação dos filhotes. O abandono do sítio reprodutivo pelos adultos e juvenis ocorreu em setembro. A baixa sobrevivência observada sugere que o crescimento populacional pode ser frequentemente reduzido pelas condições climáticas em populações de nidificação invernal.

PALAVRAS-CHAVE: Trinta-réis-de-bico-vermelho, *Sterna hirundinacea,* sucesso reprodutivo, Reserva Biológica Marinha do Arvoredo, crescimento dos filhotes.

ABSTRACT: This work describes the breeding biology of South American Tern, *Sterna hirundinacea* on Deserta Island (27°16'S, 48°20'W), southern Brazil, including information about breeding period, population size, clutch size, egg size, hatching and fledging success, and chick growth. The colony had at least 163 pairs in the 2006 breeding season. Settlement occurred in April. Most nests were built over flattened vegetation and the first egg was laid in May. The mean clutch size was 1.55 ± 0.55 (SE) and mean egg size was 45.5 ± 0.2 cm (length), 33.2 ± 0.1 cm (width) and 25.6 ± 2.0 cm^3 (volume). The incubation period was 21 days. Hatching success was 23% and most losses were attributed to predation by Kelp Gull, *Larus dominicanus.* Fledging success was 28%, and most chick losses occurred in the first week after hatching, probably due to starvation. The total breeding success was 6%. Chicks grew according to a logistic curve, and the asymptotic sizes were close to the adult sizes, which appear to be typical among the Laridae. The logistic growth curve parameters were as follows: weight: A = 125 g, k = 0.186; tarsus: A = 2.514 cm, k = 0.076; exposed culmen: A = 2.832 cm, k = 0.082. Weight, due to its variability, provides potentially important information about parental foraging conditions and feeding rates. Abandonment of breeding site by adults and juveniles occurred in September. Low survival at this colony suggests that population growth in terns may often be reduced by climate in winter-breeding populations.

KEY-WORDS: South American Tern, *Sterna hirundinacea,* breeding success, Arvoredo Marine Reserve, chick growth.

The South American Tern, *Sterna hirundinacea* is found from Colombia to Tierra del Fuego in the Pacific Ocean, and from the state of Espírito Santo (Brazil) to Tierra del Fuego in the Atlantic Ocean (Harrison 1985, Spear and Ainley 1999). Terns are common and gregarious on beaches and in coastal waters, estuaries and harbors where they forage in coastal water and kelp beds (Bugoni and Vooren 2005, Alfaro and Clara 2007). *S. hirundinacea* mostly feeds on fish, crustaceans and insects (Gochfeld and Burger 1996, Favero *et al.* 2000) and are often seen following fishing boats to scavenge fish remains (Yorio and Caille 1999, Branco 2001). With a global population estimate of 25,000-1,000,000 individuals, and not considered endangered (BirdLife International 2010), the

South American Tern still has many threats, including egg harvesting (Bege and Pauli 1988, Efe *et al.* 2000), exotic predatory species on breeding sites (Blanco *et al.* 1999), degradation of natural habitat (Yorio 2000, Campos *et al.* 2004), disturbance due to tourism (Branco 2004), rising population sizes of competitors and predators (Yorio *et al.* 1998, Yorio 2005) and changes in foraging behaviors (Yorio and Caille 1999, Branco 2001, Campos *et al.* 2004).

Breeding colonies vary greatly in size, with the largest recorded in Argentina with 67,500 breeding pairs at Punta Tombo in 1877 (Dunford 1878). Today, Argentinean colonies vary from a few to > 3,000 pairs, with

