Reproduction of *Eudocimus ruber* in the Iguape-Cananéia-Ilha Comprida estuary complex, São Paulo, Brazil

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Resumo. O guará *Eudocimus ruber* tem distribuição ao longo da costa da América Central e do Sul com uma população disjunta no sudeste e sul do Brasil, onde foi considerado praticamente extinto no final do século passado. Ninhos foram monitorados no estuário de Iguape-Cananeia-Ilha Comprida entre 2003 e 2009 para conhecer aspectos da dinâmica populacional e biologia reprodutiva da espécie. Foram contabilizados adultos e juvenis; documentada a diversidade de aves aquáticas na colônia reprodutiva; caracterizado o habitat no ninhal; contados e medidos os ovos e ninhegos e verificada a predação. O número de indivíduos reprodutivos ativos de *E. ruber* cresceu de 40 em 2003 para 1.449 em 2009. Outras espécies nidificando nas colônias mistas com o guará foram: *Ardea alba, Egretta thula, E. caerulea, Tigrisoma lineatum, Nycticorax nycticorax, Nyctanassa violacea* e *Bubulcus ibis*. As espécies arbóreas utilizadas como substrato para os ninhos foram *Rhizophora mangle, Laguncularia racemosa* e *Avicennia schaueriana*. O número de ovos por ninho de *E. ruber* foi 2.61 ±0.54, com massa variando de 32 a 51 g. Identificamos quatro classes de desenvolvimento dos ninhegos, baseado no comportamento e biometria. Eles começam a andar sobre os galhos das árvores com 15 dias de idade e com 30-40 dias podem voar.

Palavras-chave: Aves aquáticas; Colônias reprodutivas; Conservação; Manguezais; Guará

