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Full Length Research Paper

Breeding biology of South American Tern from Cardos Island, Santa Catarina State, Brazil

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The South American Tern *Sterna hirundinacea* Lesson, 1831 occurs in the Atlantic Ocean, from Tierra del Fuego (Argentina) to Bahia (Brazil) and in the Pacific Ocean all around the southern part of the continent, up the Peruvian coast. Daily observations were conducted from April to November in 2003, 2005 and 2006 to gather information on the reproductive biology of the South American Tern in the Cardos Island (SC, Brazil). Although, adults arrived earlier in 2005 and 2006, their breeding chronology followed the same pattern in all three years, with well-characterized reproductive stages. In 2006, the average time of copulation was about three minutes and the number of inseminations (sexual intercourses) stayed constant throughout the day. The period of egg-laying and total number of nests was higher in 2005 (2417 nests), than in 2003 (2124) and 2006 (1852). The smallest average egg sizes (length, width, weight) occurred at the end of egg-laying in 2003, while the largest occurred in the beginning of 2006. Eggs hatched earlier in 2005 and 2006 compared to 2003, with the earliest hatching at the end of May.

Key words: Behavior ecology, seabird breeding, *Sterna hirundinacea.*

INTRODUCTION

The South American Tern *S. hirundinacea* Lesson, 1831 is a small seabird (38-41 cm) with red beak and legs, distributed 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 (Higgins and Davies, 1996). Although there is little information about the population that breeds in the Atlantic coast, it is known that breeding in Argentina occurs from December to April followed by migration to wintering areas of Uruguay and southern Brazil (Olrog, 1979; Yorio et al., 1994; Scolaro et al., 1996; Quintana and Yorio, 1997). Along the Brazilian coast, the breeding occurs from April to October (Sick, 1997; Efe et al., 2000; Branco, 2003a, b).

Mixed colonies of South American Tern and Cayenne Terns *Thalasseus sandvicensis* (Latham, 1787), were recorded on the coasts of Rio de Janeiro (Sick and Leão, 1965; Alves et al., 2004), Espirito Santo (Efe et al., 2000), São Paulo (Campos et al., 2004), Paraná (Krul, 2004), Santa Catarina (Soares and Schiefler, 1995; Branco, 2003a, b) and Patagônia, Argentina (Yorio et al., 1994; Scolaro et al., 1996; Quintana and Yorio, 1997).

The South American Tern nests close together (nearly 50 cm) in merely depressions in the ground lined with grasses. Colonies can be as large as 10,000 pairs in the Falklands Islands. In general, clutch size varied in one to three eggs that are, predominantly brown-yellow with

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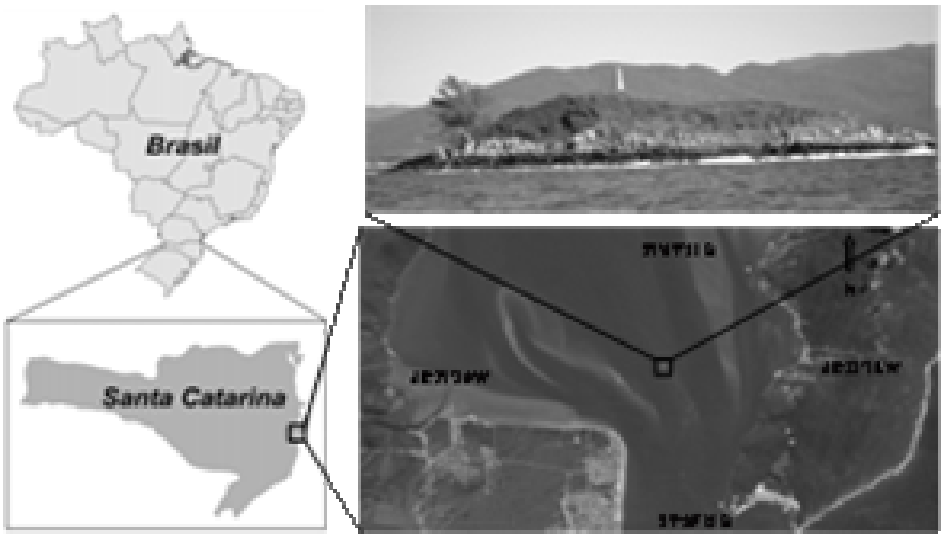

Figure 1. Map and overview of the study area, showing the location of Cardos Island in the coastal portion of Santa Catarina, Brazil.

black spots colours cryptic in appearance and they confuse predators (Scolaro et al., 1996, Branco, 2003b). The pressure from predators (hawks, vultures, lizards and kelp gulls), lack of food, and humans (eggs collection, fisheries, pollution, lack of habitat) are some of the factors that induced shifts in breeding sites from closer islands (Yorio et al., 1994; Scolaro et al., 1996; Efe et al., 2000), although along the Santa Catarina coast on the Itacolomis and Cardos Islands they have bred since 2001 (Branco, 2003b).

There is information available on the distribution and abundance of the species in Argentina (Duffy et al., 1988) and Brazil (Sick, 1997; Soares and Schiefler, 1995; Efe et al., 2000; Branco, 2003a; Branco, 2004). However, reproductive ecology was studied only in Punta Loma (Scolaro et al., 1996) and Santa Catarina (Branco, 2003b). This paper presents data on the reproductive behavior of the South American Tern during three different breeding seasons on The Cardos Island (Santa Catarina, Brazil). More specifically the reproductive and copulation period, number of inseminations, egg size and hatching timing of the species.

METHODOLOGY

Field work

Daily observations were made on terns on the Cardos Island (27°48'54"S, 48°34'52"W; area of 1.5 km^2), Florianopolis, Santa Catarina, Brazil (Figure 1), during the reproductive seasons of 2003, 2005 and 2006 (totaling 63, 121 and 144 days and 315, 847 and 1440 h of observation, respectively). Data on number of adults, reproductive behavior, mate choice, courtship feeding (delivery of fish), time and frequency of copulations and nest-building activities were obtained through observation with binoculars (10x50 Bushnell) and photography from a fixed point in the colony. Using the number of adults and nests and the egg-laying time, the reproductive season was categorized into three stages: beginning (12/04 to 04/07), middle (05/07 to 11/08) and late (after 12/08).