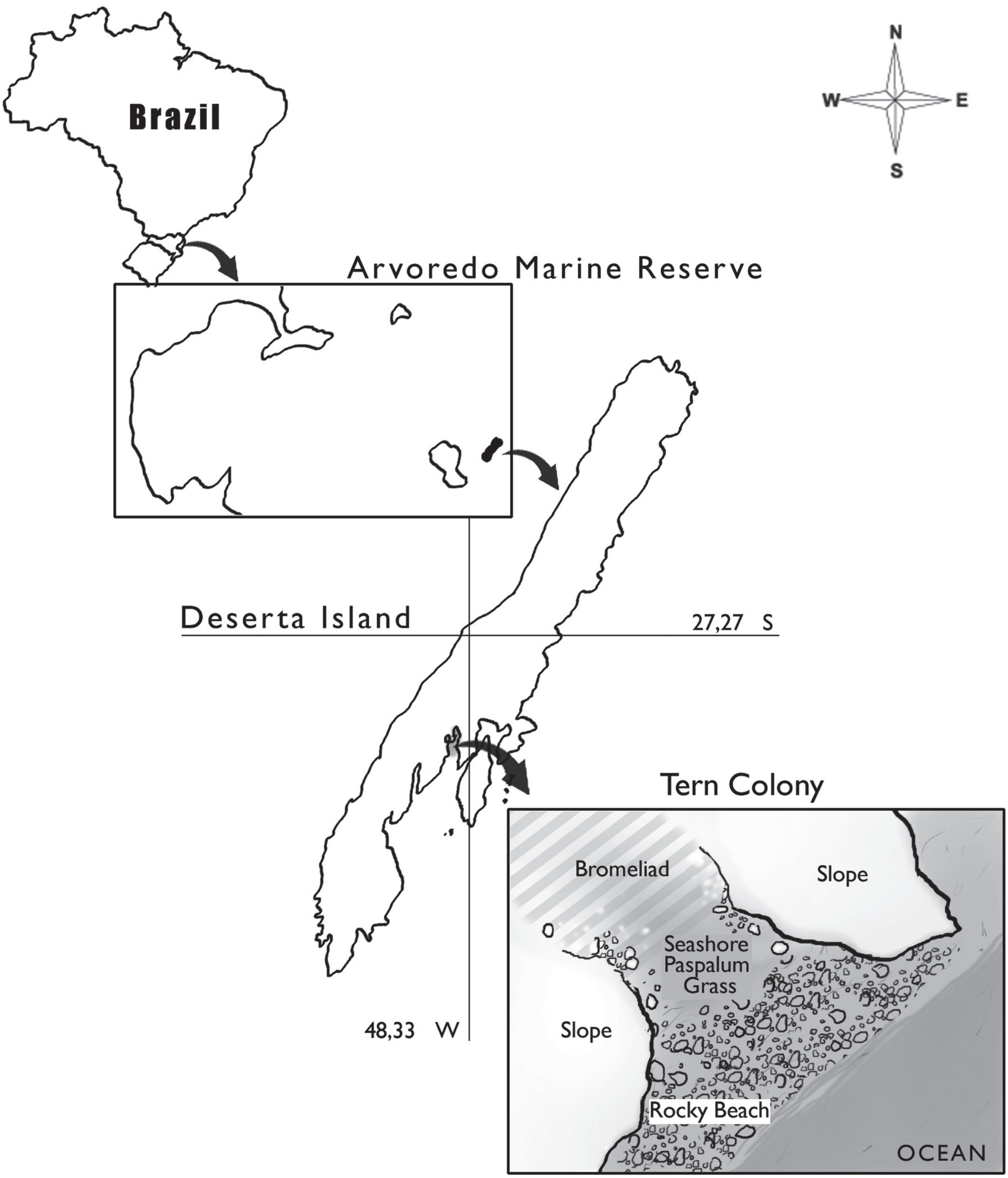

FIGURE 1: Geographic location of Tern breeding area, Deserta Island, southern Brazil.

a total population size estimated at 24,600 pairs (Yorio 2000, 2005). In Brazil, breeding occurs on islands from the state of Espírito Santo to Santa Catarina, where islands may also have breeding Cayenne Terns, *Thalasseus sandvicensis eurygnathus* (Sick 1997, Efe *et al.* 2000, Prellvitz *et al.* 2009). The largest Brazilian colony recorded was on the island of Moleques do Sul in Santa Catarina, with 1,200 pairs (Branco 2003a). In other places, colonies comprised 10-500 pairs (Branco 2003a, Alves *et al.* 2004, Campos *et al.* 2004, Efe 2004, Krul 2004).

