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Reproductive success of South American terns (*Sterna hirundinacea*) from Cardos islands, Florianópolis, SC, Brazil

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ABSTRACT

Sterna hirundinacea (Lesson, 1831) is a migratory seabird that breeds in the Pacific Coast (from Peru to Chile) and along the Atlantic coast of South America from Espírito Santo (Brazil) to Terra del Fuego (Argentina). This paper describes the reproductive success of South American Terns on Cardos Island, Florianopolis, Brazil in the breeding seasons of 2003, 2005 and 2006. The colony was formed in mid-May in 2003 and early April in other years, with the total number of nests ranging from 1,852 in 2006 to 2,486 in 2005. Hatching success was estimated at 76.39% in 2006, 62.73% in 2003 and 41.1% in 2005, the lowest value that could be attributed to predation by hawks *Caracara plancus*, lizards *Tupinambis merianae* and black vulture *Coragyps atratus*. The chicks hatched in July in 2003, and in June 2005 and 2006, and fledging success was 50.94%, 35.96 and 53.47% respectively. Cardos Island has been constantly used as a breeding site by South American Terns, and therefore represents an important area for conservation of this species. This success could be attributed to low pressure of Kelp gulls (*Larus dominicanus*), the main predator of seabirds along the Brazilian coast.

Key words: Breeding, Reproductive success, South American Terns, Brazil.

INTRODUCTION

The reproductive success of coastal seabirds is often low, but varies between and within sites and seasons due to the influence of climate, availability of food, predation, occurrence of catastrophic events (Mcnicholl 1982), vegetation succession, competition with other species, pollution and human development (Hébert 1985). Marine terns are usually more vulnerable than other coastal species such as gulls, because they are more specialized in terms of breeding and foraging grounds, and have little leeway in their energy and time budgets, partly attributed to their limited foraging ranges (Monaghan et al. 1989). The breeding biology of temperate northern hemisphere nesting terns has been quite well studied but there is much less information regarding temperate southern hemisphere nesting species.

The South American Terns (*Sterna hirundinacea* Lesson 1831) breeds along the Atlantic coast, from Tierra del Fuego (Argentina) to Bahia (Brazil) (Sick 1997) and along the Pacific coast from the southern part of the South American continent up to the Peruvian coast (Gochfeld and Burger 1996). In the Atlantic coasts of South

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America, South American and Cabot's Terns (*Thalasseus sandvicensis eurygnathus* (Saunders, 1876) breed together mostly in Brazil and Argentina (Gochfeld and Burger 1996). Despite the extensive coastline in both countries (adding to more than 12,700 km), breeding of both species is concentrated in only a small number of sites (Yorio and Efe 2008). The main threats faced by these two species in both countries appear to be human disturbance, fisheries, egging and expanding Kelp Gull (*Larus dominicanus*) populations (Yorio and Efe 2008), but the information regarding brazilian colonies is largely limited to regional reports on status and distribution (Sick and Leão 1965, Soares and Schiefler 1995, Sick 1997, Efe et al. 2000, Branco 2003a, b, Alves et al. 2004, Campos et al. 2004, Krul 2004).

The breeding biology of the South American Tern has been described only in a few localities along the coast of Argentina (Scolaro et al. 1996, Yorio et al. 1994, Yorio 2005) and Brazil (Branco 2003b, Efe 2004) and published in regional journals. This paper assembles data published in those journals together with data on the number of reproductive pairs, clutch size, hatching success and reproductive success of South American Tern nesting on the Cardo´s island (Santa Catarina, Brazil). We collected data during three breeding seasons and addressed in particular annual and seasonal changes in breeding success. This is the first comprehensive study of the breeding biology of South American Tern and an important contribution for the conservation of this species.