The duration of copulations (total time of male on the female's back) and the number of inseminations were recorded, except when the couples were disturbed (sound of helicopters, aircraft or boats, predators, or even attack from other individuals). The settlement and copulation period in 2005 was not observed because the adults arrived at the island earlier than expected (compared to 2003). In 2006, a sailor and a boat were hired to enable a greater period of observation on the island, extending the observation from 6:00AM to 06:00PM. The observation time was divided into 59 minute-intervals: that is, first observation interval started at 6:00AM and ended at 6:59AM.

We recorded: the number of nests built, number and size of eggs by laying order (marked with a Hidrocor pen “A”, “B” and “C”), distance between nests (to 0.1 cm), and the number of newborn chicks. The length of the major axis of eggs (Lt) and width (Wid) in cm were determined with a caliper (0.1 cm) and weight (Wt) in grams was determined with a dynamometer type PESOLA (60 g and accuracy of 0.5 g). The volume of eggs was determined using Hoyt’s (1979) equation: Vol (cm^3) = Kv.Lt.Wid^2 once: Kv = V/Lt.Wid^2, where volume estimated Kv = coefficient of 0.5205; Lt = total length; Wid = greater width of the axis (Branco, 2003a).

Statistical analyses

The distance between nests, biometrics and average volume of eggs, incubation period, order of laying in the seasons of 2003 and 2005 were examined through analysis of variance (ANOVA) and tested for homogeneity of variance (Bartlett test) and normality of

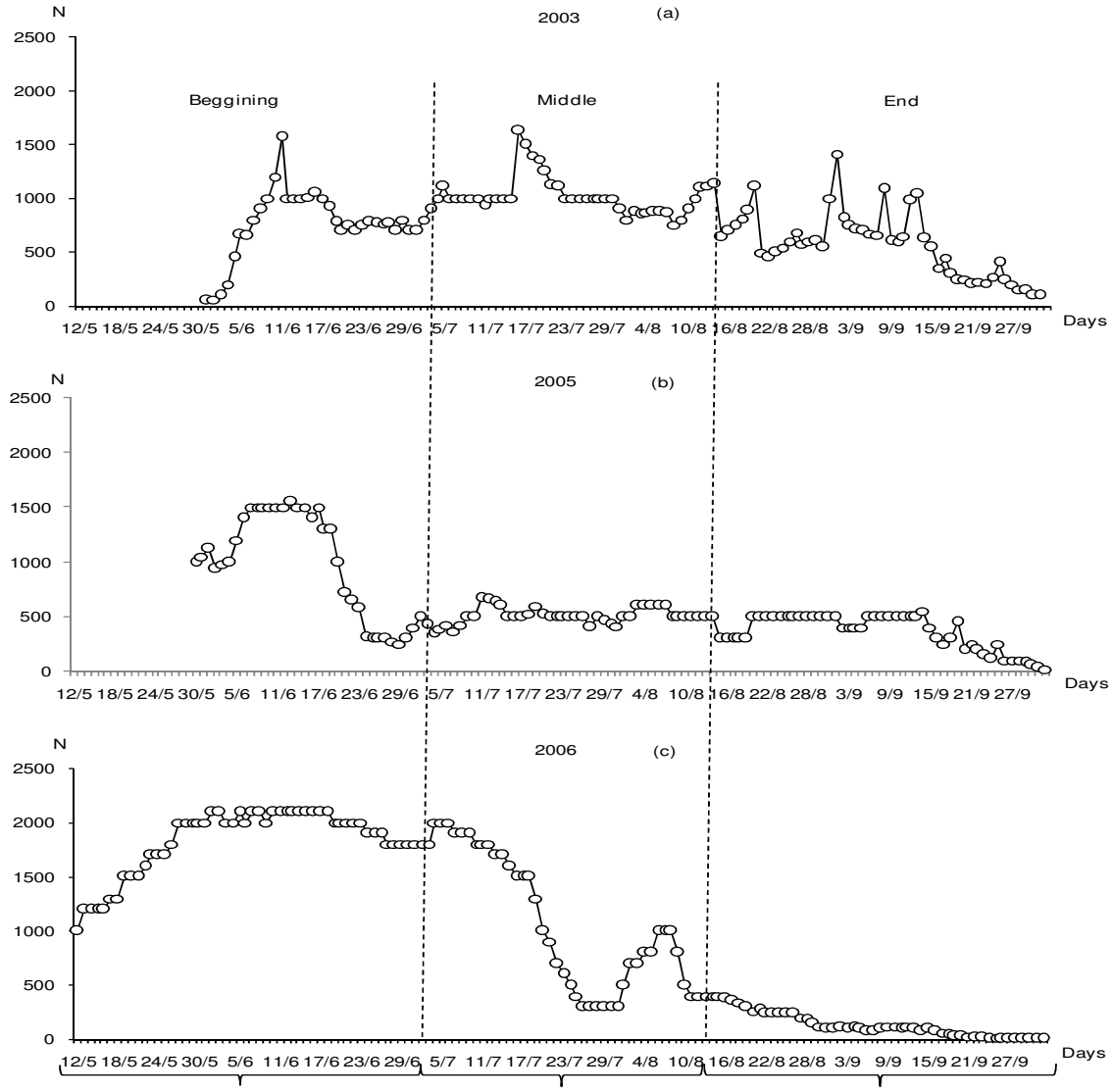

Figure 2. Daily variations in the absolute abundance of adults of *Sterna hirundinacea* during the period of (a) 2003, (b) 2005 and (c) 2006, at Cardos Island, Santa Catarina state, Brazil.

the distribution (Kolmorov-Smirnov) (Zar, 1999). The contrast of means (Tukey-Kramer test) was used to indicate which means were significantly different. The Student *t*-test ($p < 0.05$) was used to verify the existence of significant differences in the nests with two eggs between the beginning, middle and late reproductive periods of 2003 and 2005, and the center and edge of colony in 2006.

RESULTS

Establishment of the colony and Reproductive behavior

The reproductive season of 2003 began with the arrival of the first adults in mid-May, followed by a gradual increase and oscillations in the number of breeders until June, and greatest abundance in July. The island was abandoned in October (Figure 2). Colony formation in 2005 and 2006 started at the end of April, with the periods of beginning (late June), middle (July) and end (August) with the departure of adults in beginning October (Figures 2b and c).