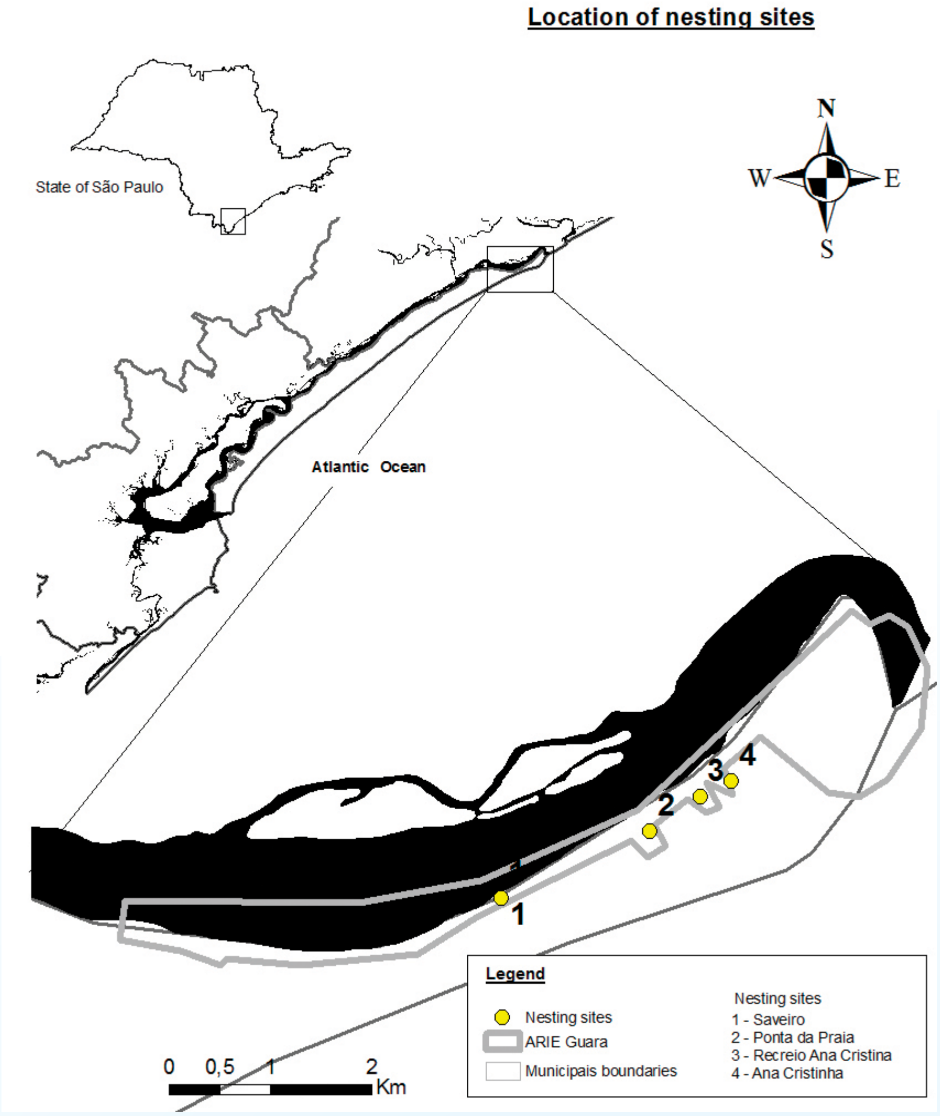

Figure 1. Map of the estuarine complex Iguape-Cananeia-Ilha Comprida, São Paulo, in the southeast of Brazil, showing *Eudocimus ruber* nesting sites from 2003-2009 and the protected area Area of Ecological Interest for "guará" (ARIE Guará).

Abstract. The Scarlet Ibis *Eudocimus ruber* (Pelecaniformes: Threskiornithidae) has a distribution along the littoral zones of Central and northern South America with a disjunct population occurring in south Brazil. It was practically considered extinct in southeastern Brazil in the second half of the twentieth century. We monitored its nests in the Iguape-Cananeia-Ilha Comprida estuary from 2003-2009 in order to understand population dynamics and reproductive biology of this unique and endangered population. We censused *E. ruber* adults and juveniles, documented species diversity of the nesting colony; characterized nest habitat,

Figure 2. VSK using technique developed to catch and return large nestlings from nests or mangrove branches . Picture: Fausto Pires de Campos.

counted and measured nests, eggs, and nestlings and verified predation on nests. The number of breeding individuals increased from 40 to 1,449 individuals from 2003 to 2009. Species nesting communally with scarlet ibis were: *Ardea alba, Egretta thula, E. caerulea, Tigrisoma lineatum, Nycticorax nycticorax, Nyctanassa violacea* and *Bubulcus ibis*. Mangrove species commonly used as nesting substrate were *Rhizophora mangle, Laguncularia racemosa,* and *Avicennia schaueriana*. The number of eggs per *E. ruber* nest was 2.61 ±0.54, with egg mass varied from 32-51 g. We identified four age classes of nestlings based on behavior and development stages. They could begin to walk in groups along tree branches at 15 days old, and at 30-40 days old they could fly.

Key words: Aquatic birds; Breeding colony; Conservation; Mangrove; Scarlet Ibis.

Introduction

The scarlet ibis, *Eudocimus ruber* (Linnaeus, 1758) (Pelecaniformes: Threskiornithidae), is a coastal aquatic bird with an occurrence pattern associated with mangroves. Its distribution extends from the Caribbean of Central and South America, along the coasts of Colombia, Venezuela, Guyana, Surinam, French Guyana, Brazil and Trinidad (Hancock *et al*. 1992). The historical distribution of scarlet ibis in the Brazilian littoral zone extended from the northeast (between the states of Amapá and Ceará) to the south, between Rio de Janeiro and Santa Catarina Island (Teixeira *et al*. 1990, Sick 1997). This south population of scarlet ibis is small and disjunct from the rest of its range in Brazil, making it a unique population (Hass 1996, Sick 1997).

The south population of scarlet ibis was considered almost extinct in the second half of the twentieth century, with hunting activities and collection of eggs being the main cause of population declines in Brazil (Sick 1997, Hass 1996, Olmos 2003). However, isolated occurrence records in the region demonstrate that it was not completely extirpated. For example, Scarlet Ibis were recorded in 1961 in São Vicente, São Paulo (Lago-Paiva 1994), in 1977 in the Baía de Antonina, Paraná (Scherer-Neto & Straube 1995), and in 1979 and 1985 in Rio de Janeiro (Sick 1997, Teixeira *et al*. 1990). In 1984 a group of up to 100 individuals was recorded in the mangroves of Santos-Cubatão, São Paulo (Bockermann & Guix 1986, 1992). In 1985 Paulo Martuscelli recorded adults in the Iguape-Cananeia estuary in the extreme south of São Paulo; a juvenile was recorded in that area in 1988 (Bockermann & Guix 1992). Through information provided by Elói Silva Souto, a photographer, a reproductive colony on Ilha Comprida, part of the same estuary system, was discovered in 1993 and observed continuously until 2003 (Paludo *et al.* 2004, 2005). While considered a species of least concern across most of its range, the species is on the list of threatened species for the state of São Paulo, Paraná and Santa Catarina. (PRO-FAUNA 2004, SMA 2010, Consema 2011).