METHODS

Daily sampling was conducted in the Cardos Island (27°48'54" S, 48°34'52" W), Florianópolis, Santa Catarina, Brazil (Fig. 1) during the reproductive seasons of 2003, 2005 and 2006. The island is covered by thick vegetation, with plenty of cactus plants growing on rocky top, where stands a foot high thistles which named the island. Some couples of guinea pigs (*Cavia porcellus*) were introduced and currently have a population of up to 20 individuals. It is reported the presence of two lizards (*Tupinambis merianae*) is not known whether they were introduced or were swimming to the island. Often the island is visited by herons (*Casmerodius albus* and *Egretta thula*), boobies (*Sula leucogaster*), Kelp gulls (*Larus dominicanus*) and cormorants (*Phalacrocorax brasilianus*). Surrounded by rocks at the base, the

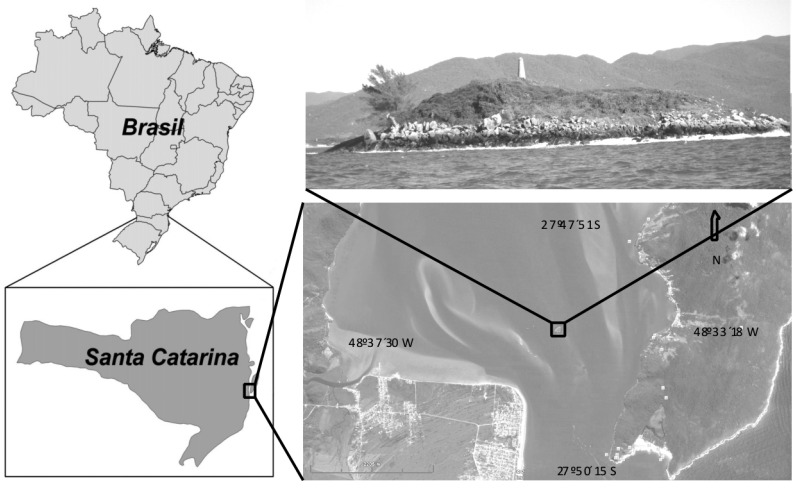

Figure 1. Map and overview of the study area, showing the location of the island of Cardos in Brazil, and coastal state of Santa Catarina.

island has a rounded shape, with two elevations to the extreme southern flank and some rocks on the surface of water. The island area is approximately 1.0 hectare (130m long and 70m wide) and its peripheral portion to the center, there is a predominance of loose rock, interspersed with grasses.

The number of adults was estimated from a fixed point in the colony, using a pair of Bushnell 10x50 binoculars. The foray into the nesting site to the nest's approach was started in the afternoon and lasted approximately thirty minutes.

In those daily incursions were recorded the number of nests where eggs were laid, eggs in laying order (marked with hidrocor pen). In 2005 the adults arrived earlier than in 2003, making it difficult to monitor the settlement period and incubation of eggs (research was initiated when the colony was already established).

The Reproductive season was divided into phases according to the number of adults and nests, and egg laying, as early (12/05 to 04/07), middle (05/07 to 11/08) and late (after 12/08) nesting birds. Causes of egg loss by natural causes (abandoned, flooded, stillbirths) and losses of chicks by starvation, attacks of neighbors, desertion and predation were recorded daily.

Individual nests with a numbered woodpile were marked as soon as a new egg was found in a controlled area (visited all day) 91 nests in 2003, 114 in 2005 and 48 in 2006, representing 110, 146 and 72 eggs to assess the clutch size (no. of eggs in completed clutches), interval between egg-laying and loss of egg mass (recorded daily with a dynamometer) and hatching success.

To avoid the escape of controlled chicks were built individual enclosures ($1m^2$) with fishing line, irons hooks and trawling net. Those nests were daily visited and represented 106 chicks in 2003, 114 in 2005 and 101 in 2006 to establish the reproductive success.

Predators were identified by direct observations (occurred mainly after 17:30h, when the research field work has ended) with binoculars or were identified by tracks, using identification manuals (Sick 1997). Losses caused by the activity of researchers were also recorded, but represented a low incidence in all seasons.

STATISTICAL ANALYSES

To analyze the period effect (Early, Middle and End) and year from the number of nests, daily loss of nests by natural and predation causes, from each one and interactions were utilized the Generalized linear model with a link function Poisson (Statistica; with a significance level of 0.05).

To assess differences in hatching and reproductive success between years, the Chi-square test (χ^2) was used, with a significance level of 0.05 and (n-1) degrees of freedom. Differences in clutch size, and mean egg laying date among years were examined using one-way ANOVA, and tested for homogeneity of variance (Bartlett test) and normality of distribution (Kolmorov-Smirnov) (Zar 1999). The contrast of means (Tukey-Kramer test) was used to indicate which means were significantly different.