In 2003, 138 copulations were observed with an average duration of 85.8 ± 11.8 s at 1:00 PM and 161.0 ± 85.8 s at 8:00 AM, and inseminations were repeated for up to seven times, ranging from 1.6 ± 0.4 (number of sexual intercourses) at 1:00 PM to 3.5 ± 0.5 at 11:00 AM

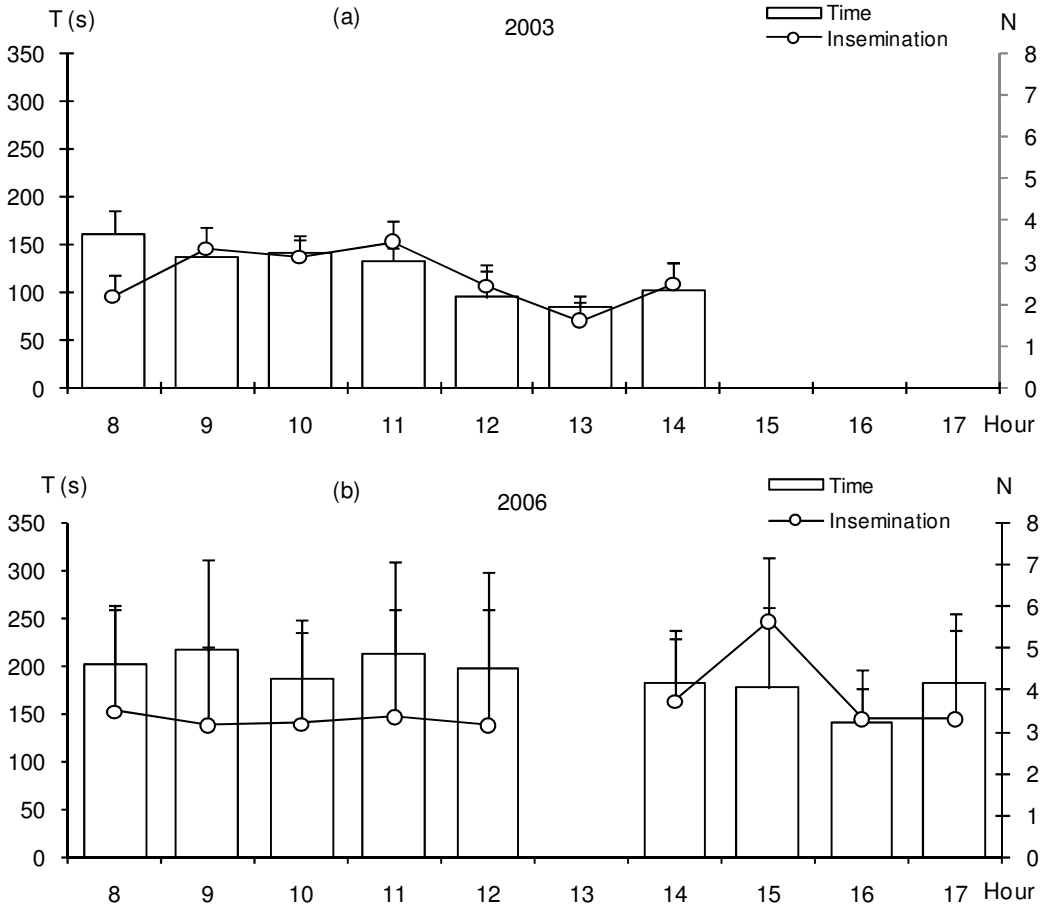

Figure 3. Number of inseminations (represented by continuous line) and duration of each insemination (represented by bars) in seconds measured during the mating of *Sterna hirundinacea* throughout the day, during the reproductive seasons of (a) 2003 and (b) 2006, at Cardos Island, Santa Catarina state, Brazil. (Vertical bars indicate the average standard error).

(Figure 3a). In 2006, the average time of copulation was 200 s, with the highest records at 9:00 AM and 11:00 AM and the lowest at 3:00 PM and 4:00 PM; the number of inseminations remained constant throughout the day, except at 3:00 AM when they were highest (Figure 3b).

Construction of nests and eggs' incubation period

After mating, the males and females started to build the nest, usually found on the ground (rarely in shrubs) using materials available on the island, such as fragments of shells and rocks, grass, dried grasses, grasses and small kindling.

The terns nested on most area of Cardos Island, excepting the Eastern side which had exposed rocks and bushes. Terns built an average of six nests/m^2, with significant differences among years ($F_{3\text{-}16} = 3.99$, $p < 0.01$ in 2003; $F_{3\text{-}236} = 23.42$, $p < 0.001$ in 2005 and $F_{3\text{-}266} = 14.51$, $p < 0.01$ in 2006) (Figure 4). The larger distances between nests were found in the highest area of the colony, covered by shrubs and big rocks, and in the lowest area, surrounded by rocks and grasses (2003) (Figure 4a) and other locations in 2005 and 2006 (Figure 4b and c; Tukey test).

In all the three years, the largest number of new nests were found at the beginning of the reproductive period (June of 2003 and 2005 and May of 2006), followed by peaks in July, with fewer new nests at its end (09/09, 25/08 and 01/09, respectively) (Figure 5).

Egg size

The smallest and largest eggs (length, width and weight) were recorded at the end and at the beginning of 2003