In the State of São Paulo, southeast of Brazil, the reproduction of *E. ruber* was documented in 1989 in the mangroves of Rio Morrão, Santos city, São Paulo (Marcondes-Machado & Monteiro-Filho 1990), and again in 1992 (Oliveira *et al.* 1993), and the reproductive biology of the colony was studied from 1994 to 1997 (Olmos & Silva e Silva 2003). Nesting has not occurred in the region since 2000 (Silva e Silva 2007).

Between 2003 and 2009 scarlet ibis nests in mangrove habitat on Ilha Comprida, south of São Paulo state, were monitored and protected through the initiative of staff from IBAMA/ICMBio and Fundação Florestal (Secretaria de Meio Ambiente do Estado de São Paulo - SMA/SP), resulting in a proposal for protecting the area utilized by scarlet ibis in a wildlife refuge to be located on Ilha Comprida (Paludo *et al*. 2004, 2005). An “Area of Ecological Interest for the Scarlet Ibis” (Área de Relevante Interesse Ecológico do Guará) and an “Environmental Protected Area” (Área de Proteção Ambiental Marinha Litoral Sul de São Paulo) were created by the state government in 2008 (SMA 2008). This work represents results of nest monitoring in this area from 2003-2009. Our objectives were to improve the understanding of the reproductive biology of this population, evaluate the apparent process of population recuperation has been undergoing, and understand patterns of communal nesting with other Pelecaniformes species in the southeastern region of Brazil. Additionally we wanted to band a large number of nestlings to permit the subsequent studies of their movements. We also wanted our work to provide data and evidence that protected areas provide important benefits for this population of scarlet ibis in the state of São Paulo.

Material and methods

Our study took place in the Iguape-Cananeia-Ilha Comprida estuary complex (24°21’36”S, 46°59’53”W and 25°18’25”S, 48°06’00”W) in the south of São Paulo State, in the southeast of Brazil, an extensive estuarine channel consisting of islands covered with mangroves and interlinked by canals. The area is delimited to the north by the Barra de Icapara, to the south by Barra de Cananeia, and to the east by Ilha Comprida, which is 70 km in length (Figure 1). The complex covers approximately 2,500 km^2, continuing to the south through the state of Paraná until Guaraqueçaba Bay.

Figure 3. Banding 2 weeks nestling, ARIE Guará, Ilha Comprida, SP. 2007. Picture: Fausto Pires de Campos.

Field surveys were carried out seasonally during the study period to search for and observe scarlet ibis, and every 15 days to observe reproductive behavior, from October 2003-March 2004, October 2004-March 2005, October 2006-March 2007, and weekly from October 2008-March 2009. We recorded nest sites but did not perform censuses during the 2005-2006 reproductive season. We searched the entire estuary during 2007-2008 breeding season and found no scarlet ibis nesting activity on the island although there were other Pelecaniformes species nesting in the colony.

Nests sites were found using information from local residents, and by following bands of individuals, and observing individuals exhibiting reproductive behavior (courtship, coupling, and nest construction) during September every year. We recorded nesting species and counted the number of adults perched or in flight. Nesting areas were characterized by type of vegetation, size, and location, using GPS, photographs, aerial photographs, Google Earth images, and measuring tapes for local-scale measures. We counted the number of *E. ruber* nests in the whole area and marked each individual nest in nearly 25% of the area to evaluate the use of the same nests in a season and among years. Each nest was monitored and its size and position in trees were measured using binoculars, ladders, and measuring tapes. We also recorded the presence and evidence of predators in our study area.

We counted the number of individual *E. ruber* adults and juveniles perched in the canopy of trees in nesting areas using binoculars. To estimate numbers of adults and juveniles of *E. ruber* using the nesting area, we counted the number of individuals that entered nests and subtracted those that exited two times per season, during late afternoon until sunset, at the end of the second and fourth month of nesting activity when the greatest numbers of juveniles were known to be flying around the nesting area. During censuses, we considered *E. ruber* individuals as adults if they were completely red; juveniles were those that were brown, but already had the capacity to fly; nestlings were identified as individuals that were dark and could not yet fly. Partially red individuals were considered to be sub-adults (1-2 years old) and when present we counted them as adults.