In Brazil, South American Tern has mostly been studied with respect to occurrence and population size (Alves *et al.* 2004, Campos *et al.* 2004, Efe 2004, Krul 2004) or reproduction (Murphy 1936, Escalante 1970, Bege and Pauli 1988, Antas 1991, Efe 2004), but seldom has the entire breeding cycle been examined (Branco 2003a,b, 2004). Here, we examined the breeding biology of this tern for one breeding cycle during 2006. Specifically, we wished to estimate reproductive success and examine the factors that might influence that success, on an oceanic island in southern Brazil.

METHODS

Deserta Island is small (1,052 × 175 m, elevation to 60 m) and part of the archipelago included in the Arvoredo Marine Reserve in the state of Santa Catarina, southern Brazil (Figure 1). Vegetation (*restinga*) is allied with the Atlantic Forest, but mostly comprising herbaceous plants and small shrubs (IBAMA 2004). Other birds also nest on the island, including Kelp Gulls *Larus dominicanus,* Cayenne Terns *Thalasseus sandvicensis eurygnathus* and Black Vultures *Coragyps atratus* (Bege and Pauli 1988, IBAMA 2004, Prellvitz *et al.* 2009).

Field-work was carried out in 2006 during six visits to the island: late March (2 days), late April (3 days), May-June (12 days), early July-early August (30 days), mid September and mid November (3 days each). During all visits most of the breeding area was observed daily. All nests were counted and their contents noted on 5 June (eggs, if present) and 26 July (eggs and chicks). New nests were counted as they were encountered and nests (n = 62) were measured (external diameter, nest height above ground at the upper rim). Eggs (n = 50) were measured (length, *l* and diameter, *d*) with calipers (0.05 mm precision). Egg volume was estimated as V (cm^3) = $l \times d^2 \times 0.51$, following Hoyt (1979). A random subset of nests was marked and checked daily throughout the nesting cycle to estimate nesting success using the Mayfield method (Mayfield 1961, 1975). To insure correct identification, eggs and chicks were individually marked with permanent marker or plaster on the left wing. Reproductive cycle length was considered to be the interval between the date that birds arrived on the breeding ground and that of colony abandonment.

Changes in feather growth and in color of the hard body parts were noted in eight chicks that were accompanied daily from the date they hatched for 28 days. Exposed culmen and tarsus length were measured following Baldwin *et al.* (1931) with calipers (0.05 mm precision) and birds were weighed (1-10 g precision). By comparison with the eight individuals that were observed daily, we estimated the age of additional chicks to describe chick development from hatching until leaving the colony. We followed growth in these three measurements over time to examine whether these data could be used as proxies to understand how chick growth may reflect foraging success of parent birds and survival of young birds. Anatomical nomenclature follows Baumel (1993).

RESULTS

Nesting site

The colony covered an area of about 280 m^2, with 50-88° slope, from the shoreline to 16 m above sea level (Figure 1). Its eastern border was an extremely steep rocky slope, where few nesting sites were available and which were small fissures and ledges. Most of the colony area (77%) was vegetated and the remaining area (23%) was rock. Dominant plant species were the grass *Paspalum vaginatum* (63% cover), the bromeliad *Dyckia encholirioides* (13% cover) and the spinach *Spinacea oleracea* (1% cover). Marine flotsam littered the area. Incidentally, by the end of the breeding season we removed 232 soft drink bottles, two 50 liter plastic barrels, one five liter plastic jug, 32 floats, 16 shoes, 35 bunches of plastic packing materials, two aluminum cans, three tin cans, pieces of cables and three 100 liter polyethylene bags.

Breeding population and breeding period

We followed the fates of 259 nests, comprising 163 nests with eggs found 5 June, 21 nests (with eggs) along the trails between 7-14 July and 75 nests with eggs and chicks (35 nests with eggs, 40 with chicks) on 26 July and, after which no further nests were found. We used the trail to gain access to the nesting colony and subsequently birds began nesting in the trail itself, which we then ceased using to avoid perturbing these nests. We estimate the breeding population size in the area to be 163 pairs, some of which may have attempted more than one nest. The interval from arrival of the birds to colony abandonment was 142 days, from late April to mid September. Adults began arriving in the last weeks of April, about three weeks prior to actual nesting. Egg laying began in

TABLE 1: Chick development stages (from newborn to juvenile entirely developed).