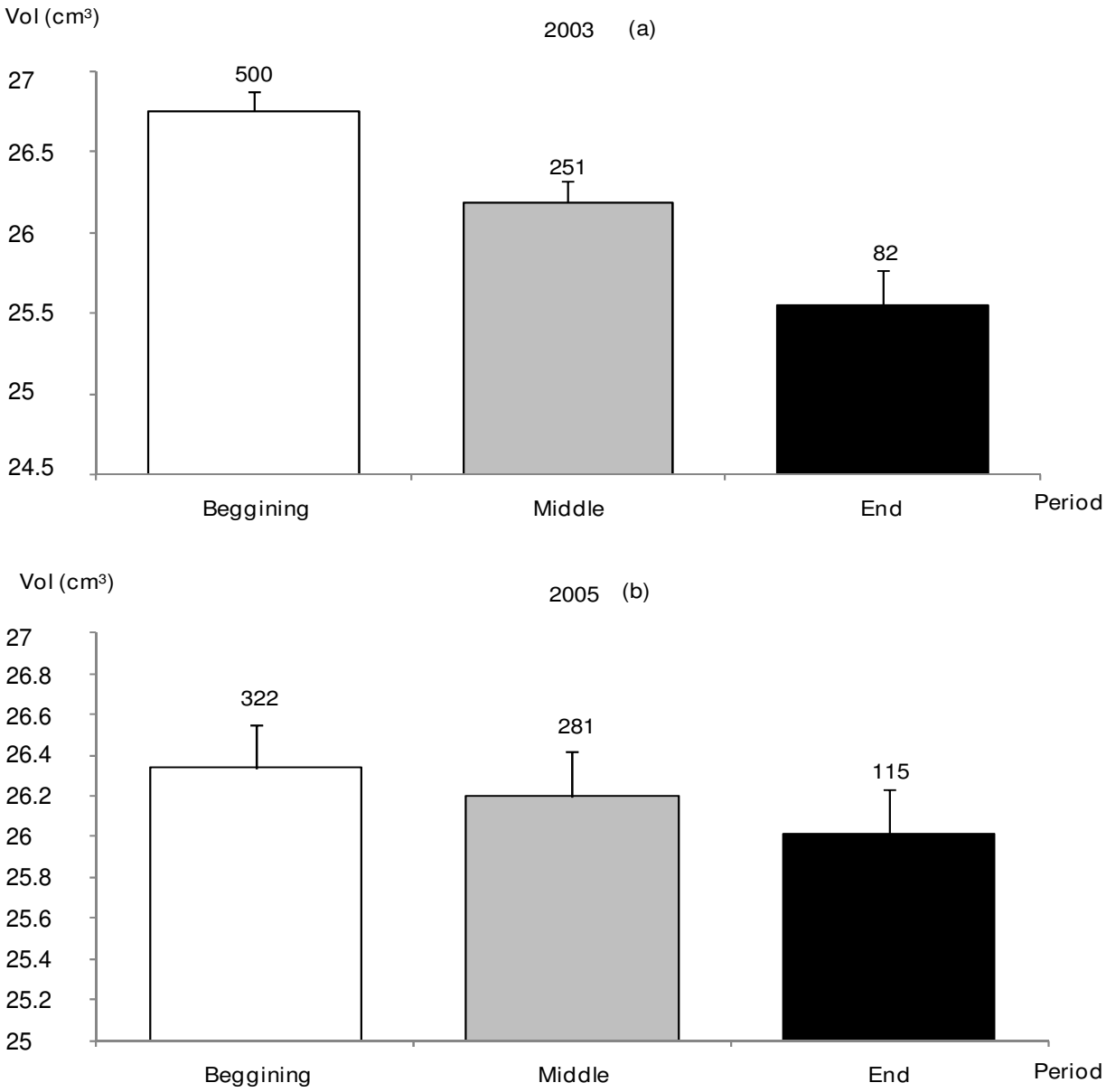

Figure 4. Distance between nests of *Sterna hirundinacea* constructed in different substrates during (a) 2003, (b) 2005 and(c) 2006 at Cardos Island, Santa Catarina state, Brazil. (The number above bars indicates quantify of measured distances, and vertical bars indicate the average standard error).

season, respectively, although weight was highest at the end of 2005 breeding season (Table 1). Eggs from 2003, regardless of laying order, did not differ significantly in length ($F_{2\text{-}830} = 1.506$, $p > 0.05$). However, they did differ in width ($F_{2\text{-}830} = 5.413$, $p < 0.05$) and weight ($F_{2\text{-}830} = 5.421$, $p < 0.05$) between periods. Differences in egg's size occur mainly at the end of the season (Table 1). In 2005, there were no differences in length ($F_{2\text{-}715} = 0.179$, $p > 0.05$) and width ($F_{2\text{-}715} = 1.186$, $p > 0.05$), although they differ significantly in weight ($F_{2\text{-}715} = 11.573$; $p < 0.001$) between the beginning and late periods due to lower values found at the beginning of the season (Table 1).

Eggs incubated in different periods in 2003 differed significantly in volume ($F_{2\text{-}830} = 10.907$, $p < 0.001$), attributed to lower value (smaller eggs) at the end of the season (Figure 6a). Eggs from 2005 did not differ