RESULTS

The reproductive season of 2003 began with the arrival of the first adults in mid-May, a gradual increase in the number of breeders until June, followed by oscillations until the greatest abundance was reached in July; and the site was abandoned around 25 September (Fig. 2a). Colony formation in 2005 and 2006 occurred at the end of April, with the periods of early, middle and late nesters occurring in late June, July and August, respectively; adults departed in early October (Fig. 2b and 2c) with no significant differences in egg laying date among years ($F_{2\text{-}390} = 0.23$, $P > 0.05$).

The mean clutch size was higher in 2006 ($F_{2\text{-}6461} = 170.14$, $P < 0.0001$) than in 2005 and 2003

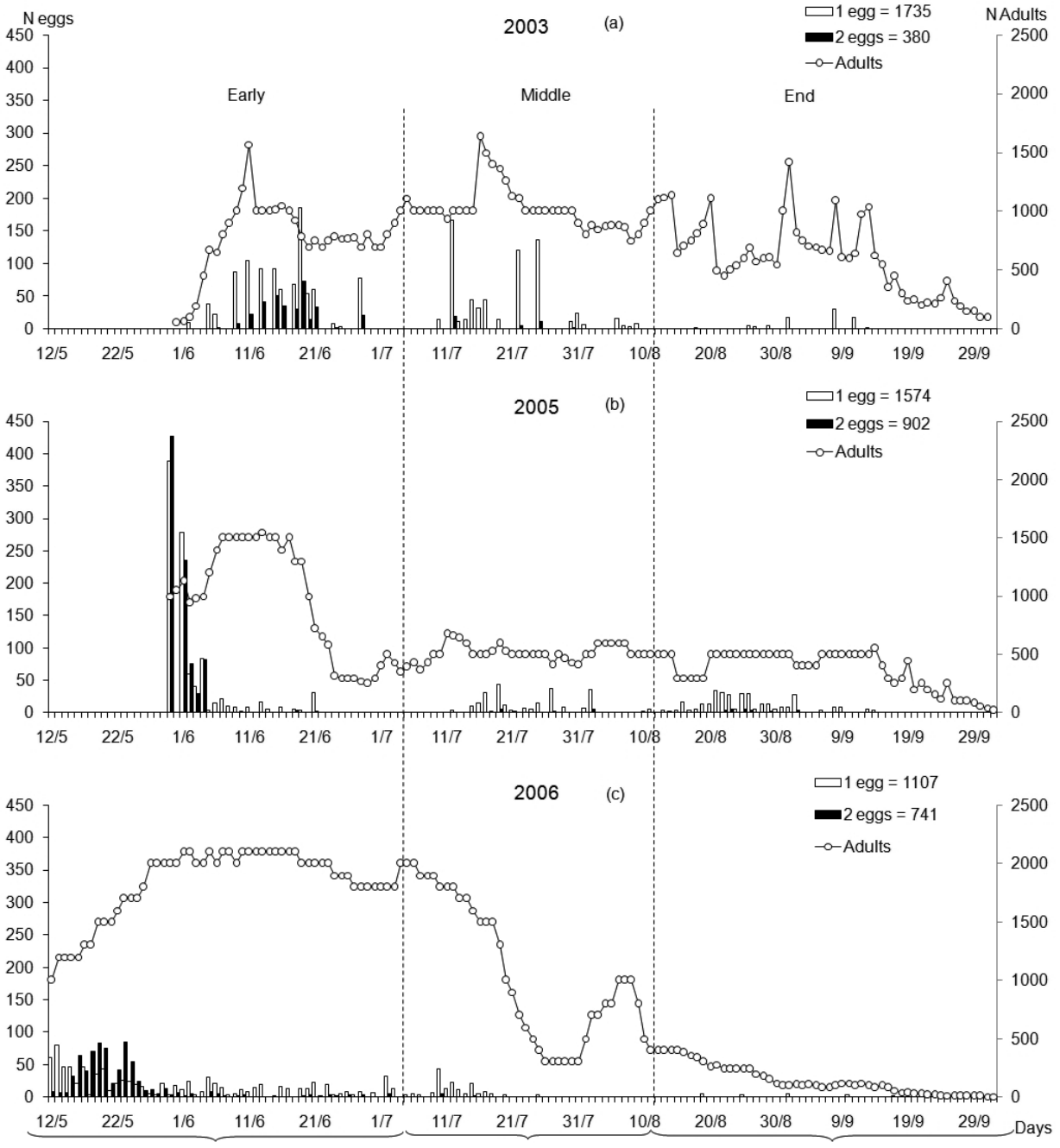

Figure 2. Frequency of adults and nests with one and two eggs of South American terns during the reproductive seasons of 2003 (a), 2005 (b) e 2006 (c).