We directly verified nests as those of *E. ruber*, using ladders and a mirror fixed to a retractable pole. We measured the external diameter, height from the ground, and number of eggs in each nest. We measured mass, length, and width of eggs from *E. ruber* nests and we classified them according to decreasing size of clutch, into groups A, B, and C (Custer & Frederick 1990, Branco & Fracasso 2005). During the 2008-2009 reproductive season nests were individually marked with numbered flagging tape and monitored from time of construction to the fledging of nestlings; eggs and nestlings were measured weekly.

Small nestlings were captured by hand and banded once the diameter of their tarsus was greater than 7 mm or their mass was greater than 200 g. For larger nestlings, VSK developed a technique of attaching a small pitchfork at a right angle to the end of a pole and using this to scoop up the more developed nestlings into a net or our hands, where they were transferred to a cloth sack (Figure 2). Nestlings were returned to the nests using the same technique. We had the SISBIO permission nº 42418 to study and capture birds and the SNA permission nº 1188 to banding.

Nestlings were placed in small cloth bags, grouped by nest or by tree (when it was not possible to identify nest), and taken to a banding station. All individuals were returned to their nest or tree of origin. We weighed individuals in bags using Pesola© scales of 100 g and 600 g, subtracting the weight of the sack. We measured culmen length and height, tarsus and tibia diameter, and tarsus length using calipers. The nestlings were banded on the left tibia with numbered, aluminum bands provided by CEMAVE (11.0 mm to 13.5 mm internal diameters) (Figure 3). In the 2008-2009 breeding season, nestlings also received yellow plastic bands on their right tibia in order to facilitate identification of banded birds in flight. We added our banding data to the CEMAVE database. Differences in mean length, width and mass of eggs 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. The correlation between the bill, tarsus and body mass of siblings was calculated using Pearson correlations (Sokal & Rohlf 1979). For statistical analysis we used *BioEstat* 3.0 © (Ayres *et al.* 2003).

Figure 4. Three weeks nestling *Eudocimus ruber* at Ponta da Praia site, ARIE Guará, Ilha Comprida, SP, 2007. Picture: Fausto Pires de Campos.

Results

During our 2003-2009 sampling period, we counted 1,390 active nests and measured their nest site characteristics. Our censuses showed approximately 1,450 scarlet ibis using the nesting area at the end of the study. This number increased from 40 to 1,449 from 2003-2009. We measured 77 eggs and banded 409 nestlings. We found 15 cases of nest predation.

During all seasons of the year from 2003-2009 small groups of scarlet ibis foraged along the mud banks of estuary islands, sand banks exposed during low tide, and below the trees of the mangrove habitat. We observed scarlet ibis along the entire estuary between Barra de Icapara and Cananeia, mainly between the municipal seat of Iguape (24°42’38”S, 47°33’27”W) and the northern Ilha Comprida (24°40’57”S, 47°26’28”W). At the end of September scarlet ibis formed large flocks, assumed reproductive plumage (brilliant red with black bills), and chose nesting sites. This behavior was observed annually, including the 2008-2009 season when no scarlet ibis nesting occurred on the estuary. Sub-adults were not common at nesting sites, although they were seen frequently in the feeding areas since 2007. We identified four areas used as nesting sites by *E. ruber*, all at the northern end of Ilha Comprida. These areas were close to one another and were used sequentially (one at a time) during the study period (Figure 1, Table 1).

Arboreal mangroves species *Rhizophora mangle* (Rhizophoraceae)*, Laguncularia racemose* (Combretaceae), and *Avicennia schaueriana* (Acanthaceae) were most commonly used as a base for the nests of with scarlet ibis (Table 1). Other Pelecaniformes bird species using the area to nest included: *Ardea alba, Egretta thula, E. caerulea, Tigrisoma lineatum, Nycticorax nycticorax, N. violacea,* and *Bubulcus ibis* (Table 1).

Scarlet ibis always nested in areas where other avian species were already carrying out reproductive activities. Species began nest construction along the estuary in chronological order each year, with *N. violacea* and *N. nycticorax* beginning first, followed by *A. alba* and *E. caerulea*, then *E. thula* and *E. ruber*, and lastly *B. ibis*. During the 2007-2008 reproductive season when *E. ruber* did not lay eggs, all other species nested in the identified nesting areas. The nests of the egrets *E. thula* and *E. caerulea*, scarlet ibis *E. ruber*, and night herons *N. nycticorax* and *N. violacea* were found in the lowest part of the canopy, with night heron and ibis nests found most often along the edge of the mangrove habitat. At the Ponta da Praia, *Ardea alba* nesting sites always occupied the center of the mangrove area, in the tallest trees; few other species’ nests were found in this nesting site (Table 2).

