Notes on breeding by Yellow-crowned Night Heron *Nyctanassa violacea* in southern Brazil

Dimas Gianuca, Joaquim O. Branco and Carolus M. Vooren

Received 25 June 2010; final revision accepted 23 December 2010
first published online 16 March 2011
Cotinga 33 (2011): 61–70

Este trabalho apresenta informações sobre a reprodução do socó-caranguejeiro *Nyctanassa violacea* em sítios nos estados de Santa Catarina (Saco da Fazenda e Manguezal do Itacorubi) e Rio Grande do Sul (estuário da Lagoa dos Patos [ELP]), na extremidade sul da sua distribuição, obtidas entre 2004 e 2009. A atividade reprodutiva dos socós-caranguejeiros estendeu-se de setembro até janeiro / fevereiro. A colônia do manguezal do Itacorubi foi a maior, com 74 ninhos ativos, e a do ELP a menor, com apenas seis. Nos sítios reprodutivos em Santa Catarina os socós-caranguejeiros nidificaram em manguezais (*Avicennia schaueriana* e *Laguncularia racemosa*), enquanto no ELP nidificaram sobre arbustos (*Myrsine parvifolia* e *Cephalanthus glabratus*) e pinheiros (*Pinus elliottii*), fora da zona entremarés. No ELP foram identificadas sete espécies de aves, quatro de mamíferos terrestres e uma serpente como potenciais predadores de ovos e filhotes, resultado da variedade de habitats utilizados pela espécie para nidificar nessa área. O tamanho máximo de postura foi de três ovos para os três sítios estudados. No ELP o volume médio dos ovos C (terceiro ovo da postura) foi 12,5% menor que o dos ovos A e B, enquanto no Saco da Fazenda não ocorreram diferenças significativas entre o volume dos ovos A, B e C. O menor volume dos ovos C no ELP pode ser decorrente da menor temperatura ambiental, o que acarreta em um maior custo energético para a manutenção corporal, além de uma baixa disponibilidade de alimento, reduzindo a energia alocada na reprodução. Os sítios reprodutivos de socós-caranguejeiros no Saco da Fazenda e no manguezal do Itacorubi estão em locais de alta influência antrópica, assim como os localizados em Santos / Cubatão (SP), situação que provavelmente representa um risco às populações do socó-caranguejeiro no sudeste-sul do Brasil.

Yellow-crowned Night Heron *Nyctanassa violacea* occurs from the USA to southern Brazil and northern Peru, including some coastal islands and the Galápagos[44]. It is specialised to feed on hard-shell crustaceans (e.g. crabs, crayfish). Although in the USA the species sometimes inhabits inland swamps, primary habitat is coastal wetlands[44,48,60,72].

Studies on the breeding and abundance of Yellow-crowned Night Heron have been undertaken in North America[9,10,19,46,72], but in South America available data on the species' breeding biology pertain solely to coastal Brazil, particularly Cajual Island, in Maranhão[16], the estuarine complex of Santos / Cubatão, in São Paulo[55], and the Perequê estuary, in Paraná[58].

The regular presence and breeding of Yellow-crowned Night Heron in South America is dependent on mangrove[16,55,58]. However, Gianuca[30] reported the species nesting in Patos Lagoon, extending its breeding range 400 km south[11]. According to Gianuca *et al*.[31] this recent expansion, as well that of Little Blue Heron *Egretta caerulea*—which in Brazil also breeds almost exclusively in mangrove—may be influenced by global warming and by degradation of some Brazilian estuaries forcing birds to colonise new areas.

Brazil lost 54% of its mangroves during the 1980s and 1990s due to human activity, yet, nonetheless, c.36% of the current total area of Neotropical mangrove is within Brazilian territory[70]. Because of the high human pressure to which Brazilian estuaries are exposed[11,21,61] and the close association between Yellow-crowned Night Herons and mangrove, the species is considered Vulnerable in Paraná[66] and São Paulo (see http://www.ambiente.sp.gov.br/fauna/livro_vermelho2009.zip).

It is important to identify the species' breeding areas in order to assess its conservation status and to define important areas for it in Brazil. According to Kushlan[43] and Frederick[27] protecting colonies is essential to the conservation of wading birds in the face of increasing human use of coastal wetlands. In Brazil, only two nesting sites of Yellow-crowned Night Heron holding >50 breeding pairs are known, both in mangrove, in São Paulo[55] and Maranhão[48].

Our aim here is to present information on the abundance and breeding ecology of Yellow-crowned Night Heron in southernmost Brazil, in Santa Catarina (SC) and Rio Grande do Sul (RS).