(Table I). There was a predominance of nests with one egg (81.69%, 63.31% and 59.77%), than with two egg (17.89, 36.28 and 40.01%), and three egg clutches (0.42, 0.41 and 0.22%) in 2003, 2005 and 2006, respectively (Fig. 2).

In 2003, the highest reproductive effort occurred at the beginning of the laying period, with a peak of nests in 19/06, the middle with most records in 12/07, and 14/07 at the end of the period (Fig. 2a). The same pattern could be observed in

2005, with the peak of nesting in 04/06 (165) on the beginning, 27/07 (39) on middle and 25/05 (35) on end (Fig. 2b) and in 2006, 19/05 (119), 10/07 (49) and 01/09 (6), respectively (Fig. 2c) with period effect (Wald X2 = 19.3, $P < 0.05$, 2 df), but not in year (Wald X2 = 1.86, $P > 0.05$, 2 df) and interaction (Wald X2 = 6.94, $P > 0.05$, 4 df).

In 2003 it was possible to monitor 27 "A" eggs and 13 "B", which took on average of 22.89 and 21.86 days to hatch. There was a reduction in mass from 22.81 (A eggs) to 20.15% (B eggs), with an average daily decrease of 0.25 g (Fig. 3a). In the 2005 season, the average daily weight loss of "A" (N = 55) and "B" eggs (N = 5) was 0.23 and 0.17 g, representing a decrease of 21.53 and 15, 67%. The mean incubation time was 23.05 days in 2003 and 22.40 days in 2005 (Fig. 3b). In 2006 the mean incubation period was 23.83 (A eggs, N = 35) and 23.68 (A eggs, N = 19) days, with a mass loss of 18.10 and 15.86%, representing a daily average loss of 0.20 and 0.17 g, respectively (Fig. 3c).

The daily loss of eggs by natural causes occurred most frequently in the middle of the incubation period, with peaks in 25/07 in all breeding seasons, and 21/06 in early 2005 (Fig. 4) with an period effect (Wald X2 = 14.32, $P < 0.05$, 2 df), year (wald X2 = 6.65, $P < 0.05$, 2 df) but not from interaction (Wald X2 = 3.67, $P = 0.45$, 4 df).

Predators on South American Tern eggs of the Cardos Island were: common vulture *Coragyps atratus*, lizard *Tupinambis merianae* and hawks *Caracara plancus*. Predation occurred