Age (days)	Description
1	Hatchlings have: black iris and eyelids, black rhamphotheca with pink parts in the rictus and tomia, conical white egg tooth, pink podotheca, black claws (unguis), body covered by prepennae (except future apteria, *vide* Sclater 1863). Head, including regio gularis, jugulum, neck, dorsum and pyga covered by short dark brown, or yellow with dark brown base, down. Dark brown down grouped forming spots. Pectus, venter, ilia and crissum covered with white down, wing dorsum same as body dorsum, underwing like pectus. Crus covered with white down. *Field identification:* chicks do not stand and stay in nest. Natal down partially or entirely wet.
1-6	Egg tooth falls near day 5. At 6 d, regio omalis molt begins with the first sheaths (vagina pennae) of adult contour feathers. *Field identification:* chicks without contour feathers
7-13	At 7 d feather sheaths grow from ilia and dorsal wings. At 9 d feather tips emerge from sheaths in the regio omalis, ilia and dorsal wing. Days 11-13, body feather sheaths form in the following order: dorsum, nucha, pectus, cauda and crus. Adult down growth slightly before that of preppenae for contour feathers. *Field identification:* no egg tooth, rhamphotheca darker; small feather sheaths in body and contour feathers in regio omalis, ilia and dorsal wings.
14-19	Dorsum, pectum, venter, cauda and crus with contour feathers, emerging from sheaths with natal down at tip. At 15-18 d, pileum and lorum begin feather sheats growth. *Field identification:* contour feathers from regio omalis and wings are long and form a continuous plumage; pin feathers on head.
20-28	Podotheca more colorful. Contour feathers on head and entire body, except neck. At ~27 d, feather sheats s in the nucha and jugulum. *Field identification:* chicks mostly covered by short feathers, but plumage is not continuous with natal down on head and neck.
29-35	Contour feathers longer and tectrices alae and caudae have a silver-white portion. Continued growth of head and neck feathers, which loosen the down at their tips. Plumage more uniform. *Field identification:* feathers in head, neck. Remiges long; chicks almost adult size.
36-42	Contour feathers complete, first flight. Iris, eyelids and rhamphotheca are black; podotheca pinkish, tending to orange, black claws. Adult down forms dense and extensive cover hidden under contour feathers. Frons feathers brown, corona with darker feathers, tending to black, streaked with white feathers; jugulum covered by white feathers; dorsum trunci covered by feathers alternating light and dark brown (striated pattern); white feathers on dorsum and pyga; dark grey rectrices with brown tips and white tectrices; white feathers cover pectus, venter, ilia and crissum; remiges primarii and tectrices dark grey, with light brown or white tips; remiges secundarii grey with white tips; tectrices secundariae dorsales majores grey, with light brown tips; tectrices secundariae dorsales mediae and minores have striated pattern of the dorsum trunci; crus covered by white feathers. *Field identification:* juveniles fly

the second week of May and ended during the second week of July. The last egg hatched 31 July, with incubation in at least some nests during an 11 wk interval. The first chick hatched 3 June. The nestling period ended in early September and by mid September, all birds had left the colony.

Laying, incubation and hatching stages

Nests are circular and built of dry plant material, mostly grass, with a slight central concavity. External diameter averaged 15.4 ± 3.8 cm (mean ± SE, range 10-26 cm) and the height averaged 13.2 ± 7.9 cm (4-32 cm). Nests, in addition to the normal branches and vegetation, also included many artificial objects, such as plastics, fishing line and nets. Most nests (59%) were built on flattened vegetation, followed by slopes (19%), rocky beach (12%) and bromeliads (10%).

Eggs varied in color and pattern. Color varied from dark brown, beige, light beige and greenish brown. Patterns comprised variation in splotches and patches of color on the lighter background. Egg length was 45.5 ± 0.2 mm, width was 33.2 ± 0.1 mm and volume 25.5 ± 2.0 cm^3, respectively (n = 50). Clutches included 1 (n = 21), 2 (n = 23) or 3 (n = 1) eggs. Minimal mean clutch size was 1.55 ± 0.55 eggs per nest. The incubation period of one egg whose entire history from laying to hatching was observed, was 21 days.