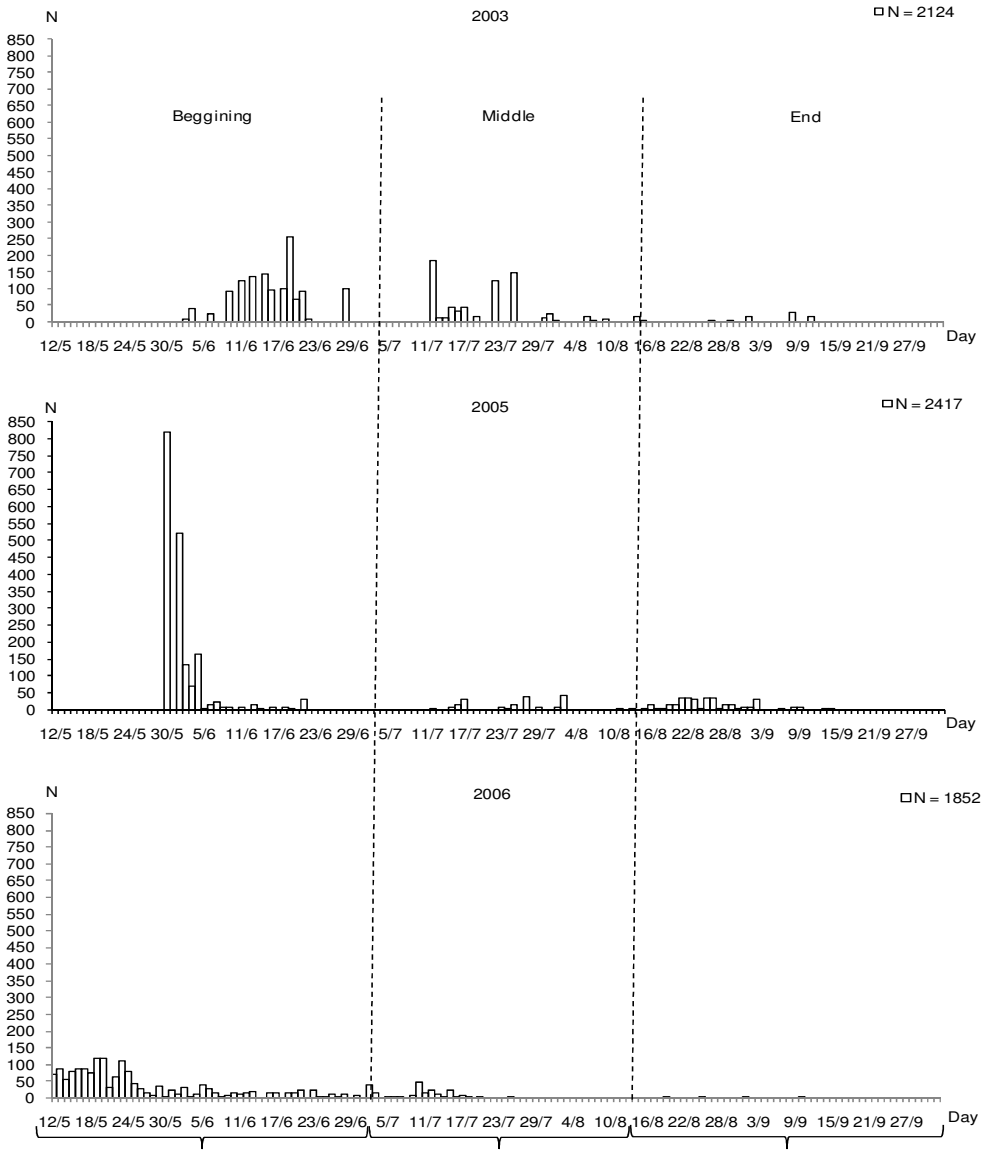

Figure 5. Daily abundance of new nests of *Sterna hirundinacea* during the beginning, middle and end of (a) 2003, (b) 2005 and (c) 2006 breeding seasons at Cardos island, Santa Catarina state, Brazil.

Table 1. Number of eggs of *Sterna hirundinacea*, and its biometry (length, width, and weight) recorded in the Cardos Island, Santa Catarina State, Brazil. (< = lower limit, > = higher limit values).

Year	Period	Length (cm)			Width (cm)			Weight (g)			N
		<	>	Mean ± error	<	>	Mean ± error	<	>	Mean ± error	
2003	Beggining	4.10	5.60	4.59 ± 0.01	3.00	3.50	3.29 ± 0.01	18.00	40.00	26.00 ± 0.12	500
	Middle	3.90	5.20	4.57 ± 0.01	3.00	3.20	3.26 ± 0.01	20.50	31.00	25.83 ± 0.13	251
	End	3.90	5.40	4.55 ± 0.02	3.00	3.40	3.23 ± 0.01	20.00	29.50	25.07 ± 0.23	82
2005	Beggining	3.90	5.30	4.57 ± 0.02	3.00	3.5	3.27 ± 0.01	18.00	32.00	25.46 ± 0.23	322
	Middle	4.00	5.10	4.57 ± 0.02	3.00	3.5	3.26 ± 0.01	20.00	30.50	26.06 ± 0.23	281
	End	4.10	5.10	4.56 ± 0.02	3.00	3.5	3.26 ± 0.01	22.00	31.00	26.41 ± 0.22	115