Methods

Study area.—Patos Lagoon estuary, Rio Grande do Sul (31°58'03"S 52°07'20"W) occupies 971 km^2 and is connected to the ocean by a 0.5–3.0 km wide, 20-km long, and 18-m deep channel[2]. Tides are lower than 0.5 m, and variations in salinity and hydrology are mainly controlled by

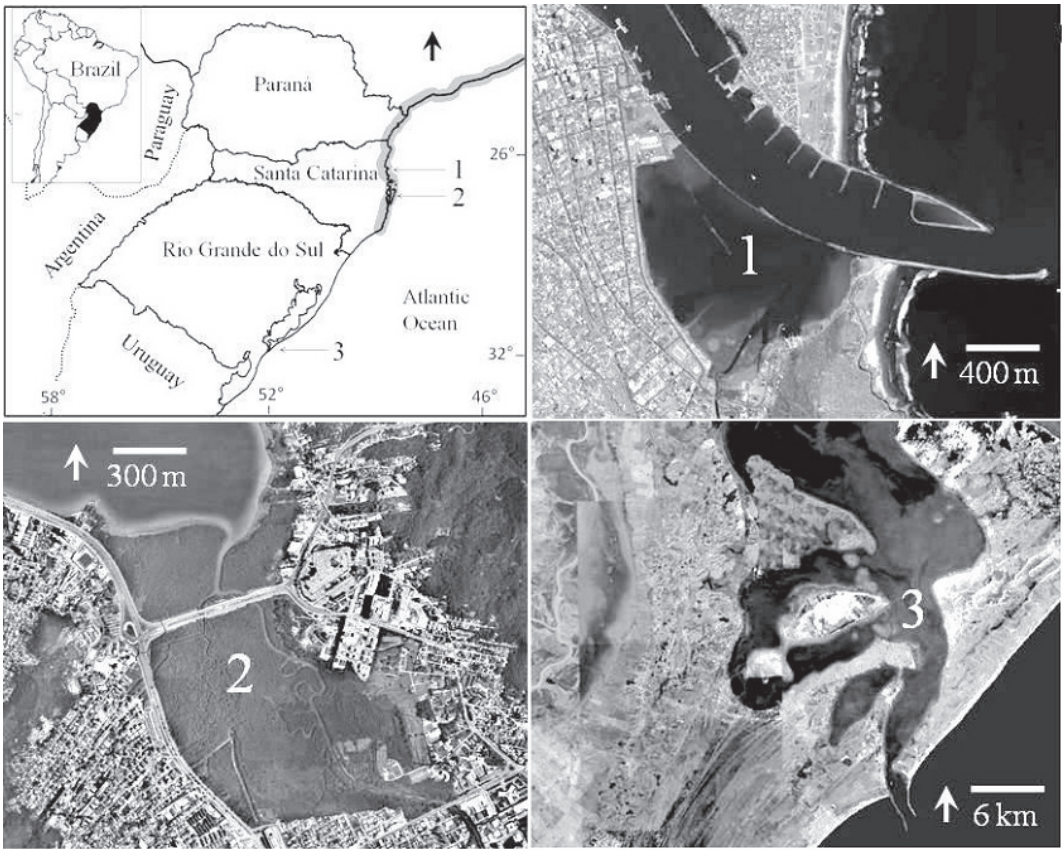

Figure 1. Southern Brazil showing the three study sites: (1) Saco da Fazenda, (2) Itacorubi mangrove and (3) Patos Lagoon. The grey line along the coast indicates mangrove distribution.

meteorological factors[14]. Climate is subtropical[40], and saltmarsh covers 70 km^2 of the estuary[13]. The nesting sites of Yellow-crowned Night Herons are Pólvora Island (32°01'18"S 52°06'17"W), the Oceanographic Museum Professor Eliezer de C. Rios (500 m south-west of Pólvora Island; 32º01'34"S 52º06'22"W), and within a mixed colony of Ciconiiformes on Marinheiros Island (32°01'25"S 52°09'13"W).

Saco da Fazenda estuary is located in the mouth of the rio Itajaí-Açú, near Itajaí, Santa Catarina (26º54'44"S 48°38'52"W). Due to the construction of containment piers that changed the original outflow of the river, the estuary is a semi-closed waterbody of c.0.7 km^2, with a silt-clay substrate, maximum depth of 2 m (except in the channel, where it reaches 9 m) and tides <1.4 m. It receives fresh water and domestic effluents from the Ribeirão Schneider and the Saco da Fazenda neighbourhood, respectively[7]. Nests of Yellow-crowned Night Herons are in mangrove patches surrounded by saltmarsh along the channel banks.