Survival to hatching was 23% (15 nests – 21 eggs). Most egg that failed simply disappeared (5 eggs), followed by addling (1 egg) and dead while hatching (1 egg). In the trail, all eggs (n = 28) disappeared prior to hatching. We did not include these nests in any analysis because we felt that these nests were too artificial, since they only appeared after the trail was made and because nest failure was 100%.

The nestling stage; survival and growth

Chicks were classified in seven developmental stages, from newborn to juveniles entirely developed (Table 1 and Figure 2). Chick survival through the sixth week (entire development) was 28% (15 nests – 17 chicks). Most deaths (n = 6) occurred during the first week after hatching. They were generally found in their nests without any apparent injury (n = 7) or disappeared (n = 2). The total breeding success was 6%.

Logistic regressions fit chick growth (weight, tarsus and culmen) well (Figure 3). As expected, weight was more variable and during the nestling stage may increase or decrease for any individual (Figure 4) and therefore can provide information about feeding or foraging rates. Growth of the tarsus and culmen, on the other hand, is always positive and hence changes in growth are less evident.

FIGURE 2: Nestling growth and feather developmental patterns over time. A1 and A2, soon after hatching (< 24 hours), B: 1-6 days, C: 7-13 d, D: 14-19 d, E: 20-28 d, F: 29-34 d, G: 35-42 d.

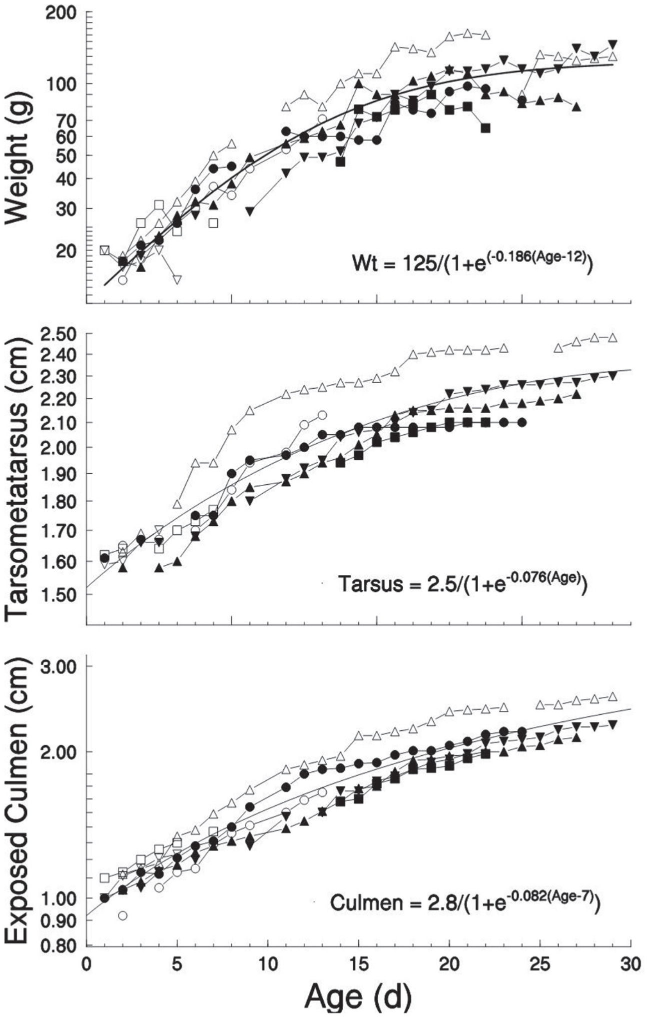

FIGURE 3: Nestling growth by age since hatching and their appropriate logistic growth equations. Symbols are by individual and the same symbols in different figures indicate the same individual. A) Weight, B) Tarsometatarsus, C) Exposed culmen.