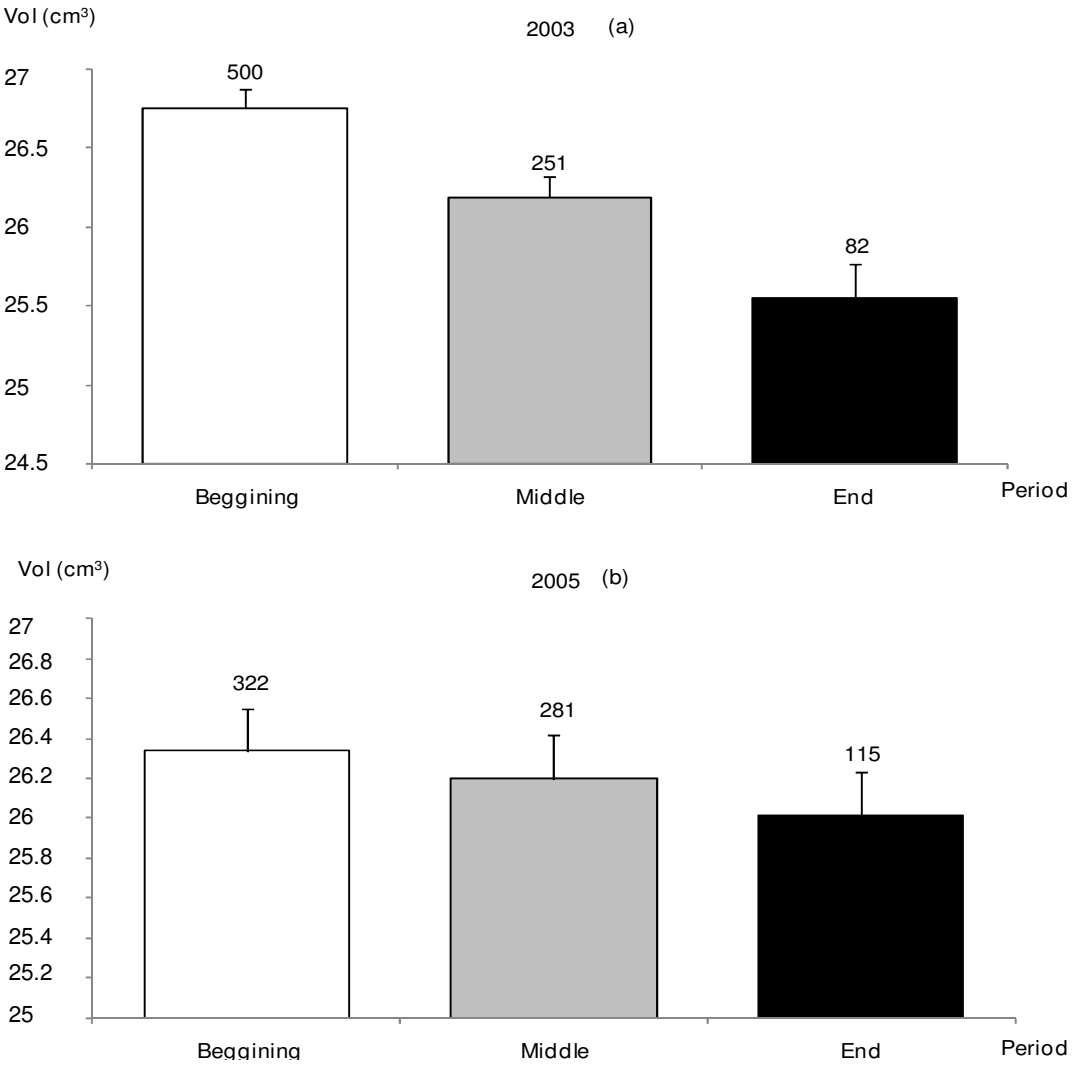

Figure 6. Average volume of *Sterna hirundinacea* eggs in the beginning, middle and end of the breeding season in (a) 2003 and (b) 2005 at Cardos Island, Santa Catarina state, Brazil. (The number above bars indicates quantify of measured eggs, and vertical bars indicate the average standard error).

significantly in volume between periods ($F_{2\text{-}715}$ = 1.214, p > 0.05) (Figure 6b).

In nests with only one egg there were no differences in size in the beginning, middle and late periods of 2003 ($F_{2\text{-}87}$ = 2.424, p > 0.05) and 2005 ($F_{2\text{-}48}$ = 1.622, p > 0.05). Similarly there were no differences in nests with two eggs (t = 0.188, p > 0.05) and ($F_{2\text{-}160}$ = 0213, p > 0.05), respectively (Figure 7). However, there were significant differences between the volume of "A" and "B" eggs in nests with two eggs between beginning (t = 4.564, p < 0.001), (t = 7.681, p < 0.001) and middle nesting periods (t = 2.370; p < 0.05), (t = 3.207; p < 0.05) in 2003 and 2005, respectively, but there was no difference between eggs in late nests in 2005 (t = 1.800, p > 0.05) (Figure 7b).

The 236 eggs found in 2006 had an average length of 4.61 ± 0.01 cm, average width of 3.30 ± 0.01 cm and average weight of 27.19 ± 0.12 g. Despite having recorded lower volume values at the edge than in center of the colony, there were no significant differences in the size of eggs "A" (t = 1566, p > 0.05) and "B" (t = 1016; p > 0.05) (Figure 8).

Abundance of newborn chicks

In 2003 the first eggs hatched in late June, with a gradual increase in the number of chicks until the peak in July 7 (N = 525), followed by decrease until August 4 (N = 31)

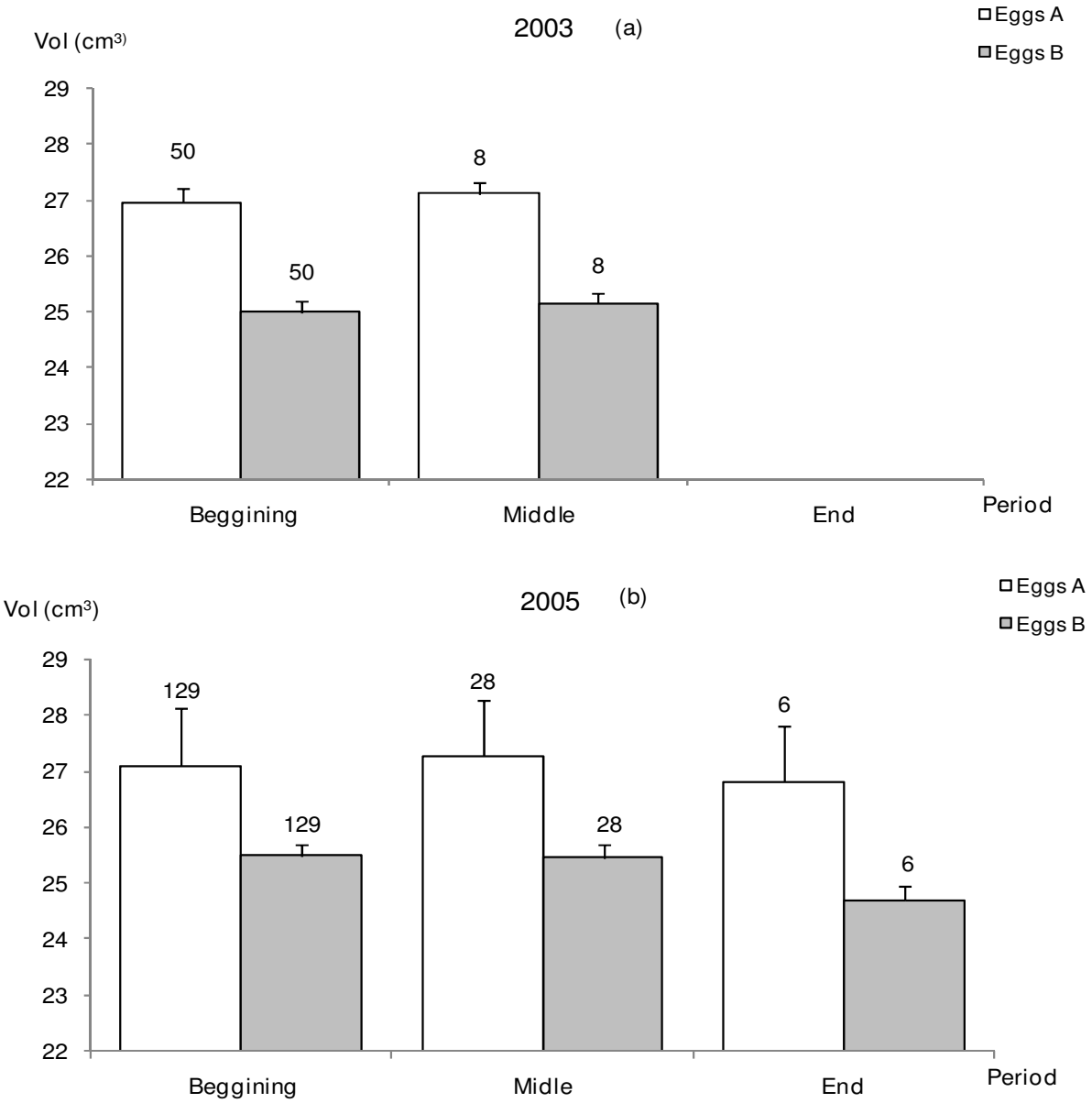

Figure 7. Average volume of *Sterna hirundinacea* A and B eggs tern during different periods of (a) 2003 and (b) 2005 breeding seasons at Cardos Island, Santa Catarina State, Brazil. (The number above bars indicates quantify of measured eggs, and vertical bars indicate the average standard error).

and oscillation from the middle towards the end of the season (September 15) (N = 14) (Figure 9a). In 2005, the first chicks appeared at the end of May, and followed the same trend of past seasons, with three peaks of abundance: June (N = 590), August (N = 54) and September (N = 26) (Figure 9b). The hatching of first egg in 2006 was in May 31st, with the highest values at the beginning of the season (N = 485), decreased in the middle and ceased at the end of the season (Figure 9c).