Over the study period *E. ruber* was the most numerous species. Except for one pair of *Tigrissoma lineatum* found in Saveiros, *Bubulcus ibis* was the least numerous breeding species. The Recreio Ana Christina nesting site was used during the 2005-2006 reproductive season by *E. ruber*, *E. thula, E. caerulea, N. nycticorax*, and *N. violacea*, but only by *N.*

Table 1. Scarlet ibis *Eudocimus ruber* colonies on Ilha Comprida, 2003-2009, with nest site characteristics, other bird species using the sites, and time period of utilization.

Nest site	Location	Total area (m²)	Arboreal species	Nesting species	Utilization period
Saveiro	24º42’02”S 47º28’01”W	40,100	*R. mangle, L. racemosa*	*E. ruber*, *A. alba*, *E. thula*, *E. caerulea*, *T. lineatum*, *N. nycticorax, N. violacea*, *B. ibis*	Dec/2003 to Feb/2004
				N. violacea	Oct/2006
Ponta da Praia	24º41’41”S 47º27’13”W	28,900	*R. mangle*, *L. racemosa*, *A. schaueriana*	*A. alba*	Dec/2003
				E. ruber, *A. alba*, *E. thula*, *E. caerulea*, *N. nycticorax*	Oct/2004 to Feb/2005
				E. ruber, *A. alba*, *E. thula*, *E. caerulea*, *N. nycticorax*, *N. violacea*, *B. ibis*	Oct/2006 to Feb/2007
				A. alba, *N. violacea*	Oct/2008 to Dec/2008
Recreio Ana Cristina	24º41’30”S 47º26’57”W	24,200	*R. mangle*, *L. racemosa*, *A. schaueriana*	*E. ruber*, *E. thula*, *E. caerulea*, *N. nycticorax*	Oct/2005 to Feb/2006
				N. violacea	Oct/2006
				N. violacea	Sep/2007
Ana Cristina	24º41’25”S 47º26’47”W	19,600	*R. mangle*, *L. racemosa*, *A. schaueriana*	*E. ruber*, *E. thula, E. caerulea*, *N. nycticorax*	Oct/2008 to Feb/2009

violacea in the next three breeding seasons. The Ana Cristina nest site was used only in 2008-2009 by *E. ruber*, *E. thula, E. caerulea, N. nycticorax,* and *B. ibis*.

The Saveiro nest site had the highest number of avian species but low numbers of individuals and a low density of nests spread out across the area. This site was used by *E. ruber* only during the 2003-2004 nesting season, and by *N. nycticorax*, *N. violacea*, and *E. caerulea* in the following years (Table 2).

The Ponta da Praia mangrove was used as a nesting site by large groups of *A. alba* for at least 30 years. During all years the study area was used for reproduction by *N. nycticorax* and *N. violacea*, and in 2003-2004, 2004-2005, and 2006-2007 *E. thula* and *E. caerulea* nested at this site (Table 2). During the 2007-2008 season the night herons initiated nest construction and egg laying, but all nests were abandoned (n = 15) and six of them had egg shells in them at the end of September, indicating predation either before or after abandonment (Table 2).

The number of adult scarlet ibis observed in reproductive activity in the Iguape-Cananeia-Ilha Comprida estuary increased by 27 times from 2003-2009 (Table 3). There was also an increase in the number of nests, nestlings, and juveniles in flight over this time period. We banded the greatest number of nestlings during the 2008/2009 season (Table 3).

The mean number of eggs per *E. ruber* nest was 2.61 ± 0.54 (n = 241 eggs; 25 in season 2004/2005, 39 in season 2006/2007, and 177 in season 2008/2009). The first clutch of each season occurred in October and almost always consisted of 3 eggs, while 2-egg clutches were most common in December. Nests were not used for more than one clutch, but trees and nesting material were re-used. For example, tree ER 3, in December 2008 had 30 active *E. ruber* nests. The same tree in February 2009 had 17 active nests, all in a different position from those encountered in December.

The first eggs measured of each clutch were larger than those in the rest of the clutch (Table 4), with a significant difference between mean length ($F_{29,27}$ = 3.06 , $p < 0.05$), width ($F_{29,27}$ = 2.56, $p < 0.05$) and mass ($F_{29,27}$ = 2.79 , $p < 0.05$) of the first egg (A) and the second (B). Between the second egg (B) and the third (C), we found a significant difference only in mean width ($F_{27,18}$ = 2.71, $p < 0.05$). Length and mass of eggs B and C were statistically similar ($F_{27,18}$ = 1.44; $F_{27,18}$ = 1.24, $p > 0.05$).