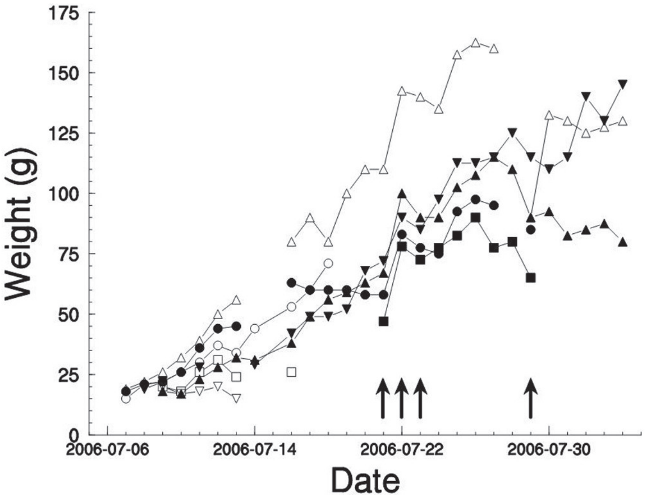

FIGURE 4: Growth as weight plotted by date clearly indicates patterns common to several young at the same moment in time (arrows) that probably indicate something about foraging conditions. Tarsus and culmen (not shown, see Figure 3) are smoother curves over time and never decline and so are not as useful as indicators of feeding.

DISCUSSION

Interestingly, winter nesting South American Terns on Deserta Island often suffer from the consequences of inclement winter weather and starvation of young was the most common cause of mortality. However, birds also apparently benefit from southern, colder ocean waters bringing nutrients and fish that allow them to breed. Other aspects of breeding are similar to those reported in the literature (Alves *et al.* 2004, Campos *et al.* 2004, Krull 2004).

Apparently, the number of breeding pairs (~160) has declined since 1999 (500 pairs, Branco 2003). In addition, from 1999-2002 all pairs failed in their reproduction attempts due to nest predation by the Kelp Gulls (Branco 2003). During 2004 approximately 200 pairs were found breeding on Deserta Island (A. Fillipini *in litt* 2006), similar to that reported here. Early abandonment of the breeding colony and changing breeding locations are common occurrences for terns, which are known to be sensitive to any disturbance (Atwood and Massey 1988, Bege and Pauli 1988, Yorio *et al.* 1994). Thus, habitat availability and quality for breeding are important to determine the distribution, abundance and breeding success of seabirds (Burger and Gochfeld 1994). In addition, their sensitivity to disturbance and frequent changes in breeding locations have important implications for monitoring nesting colonies. Inconsistent and variable breeding colony location impedes good studies of population dynamics (Bege and Pauli 1988, Campos *et al.* 2004, Yorio 2005).

The breeding period in autumn and winter lasted for 142 days, similar to that found in other locations in Brazil (Branco 2003b, Alves *et al.* 2004, Campos *et al.* 2004, Efe 2004, Krul 2004), but is quite different from that in Argentina, where they breed during spring-summer for ~86 days (Scolaro *et al.* 1996, Blanco *et al.* 1999). The breeding season has been suggested to occur when food will be most available for the young birds soon after they fledge as a strategy to maximize their survival after leaving the colony (Ashmole and Ashmole 1967, Schreiber 1980, Le Corre 2001, Jaquemet 2007). However, between latitudes 20-40°S, oceanic subtropical convergence moves northward in the winter, bringing with it food sources such as the fish *Eugralis anchoita* (Castello 1998, Favero *et al.* 2000, Bugoni and Vooren 2005). We suggest that the difference between breeding seasons in Brazil and Argentina is probably related to this seasonal cycle of ocean productivity.

Egg size (33.2 × 45.5 mm) and estimated volume (25.6 cm^3) were similar to those found elsewhere (width: 32.2-34.4 mm, length: 44.8-46.0 mm and volume: 25.4-27.37 cm^3; Murphy 1936, Branco 2004, Efe 2004). Clutch size is also similar to elsewhere, with a modal clutch of one egg although the number of clutches with 2 eggs was greater than usually observed on the island

and in other nearby locations (range: 1.22-1.44; Branco 2004). However, in Punta Loma and Punta Tombo (Argentina), the modal clutch size is 2 eggs (average clutch size was 1.65-1.66 respectively; Dunford 1878, Scolaro *et al.* 1996). Clutch size variation can be influenced by food abundance and, on a larger scale, to geographic location (Lack 1968). In this case, clutch size is larger when food availability is greater and in temperate species than in tropical species (Langham 1983, Nisbet and Ratcliffe 2008). The geographic range of South American Tern includes temperate and tropical regions and clutch size also seems to vary latitudinally (Scolaro *et al.* 1996). We suggest that monitoring clutch size over time may provide a useful tool to understand resource abundance just prior to the nesting cycle.