DISCUSSION

Many species of terns breed in large colonies like *Sterna antillarum* (Lesson, 1847), *Sterna hirundo* (Linnaeus, 1758) and *Sterna dougalli* (Montagu, 1813) that usually nest on the coast of the United States in beginning April or May (Jackson and Jackson, 1985; Spendelow, 1982; Nisbet et al., 1984; Hébert, 1985). Most seabirds are philopatric. However, some Sternidae that nest in

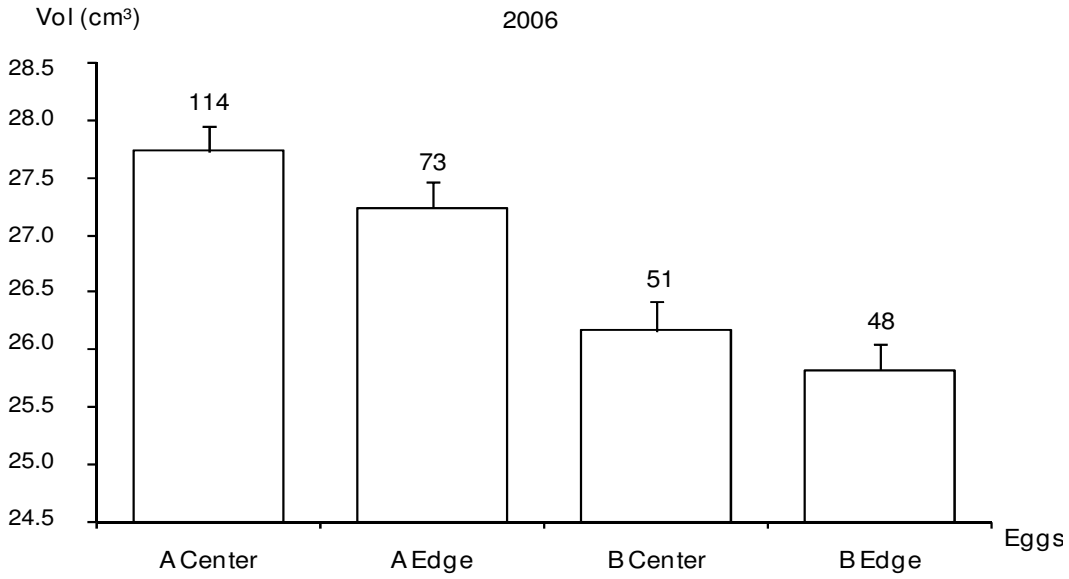

Figure 8. Average volume of *Sterna hirundinacea* A and B eggs tern in the center and edge of the colony, during the 2006 breeding season at Cardos Island, Santa Catarina State, Brazil (The number above bars indicates quantify of measured eggs, and vertical bars indicate the average standard error).

unstable environments are prone to change locations from year to year (Baird, 1990). *S. hirundinacea* and *S. eurygnatha* frequently and massively abandon their nesting areas due to disturbances (Yorio et al., 1994; Soares and Schiefler, 1995; Scolaro et al., 1996; Quintana and Yorio, 1997; Efe et al., 2000; Alves et al., 2004; Campos et al., 2004; Krull, 2004; Branco, 2003a, b).

The reproductive period of South American Tern in Santa Catarina coast, from May to October (Soares and Schiefler, 1995; Branco, 2003a) is similar to the one in the islands of Espirito Santo (May) (Efe et al., 2000), to the season in the coast of Rio de Janeiro (from March to October) (Sick and Leão, 1965; Sick, 1997), Paraná (from June to September) (Krull, 2004) and in São Paulo (from May to August) (Campos et al., 2004). According to Branco (2003b) the first adult of *S. hirundinacea* were observed at Cardos island in mid-April (2002), with a gradual population increase until July, which corroborates our observations for 2005 and 2006. In 2003 the occupation of our site was late (end of May), which can be attributed to variation in average temperature and food availability near the colony. In Argentina the breeding season is from November to December (Scolaro et al., 1996) and genetic homogeneity was found among South American tern breeding colonies from Brazil (Faria et al., 2009). Low, but significant, genetic differentiation was detected between the Patagonian and some Brazilian colonies (providing evidence that the Atlantic populations of these terns are not completely panmictic. These findings are supported 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).

The reproductive behavior of observed for *S. hirundinacea* at Cardos island is consistent with that described for Terns in general (Nelson, 1980; Krebs and Davies, 1996) and specifically reminds that of *S. eurygnatha* on the island Itatiaia (ES) (Efe, 2004). In Itatiaia the season began in mid-May and displays were more intense in the beginning hours of the day (Efe, 2004).

The pattern and spread of egg-laying in colonial species is viewed as an adaptive function to reduce losses by predation (Houde, 1983). That is, highly synchronous breeding reduces predation through swamping (predators can eat only one egg so many each day). The population of South American Terns that nest in Punta Loma (Argentina) follows the pattern established for other species of Terns in temperate zones (Langham, 1983), with dense colonies (Buckley and Buckley, 1980; Burger, 1981; Scolaro et al., 1996). At Cardos Island we observed a similar trend of colony occupation in various types of substrates, with disputes with Cayenne Terns occurring frequently in higher areas above the tide.