During all reproductive seasons scarlet ibis produced three clutches, but they were not well defined. There was a strong synchrony in first-clutch initiation at the beginning each reproductive season. From the time of the initiation of the first clutch, it took about three weeks for chicks to hatch, and by 15 days after hatching, nestlings would begin to walk in groups along tree branches and among nests. At 30-40 days nestlings fledged and could fly. The second and third clutches were continuous and not as synchronized as the first, intense activity at the nesting site was maintained throughout the reproductive season, with nest building ongoing and clutches in different stages of development.

Egg mass varied from 32-51 g. From 22 sampled eggs the mass lost was 13% from laying to hatching, with a mean loss of 1.8 g per week. Nestlings ready to hatch emitted peeps from inside the egg. Eggs were between 28-33 g at this stage. Eggs hatched with an average mass of 35 g, and nestlings gained weight rapidly. The smallest nestling we measured was recently hatched and had a mass of 36 g, bill length of 25

Table 2. Primary species occupying colonies when *Eudocimus ruber* was nesting. Number of adults observed in flight* or perched in the canopy (**), Ilha Comprida, São Paulo, 2003-2009.

Nest site	*Eudocimus ruber*	*Egretta thula*	*Egretta caerulea*	*Nycticorax nycticorax*	*Ardea alba*	*Bubulcus ibis*
Saveiro**	40 (19%)	62 (29%)	42 (20%)	58 (28%)	8 (4%)	-
Ponta da Praia 2004/05**	264 (17%)	518 (32%)	198 (13%)	124 (8%)	400 (25%)	80 (5%)
Ponta da Praia 2006/07*	645 (38%)	260 (15%)	123 (7%)	210 (13%)	350 (21%)	90 (5%)
Ana Cristina *	1,449 (84%)	144 (8 %)	30 (2%)	89 (5%)	-	-

Table 3. Abundance of *Eudocimus ruber* at nesting sites along Ilha Comprida, São Paulo, southeast Brazil, 2003-2009.

Reproductive season	Nº adults	Nº nests	Nº nestlings	Nº juveniles in flight	Total
2003/2004	40	16	25	28	68
2004/2005	264	208	418	214	478
2005/2006	-	-	-	-	-
2006/2007	645	296	485	265	910
2008/2009	1449	870	1750	583	2032

Table 4. Reproductive effort of *Eudocimus ruber* on Ilha Comprida, São Paulo, southeast Brazil, during egg laying between October-November 2008, showing number of eggs measured and eggs per size class from nests with up to three eggs (A, B, and C).

	Total (A+B+C)	Eggs in class A (n = 30)	Eggs in class B (n = 28)	Eggs in class C (n = 22)
Egg length (cm)	5.58 ± 0.38	5.74 ± 0.45	5.49 ± 0.25	5.45 ± 0.31
Egg width (cm)	3.74 ± 0.12	3.79 ± 0.13	3.75 ± 0.07	3.65 ± 0.13
Egg mass (g)	39.85 ± 4.65	42.07 ± 5.26	39.71± 3,15	36.58 ± 3.51

Figure 5. Adult of *Eudocimus ruber* banded on right leg from Santos-Cubatão estuary observed at ARIE Guará, Ilha Comprida, SP. Picture: Daniel Martuscelli.

mm, bill height of 9 mm, tarsus diameter of 9 mm maximum and 5 mm minimum, and tibia diameter 6 mm maximum and 5 mm minimum. Of the 19 nests we monitored, hatching rate was 100%.

We identified 4 age classes of nestlings based on their motor development and behavior. Nestlings up to one week old stayed in the nest. From 1-2 weeks of age, nestlings stayed in the nest, but would stand up and when startled could exit the nest. Clutches 2-3 weeks old tended to walk as a group along with young from other nests along the tree branches, they often collected themselves in nearby nests and would take small jumps (Figure 4). Clutches more than 3 weeks old stayed close to the tree canopy, took small flights, and were difficult to capture. Biometric measurements of nestlings, along with their age class are found in Table 5.

We found strong positive correlations between body mass and tarsus length (Pearson's $r = 0.9751$; $n = 92$). Correlations were also strong between bill length and tarsus length (Pearson's $r = 0.9591$) and body mass and bill length (Pearson's $r = 0.9536$). Tibia diameter represented only 0.48% of the total variance in biometric measurements taken. Among 273 nestlings between the ages of recently hatched to 25 days, the diameter of the tibia varied from 4-12 mm, with a mean ± *SD* of 8.19 ± 1.37mm. With these measurements, we chose to use CEMAVE size T bands (internal diameter 11 mm) and sometimes used size U (internal diameter 13.5 mm) instead of band size S (internal diameter 9.5 mm) as recommended for *E. ruber* by the CEMAVE banding manual (IBAMA, 1994).