The 21 days incubation period is similar to that observed in other colonies, which varies between 19 and 26 days (Scolaro *et al.* 1996, Efe 2004). Few eggs hatched (23%) due to nest predation, which is comparable to elsewhere (Branco 2003b). Kelp Gulls are the main predator and are important for their predation on eggs and young, their kleptoparasitism as well as competition for nesting space (Quintana and Yorio 1998a, b, Yorio *et al.* 1998, Branco 2004). We attribute the high nest loss in the trail on Deserta Island to predation by this gull. Colony edges were also more predation-prone and it has been suggested that breeding pairs along the edges may often be young, reproductively inexperienced birds. (Coulson and White 1958, Coulson 1968, Velandro and Freire 2001).

Greater chick mortality soon after hatching has been observed in South American Tern and other seabirds (Langham 1972, Scolaro *et al.* 1996, Efe 2000, Prellvitz *et al.* 2009). During this period, chicks are more sensitive to environmental variations and do not have sufficient energetic reserves to support long periods of food deficiency (Langham 1972, 1983). As observed on Deserta Island, starvation seems to be the main cause of early chick mortality. Clearly, there are poor days for foraging as seen in the reduction in nestling weight at certain moments during the nesting cycle, suggesting that inclement weather may often interfere with parental foraging performance. Logistic growth curves with respect to weight were similar to those observed in Scolaro *et al.* (1996) for this species, and for those observed in other tern species (Starck and Ricklefs 1998). Also, using chick weight plotted by date (rather than age) provides an interesting view on how foraging and feeding has been influenced by climate. Matching days of weight loss with climate may provide a much better understanding of how foraging in adults is hindered by inclement weather.

Nest predation on eggs and early chick mortality on Deserta Island resulted in low breeding success. Nevertheless, this low success was greater than that previously recorded on the island. However, due to variable methods, success rates have been estimated in a variety of ways. By using the ratio of juveniles to the number of nests with eggs, nesting success in Santa Catarina colonies was estimated to vary between 34-66% (Branco 2003b). From data in Gross and Clark (1975), breeding success to 27 days was estimated at 35% in Punta Loma (Scolaro *et al.* 1996). In general, breeding success depends on a set of reproductive factors that includes colonial breeding, parental care and fitness of breeding pairs, climate, environmental conditions and geographic localization (Coulson 1968, Brown and Brown 1987, Nisbet *et al.* 2002). All these relate mainly to food availability and colony quality (Ashmole 1963, Langham 1983, Furnness and Birkhead 1985).

Fewer terns were breeding on Deserta Island in 2006 that previously observed. This may have been due to consecutive desertions during previous years. Breeding season patterns are similar to other colonies at similar latitudes, but quite different from colonies that breed farther south. Breeding success was very low due to the predation of eggs and chicks by Kelp Gulls. Nonetheless, successful tern nests had not previously been observed on Deserta Island. While food is clearly important in growth and survival of young birds, the greatest source of nest failure this year was nest predation. However, in contrast with Argentina, Kelp Gulls is not increasing on Deserta Island (Yorio *et al.* 1998, Prellvitz *et al.* 2009). Nonetheless, population dynamics of this species must be studied to determine whether the combined low nesting success and adult survival are sufficient to maintain the population. Also, we recommend cooperative studies among the countries where the tern breeds, which would provide breeding information on a larger scale and may better address the relationships between resource availability, nest predation (by natural or introduced predators) and anthropogenic impacts on the population dynamics of the South American Tern.

ACKNOWLEDGEMENTS

We thank Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) for permission to work on Deserta Island, Estação de Apoio Antártico (ESANTAR) for the loan of camping material, and PARCEL Dive Center and Policia Militar Ambiental de Santa Catarina for the valuable logistical assistance. Associação Atlantis, Western Bird Banding Association (WBBA) and HSBC Bank partially funded the fieldwork. We are also grateful to many people who provided valuable suggestions and small contributions or loaned equipment. James J. Roper provided an in-depth revision of the English as well as many important suggestions for improvement of the manuscript, for which we are grateful.

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