South American Terns occupy small areas with high concentrations of nests; on Cardos Island the average

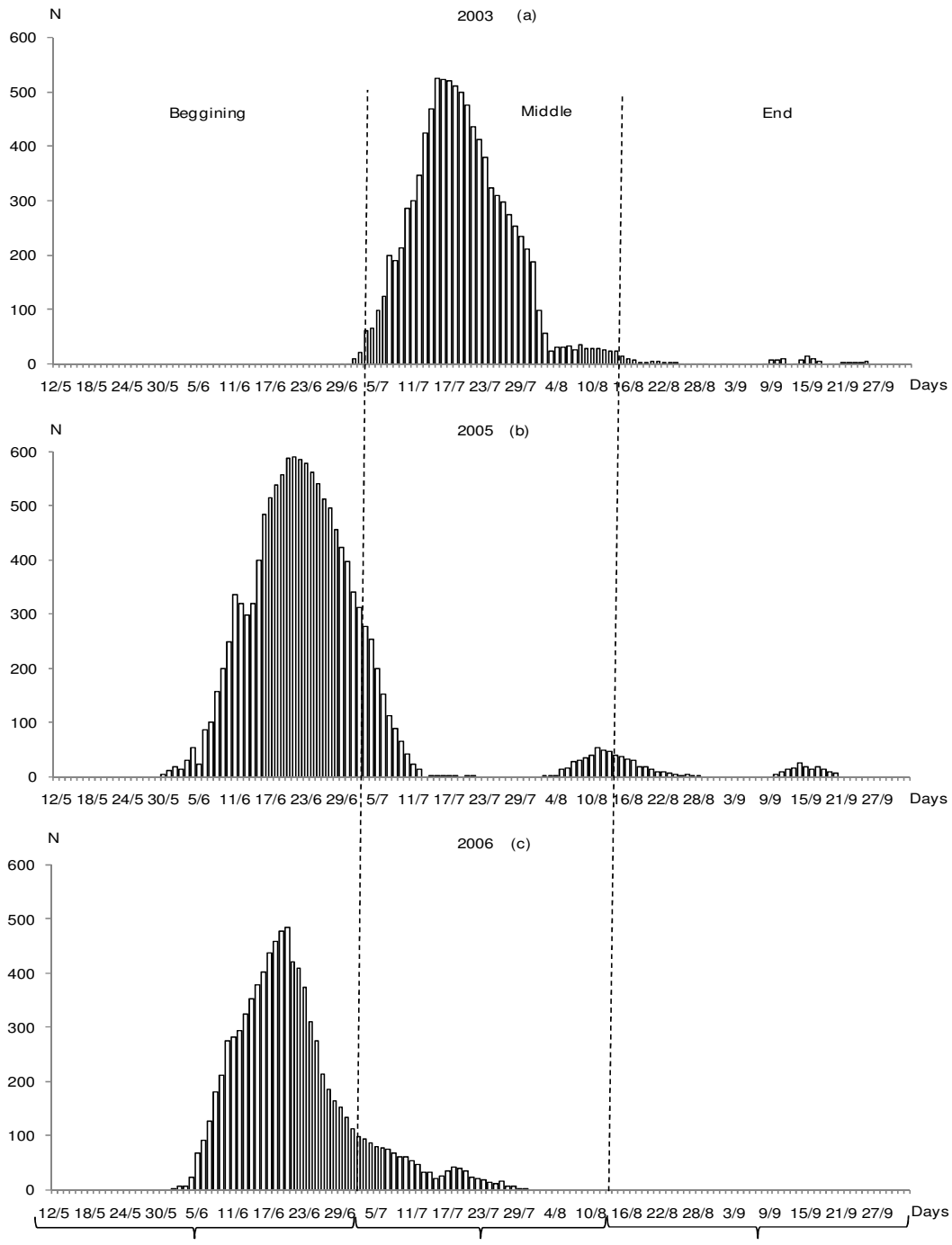

Figure 9. Daily variations in the number of newborn chicks of *Sterna hirundinacea* along the reproductive seasons of (a) 2003, (b) 2005 and (c) 2006 at Cardos Island, Santa Catarina state, Brazil.

Distance between nests was 0.7 m in an area of approximately 0.5 ha (six nests/m^2), while on Itaçuce Island (coast of São Paulo) there were 400 nests in 0.6 ha, (four nests/m^2) (Campos et al., 2004). The distance between the nests of Common Terns in New Jersey (USA) marshes was lower (between 1.50 to 2.12 m) than in areas of beach (2.69 to 2.71 m) (Erwin and Smith, 1985).

Data on egg-laying dates for South American Terns are not available for enough years to establish a pattern for egg-laying activities, but Common Terns have become earlier egg-layers over the last years (Nisbet et al., 1984), and they also have higher average number of eggs per clutch (Spendelow, 1982). The egg-laying period for South American Terns in the coast of Argentina began in December and showed two peaks, mid-December and beginning January, with late nests at the end of January (Scolaro et al., 1996), while in Espirito Santo and Santa Catarina it began in May with the largest number of eggs in June (Efe et al., 2000; Branco, 2003b), indicating two distinct populations, corroborated by Faria et al. (2009).

The eggs of South American Terns on Cardos Island were smaller, narrower, lighter and of less volume than eggs from Deserta Island (27.35 ± 5.23 cm^3) (Branco, 2003b). This difference may be related to climate variations, plus the availability of food near the colony, once that Deserta is part of a Biological Marine Reserve, and is forbidden to fish and in Florianopolis there are few fisheries of by-catch discards.

On the coast of Espirito Santo the first chicks of Cayenne Terns appeared in beginning of July (Efe, 2004) and the South American Terns of Cardos Island between May 20 to 25, 2002 (Branco, 2003b). In the following season (2003), chicks appeared in June, and 2005 and 2006 their presence was brought forward to May, which may have been favored by a better suited to the climate and growth due to lower harassment from predators.

S. hirundinacea breeds uninterruptedly at Cardos Island since 2001. Some characteristics of this island, such as the physical conditions (low probability of flooding), lower number and action of predators, protection by vegetation or rocks, little distance from the area of foraging, low exposure to the prevailing winds, and the presence of *Sterna eurygnatha*, which often helps in defense against predators defense, despite the competition for food and space, allowed uninterrupted breeding of *S. hirundinacea* on the island of Cardos since 2001, making this island an important reference for the conservation of the species in the Brazilian coast (Buckley and Buckley, 1980; Burger, 1981; Thompson and Slack, 1982).

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