Causes of egg loss included weather events and predation. On 5 October 2008, high winds reached Ilha Comprida and many nests fell from trees, however egg losses were minimal, since most of the nests were empty. Adults rapidly resumed construction activities. On 23-25 February 2009, the area experienced continuous heavy rain and we observed large losses of eggs and recently hatched nestlings. We observed evidence of predation at all nesting sites. We observed flocks of up to 10 vultures *Coragyps atratus* and 2 caracaras *Caracara plancus* flying over the nesting sites. At sites Recreio Ana Cristina, Saveiro, and Ponta da Praia we found raccoon *Procyon cancrivorus* footprints and at Ana Cristina we found evidence of domestic dogs. At all sites we found evidence of predation of scarlet ibis adults.

Discussion

Scarlet ibis nests have been found in different habitats and on different vegetation, like in the flooded grassland plain of Lhanos in Venezuela (Eisemberg 1979) and on mangroves trees in Brazil (Rodrigues 1995, Hass *et al*. 1999, Olmos & Silva e Silva 2003). The substrate used by *E. ruber* during the April-August 1991 reproductive season on the Ilha de Cajual, Maranhão, were *Aviccenia* sp. trees, 8-12 m tall (Rodrigues 1995). During the reproductive season of February-August 1994 *Laguncularia racemosa* and *Aviccenia* sp. trees were used (Hass *et al*. 1999). In our observations, *E. ruber* nests only in mangroves trees, and additionally we found *E. ruber* nesting on mangrove trees of *Rhizophora mangle,* similar to how they nest in Santos- Cubatão site according Olmos & Silva e Silva (2001). They changed their nest site during the study period, but all of the sites are composed of fragmented mangroves with new trees. Mangrove habitat occurs throughout the region, often in isolated and difficult to access locations with bigger trees. However, the nesting colonies on Ilha Comprida occurred in fragmented mangrove habitat, close to human activities and easily accessed by humans. The nesting of scarlet ibis in small mangrove fragments that provide less canopy cover than larger fragments nearby seems to be asso-

Table 5. Biometric data of *Eudocimus ruber* young, grouped by estimated age class.

Age	Mass: range, mean ± *SD* (g)	Bill length: range, mean ± *SD* (mm)	Bill width: range, mean ± *SD* (mm)	Tarsus length: range, mean ± *SD* (mm)	Tibia diameter: range, mean ± *SD* (mm)
Up to 1 week	36-194 103.22±45.95	23-39 29.46±4.48	8-15 10.29±1.71	19-45 30.79±1.14	4-9 5.93±1.09
1-2 weeks	204-332 288.37±45.72	36-53 46.65±4.59	10-18 14.28±2.01	44-65 56.50±6.57	6-9 7.33±1.04
2-3 weeks	332-439 374.98±29.99	42-64 55.17±4.80	14-19 16.11±1.37	51-77 67.91±4.72	6-10 7.97±0.89
> 3 weeks	452-630 532.18±70.08	59-78 67.90±5.63	15-22 19.31±2.07	69-90 80.09±6.77	8-11 9±1.41

ciated with the location of foraging substrate and presence of other avian species nests, rather than the robustness of the mangrove habitat itself.

In the llanos of Venezuela, Ramo & Busto (1988) found the scarlet ibis reproductive period to occur in July-August. While this is a different time of year than the reproductive season on our study sites (September-March), it marks the beginning of the rainy season in both regions (Rodrigues 1995, Hass *et al*. 1999, Ramo & Busto 1988). In the São Paulo littoral zone the rainy season begins during the second half of September and continues through March (Minuzzi *et al*. 2007).