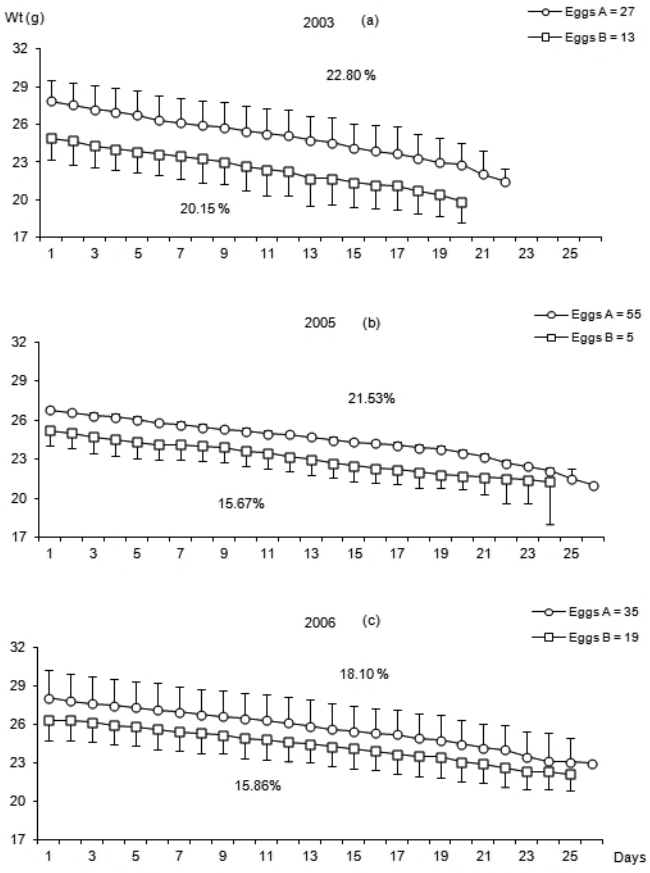

Figure 3. Average daily loss in the weight on "A" and "B" eggs of South American terns during the incubation period in 2003 (a), 2005 (b) e 2006 (c).

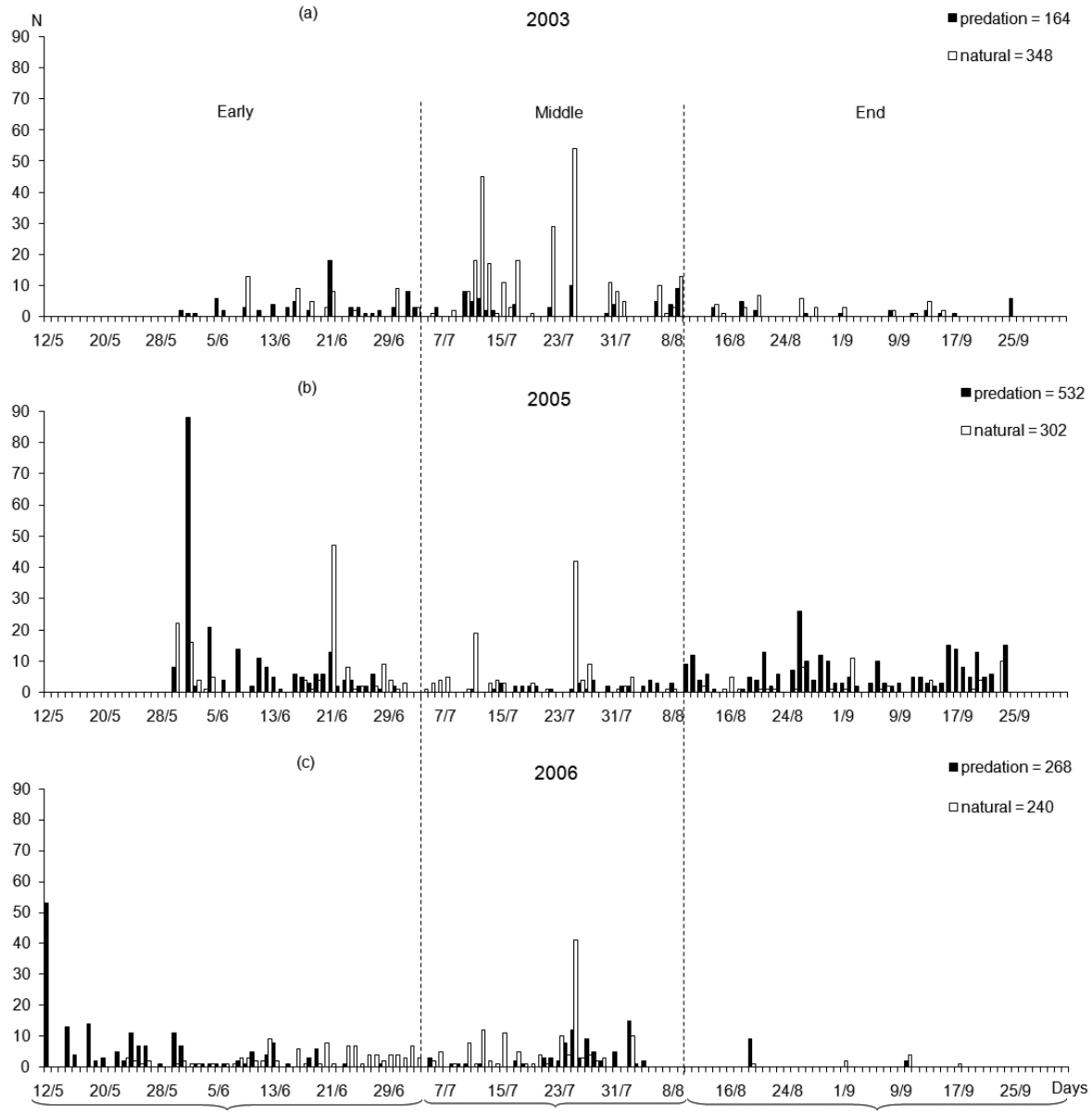

Figure 4. Frequency of eggs daily loss of Sterna hirundinacea during reproductive seasons of 2003 (a), 2005 (b) e 2006 (c).

throughout the reproductive period, with the highest rate of hawk in the beginning of 2003 and 2006, and the highest rate of lizard predation in the middle of the season of 2005, representing 32.0%, 63.8% and 52.8% in 2003, 2005 and 2006, respectively (Fig. 4) without period effect (Wald X2 = 3.96, $P > 0.05$, 2 df), but year (Wald X2 = 6.4, $P < 0.05$, 2 df) and interaction effect (Wald X2 = 32.27, $P < 0.05$, 4df).

The cryptic color of the eggs, and the proximity of nests, resulted in some loss of eggs from the activities of the researchers, and by other intruders that stepped on or removed eggs from the nests. Losses due to researcher occurred during the entire reproductive period, with a higher incidence in the early season of 2003 (less than 0.1%).

In 2003, 110 eggs were monitored: 18.18% were lost to predators or other natural causes and 0.91%

TABLE I
Number of eggs and chicks, clutch size, predation, natural death, research activities, hatching and reproductive successes in 2003, 2005 e 2006.

	2003		2005		2006	
	eggs	chicks	eggs	chicks	eggs	chicks
Number	100	106	146	114	72	101
Clutch size	1.19	-	1.33	-	1.45	-
Predation	20	2	49	15	6	3
Natural	20	50	33	58	11	44
Research	1	-	5	-	-	-
Success	62.73	50.94	41.10	35.96	76.39	53.47

were lost because of researcher activity; hatching success was 62.73% (Table I). In 2005 hatching success was very low (41.10%) because 33.56% were predated, followed by other natural causes and the research activity (Table I). In 2006 hatching success was the highest (76.39%) due to lower predation levels and other natural causes (Table I) with no significant differences between years (χ^2, $P < 0.05$).

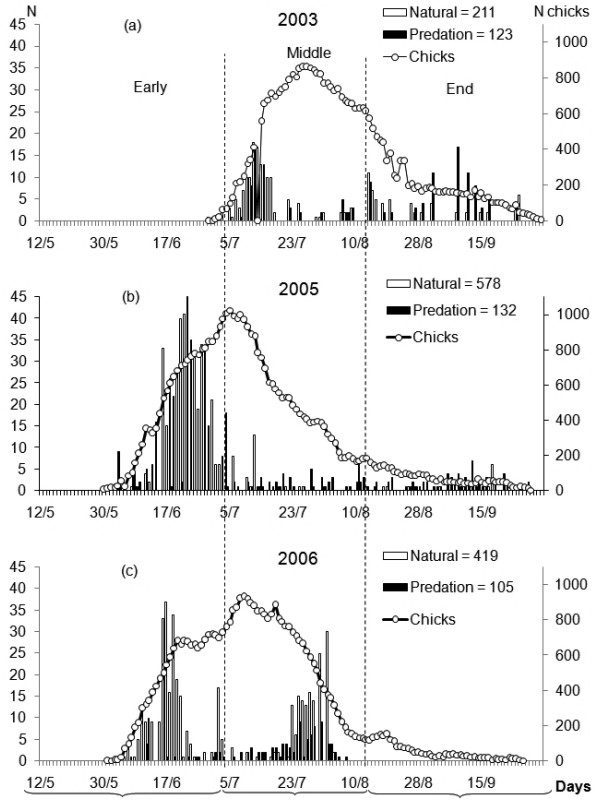

Figure 5. Accumulative abundance of chicks and daily loss by natural causes and predation along the seasons of 2003 (a), 2005 (b) e 2006 (c).

In 2003, the first egg hatched in late June, with gradual increases to the 10/07, when 291 hatched, followed by oscillations of 14/08 (N = 221) and 13/09 (N = 155) and gradual abandonment of the colony in early October (Fig. 5a).