The six species of birds that nested along with *E. ruber* on our study sites were similar to the five co-nesting species – *E. thula*, *E. caerulea*, *E. tricolor*, *N. nycticorax* and *N. violacea* – documented by Martinez (1998) on the island of Cajual, Maranhão, who noted *E. tricolor*, but had no records of *B. ibis* and *A. alba*. In the llanos of Venezuela *E. ruber* has been studied since 1949, and the colonies there were composed of only *Eudocimus albus* and *E. ruber* (Ramo & Busto 1988). At our study sites, *E. ruber* was only found in mixed nesting sites and only began nesting at sites that already had active nests of other species present. Colonies of heterospecific nesting birds are common in mangrove areas and apparently contribute to group protection through reduced predation risk (Custer & Osborn 1978, Custer *et al*. 1980, Josens *et al*. 2009). The use of places that already had breeding established by other Pelecaniformes nests, plus the strong synchrony in scarlet ibis first-clutch initiation at the beginning each reproductive season found in our study area can be considered a beneficial strategy adopted by Scarlet Ibis to reduce losses by predation. The pattern and spread of egg-laying in colonial species is viewed as an adaptive function to reduce losses by predation. That is, highly synchronous breeding reduces predation through swamping (Houde 1983).

According Custer *et al.* (1980), reproductive success is directly related to food availability. We observed scarlet ibis eating little crabs, mainly *Uca* spp., as also reported by Martinez (2004) and Hass (1996) and Olmos & Silva e Silva (2001). Small Crabs are a resource that is very abundant in mangroves. There is not significant feeding overlap between *E. ruber* and the avian species we encountered nesting communally with them on Ilha Comprida. The egrets *E. thula, E.caerulea,* and *A. alba* feed mainly on fish, and night herons *N. violacea* feed mainly on crabs *Ucides cordatus*, so, food availabity and absence of food competitors seems to contribute to reproductive success and to increase population size in Iguape estuary.

The sudden increase in *E. ruber* population size at our study sites from 2003 to 2009 seems to be due in part to a movement of reproductive adults from the Santos-Cubatão estuary to the Ilha Comprida estuary, as well as to the reproductive success experienced at Ilha Comprida from 2003-2009, under the protection of IBAMA and ICMBio. Mean number of eggs per clutch at our study sites was greater than what Olmos and Silva e Silva **(2003)** found at their study site in Santos--Cubatão. They recorded 2.45 eggs per nest in 99 first-clutch nests and 2.26 eggs per nest in 215 nests over the 1996-1997 reproductive season (Olmos & Silva e Silva 2003**).** *Eudocimus ruber* nestlings are more agile and robust than nestlings of egrets and night herons and develop the capacity to move between nests along tree branches more rapidly, an ability which may be advantageous against predators. The behavior of forming groups of nestlings seems to increase their protection and facilitate feeding and attention by adults. It was not possible to distinguish which nestlings belonged to which nests once these groups were formed. We did find dead nestlings and fallen eggs, especially after days with strong winds and rain. However it was not possible to estimate total losses.

The nests appeared fragile, but we observed them persisting for over a year after abandonment. Nests were not reused between seasons, but individuals did reuse nesting materials to construct new nests. *E. ruber* reproductive success in the colonies on Ilha Comprida was high. There were high numbers of nests and eggs, a high hatching rate, and abundance of *E. ruber* increased 27 times over the study period – due to recruitment of birds from Santos-Cubatão. We found evidence that banded birds dispersed from our study site to locations across the region, based on records of banded bird sightings.

During our first monitoring season we already recorded banded *E. ruber* using our site, evidence individuals had moved from a location where they were previously banded by Olmos and Silva e Silva **(2003)** (Figure 5**).** After our study ended, we observed banded young in the Santos-Cubatão estuary, confirming the use of both estuaries by the same individuals. Scarlet ibis banded during our study were also recorded to the south, in the states of Paraná and Santa Catarina (linear distance 100-190 km), demonstrating the capacity of this species to disperse and occupy new areas.

Despite their proximity to the nesting colonies, few people (residents or tourists) perturbed scarlet ibis nests on Ilha Comprida, which was likely key to their reproductive success.

We noted a reduction in reproductive activities in the Saveiros nesting site. This was likely associated with the disturbance generated by the use of Jeeps for rallies in the neighboring dunes. In a study of wading birds in Merritt Island National Wildlife Refuge, Florida, vehicles caused disturbances that affected species' feeding patterns (Stolen 2003). Environmental education activities carried out by government agencies (IBAMA/ICMBio, SMA/SP, and the prefecture of Ilha Comprida) during our study stimulated local Ilha Comprida residents to help monitor nests, which was fundamental to their protection. According to Olmos and Silva e Silva (2003) disturbance and vandalism observed on the nesting areas of *E. ruber* in Santos-Cubatão were the principal causes of nest abandonment on their study sites. Measures to protect nesting sites, especially in the phase of establishment until the first clutch is laid, seem to have been important to Ilha Comprida becoming an area of reproduction for *E. ruber*.

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