In 2005 and 2006, the first chick hatched at the end of May, with peak hatching in June (N = 527 and 312), July (N = 517 and 418) and August (N = 187 and 152, respectively) and following of adults in mid-September (Fig. 5b and c).

The main cause of chick death was natural, and occurred at the beginning of the reproductive period and in 2005, 2006 and 2003, followed by fluctuations in the middle and end of the season (Fig. 5). Nestlings were killed mainly by hawks, with greater intensity in the middle of the reproductive period in all years, with lower rates at the end of the season in both 2003 and 2005 (but not 2006, Fig. 5). Most chicks died from natural causes other than predation: 47.17% in 2003, 50.88% in 2005 and 43.56% in 2006. The highest rate of predation was in 2005. Reproductive success of South American Tern on the Cardos Island was 50.94, 35.96 and 53.47% in 2003, 2005 and 2006, respectively (Table I) with no significant differences between years (χ^2, $P < 0.05$).

DISCUSSION

South American terns breeds in association with Cabot's Terns (have bred in at least 38 breeding sites, 15 in Brazil and 23 in Argentina) and Royal Terns (*Thalasseus maximus*, have bred in a total of 20 sites, six in Brazil and 14 in Argentina) (Yorio and Efe 2008) at least in 12 localities in Brazilian coast in the past year (Fracasso, unpublished data). Along these areas, few information about colony stabilization, egg laying date, clutch size, eggs mass loss, daily loss of eggs by natural and predation causes, hatching success, daily loss of chicks by natural and predation causes and reproductive success, were found to compare with present study and understand better the biology of these species.

Egg laying of South American Tern along the Argentina coast began in December and showed two peaks (mid-December and early January, Scolaro et al. 1996), while in Espírito Santo and Santa Catarina egg-laying began in May with the highest number in June (Efe et al. 2000, Branco 2003b). These differences may reflect two distinct populations, corroborated by two different types of molecular markers (799 bp of mtDNA and five microsatellites), which despite their dissimilar inheritance models and evolutionary rates, provided concordant results (Faria et al. 2009). South American Terns lay one to three eggs, while *Sterna dougalli* lays on average 2.27 ± 0.18 (Hébert 1985) and *Sterna hirundo* reaches up to three, with a mean clutch size of 2.6 ± 0.3 eggs (Buckley and Buckley 1982).

In Argentina, 43.8% of the nests were one egg clutches, 47.4% two eggs, and 8.8 % three (Scolaro et al. 1996); in Santa Catarina, 53.1% laid one egg clutches, 43.5 laid two, 2.9 laid three, and 0.5% laid four (Soares and Schiefler 1995). This study followed the same trend observed in Moleques do Sul (Branco 2003b), with the highest incidence of nests with one egg.

The average clutch size of 1.65 eggs of South American Tern recorded in Punta León, Argentina by Scolaro et al. (1996) was higher than those recorded by Branco (2003b) on the coast of Santa Catarina, Moleques do Sul (1.44±0.54), Cardos Island (1.31±0.13), Itacolomis (1.36±0.51) and Deserta (1.22±0.51). In this study, the average clutch size ranged from 1.19 to 1.45, suggesting that the fluctuations in the number of pairs, competition for space and food, adverse weather conditions, and activity of predators can change both nesting behavior and investment between years and locations (Hébert 1985).

The average incubation period of South Americans in Argentina was 21.5 days (Scolaro et al. 1996), and in Santa Catarina it was 21-23 (Branco 2003b) days, corroborating the data from Cardos Islands. Colonies of Cayenne Terns in Espírito Santo required an average 23 days (19 - 26) (Efe 2004). Many factors can affect the incubation period, such as temperature variations and the direct and indirect actions of predators (Nisbet and Welton 1984). According to CPTEC/INPE, a climate organization of Brazil, no significant differences ($F_{2,15}$= 0.233; $P > 0.05$) in mean temperature occurred among the years of 2003, 2005 and 2006.

The hatching success of South American Tern from the Cardos Island (Branco 2003b) was lower than that recorded by Efe (2004) for birds nesting on the coast of Espírito Santo (65.4 to 66.1%), while the highest rates observed in Argentina were 73.4% in Punta Loma (Scolaro et al. 1996). Cayenne Terns had reproductive success of only 45.3% in the colony of Punta Leon (Yorio et al. 1994). The failure of South American Tern eggs to hatch in Punta Loma was attributed to predation (12.6%) and desertion (14%) (Scolaro et al. 1996), while in the Santa Catarina coast, the removal of eggs by fishermen and tourists (Bege and Pauli 1988, Sick 1997, Soares and Schiefler 1995), the constant predation of Kelp gulls *Larus dominicanus* (Branco 2003b), hawks, vultures and lizards, other natural causes, and human disturbances in the colonies (present study) were the main causes of loss of eggs.

The interval between the hatching of the first and the second egg was 53.8 hours in Argentina (Scolaro et al. 1996), while on the island of Cardos the interval was 48-60h. These differences can be related to the laying of eggs during the winter months (SC) and spring (Argentina), in addition to differences in the availability of food, colony size and pressure from predators (Branco 2003b).

On the coast of Espírito Santo, the first chicks of Cayenne Terns hatch in early July (Efe 2004), while South American Terns in Cardos Island hatched between 20 to May 25, with gradual increase from June and reached peak abundance in September (Branco 2003b). In the present study the first chicks appeared in May, with the highest abundance in July.

On the coast of Argentina, breeding success was 35.1%, and mortality of chicks during the period was 52.2% (Scolaro et al. 1996). *S. hirundinacea, S. eurygnatha* and *S. maxima* on the coast of Espírito Santo, Rio de Janeiro, São Paulo and Paraná, had low reproductive success because gulls *L. dominicanus* nested in the same area and during the same period (Burger and Gochfeld 1994). Although the main long-term defense of terns is to abandon colonies settled by gulls (Burger and Lesser 1978), they also reduce predation by having cryptic eggs and young and active defense. Additional mortality occurred because of the overnight activity of fishermen; disturbed chicks ran to the sea and drowned (Sick and Leão 1965, Efe et al. 2000, Krul 2004, Campos et al. 2004, Alves et al. 2004). Terns on the Islands of Santa Catarina had relatively high reproductive success, despite pressure from the hawks and seagulls, which was between 34.1% and 24.5% (Branco 2003b).

Coloniality may be a passive advantage when many birds resort to an isolated breeding island or an active social phenomenon that enhances the effectiveness of anti-predator behaviours (Burger and Gochfeld 1994). Sandwich Tern defend their brood by nesting at high densities and sitting tight on eggs and chicks and displaying only few threats towards a potential predator, whereas common terns defend by direct aggressive and social attacks (Veen 1977).

In this study, reproductive success was higher than other location on Brazilian coast, probably due to little interference from gull during egg-laying period and hatching. These factors resulted in the uninterrupted breeding of South American Terns of the Cardos Island since 2001, making this an important conservation site for this species on national nidification areas.

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RESUMO

Sterna hirundinacea (Lesson, 1831) é uma ave migratória que nidifica na costa do Pacífico (do Peru ao Chile) e ao longo do Atlântico Sul do Espírito Santo (Brasil) até a Terra do Fogo (Argentina). Este trabalho descreve o sucesso reprodutivo do trinta-réis do bico-vermelho na ilha dos Cardos, Florianópolis, Brasil, durante as temporadas reprodutivas de 2003, 2005 e 2006. A formação da colônia ocorreu em maio de 2003 e inicio de abril nos outros anos, com um total de ninhos variando entre 1.852 em 2006 a

2.486 em 2005. O sucesso de incubação foi estimado em 76,39% (2006), 62,73% (2003) e 41,1% em 2005, sendo que os menores valores puderam ser atribuídos a predação dos gaviões *Caracara plancus*, lagartos *Tupinambis merianae* e urubus *Coragyps atratus*. As primeiras eclosões foram observadas em julho de 2003, e junho de 2005 e 2006, com o sucesso reprodutivo de 50,94%, 35,96 e 53,47%, respectivamente. A ilha dos Cardos tem sido constantemente usada para a nidificação de trinta-réis do bico-vermelho da América do Sul, e a baixa predação pelo principal predador na região, a gaivota (*Larus dominicanus*), tornam a ilha um importante local para a conservação da espécie.

Palavras-chave: Reprodução, Sucessso reprodutivo, Trinta-réis, Brasil.

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