Itacorubi mangrove (27º34'47"S 48º31'02"W) covers 1.02 km^2, or 81% of its original area. It is situated in the urban zone of Santa Catarina Island and is subject to increasing human influence, including structural impacts (deforestation, construction of drainage channels) and contamination by sewage and chemicals, including metals[56,61,68]. Yellow-crowned Night Herons mainly breed in a colony adjacent to the confluence of the rio Itacorubi with the Baia do Norte (27°34'30"S 48°31'14"W).

Data collection.—Breeding sites of Yellow-crowned Night Herons at Saco da Fazenda and Patos Lagoon (Pólvora Island and the Oceanographic Museum) were visited at least once a month between August 2004 and March 2009. Additionally, some data were obtained at Itacorubi mangrove in the 1990s by JOB, whose field work numbered 60 days at all seasons over five years, and in October 2007 by DG, who discovered the main colony. DG & CMV visited the colony on Marinheiros Island twice in November 2007, and 18 times between August 2008 and May 2009.

At each breeding site, active nests (with eggs or nestlings) were counted once. Nests that

Table 1. Growth classes of Yellow-crowned Night Heron *Nyctanassa violacea* nestlings. Culmen length = (Lc).

Growth stage	Lc (cm)	Plumage	Behaviour
I	1–3*	Sparse grey feathers over the head, back and wings.	Quiet, generally remaining in the centre of the nest.
II	3.1–4.0	Brown mixed with white on the neck and wings, with longer, narrower feathers on the head; naked abdomen.	Able to stand in the nest but do not venture onto adjacent branches.
III	4.1–5.0	Brown over the entire body, admixed beige over the neck, chest and abdomen; pinions emerging.	Active, exercising the wings and making short sorties onto nearby branches.
Fledgling	5.1–6.0	Brown over the entire body, admixed beige over the neck, chest and abdomen. Noticeable development of the pinions and rectrices.	Able to walk nimbly through the branches and leave the nest if threatened.
Juvenile	6.1–7.0	Brown admixed beige, especially over the neck, chest and abdomen. Pinions and rectrices fully developed.	Leave the nest, walking on branches and able to fly short distances.

* Presence of egg tooth.

contained only eggs were identified as belonging to *N. violacea* by the presence of regurgitates consisting of fragments of crabs, characteristic of the species[44]. No other bird species in this area forages on hard-shell crustaceans. Nest height in Patos Lagoon was measured with 10-cm accuracy. A measuring stick and / or a ladder were used to access the highest nests, whereas in Itacorubi mangrove and Saco da Fazenda visual estimates of the maximum and minimum height of nests were made.

Qualitative data about nesting sites were obtained, e.g. habitat type, support vegetation, any other species of Ciconiiformes nesting in the environs, and potential predators of eggs and nestlings. Raptors observed foraging above the colony or landing nearby, as well as snakes and mammals (carnivores and marsupials) were considered potential predators; presence of the latter was confirmed by direct or indirect observations (footprints or faeces).

Total length (Le) and max. width (Wid) of eggs at Saco da Fazenda (n=9 nests and 26 eggs) were measured in September 2005. In September 2006, the eggs in only three of the total four nests in Patos Lagoon (n=9 eggs) were measured, because in the fourth nest the eggs were already hatching. Callipers with 0.05-mm accuracy were used to measure eggs.

Egg volume was determined as follows: Vol (cm^3) = $Kv.Le.Wid^2$, where Kv = volumetric coefficient, Le = total length, and Wid = largest width of the axis of the egg[35]. The volumetric coefficient used (Kv = 0.5193) was that obtained for Black-crowned Night Herons *Nycticorax nycticorax*[8] according to their similar egg size and the taxonomic similarity between this species and Yellow-crowned Night Heron.

Culmen (Lc) and tarsus (Lt) length, and nestling mass during different growth classes (except recently hatched) were recorded only at Saco da Fazenda, during the 2005–06 breeding season. As many nestlings in each growth class as possible were captured. Five growth classes were established based on culmen length (Lc), plumage characters and behaviour (Table 1). Callipers and spring scales (Pesola) of 100, 350 and 500 g, with 1, 3 and 5-g accuracy, respectively, were used to obtain biometric data and to measure mass.

Data analysis.—The eggs in each nest were classified A, B or C (highest to lowest volume) based on Custer & Frederick[17]. Volume of A, B and C eggs (separately) was analysed at each site using non-parametric ANOVA. Possible differences in the volume of A, B and C eggs at Saco da Fazenda and Patos Lagoon were examined using a Student test (t-test)[64].

Results

Breeding period and abundance.—Breeding at the three study sites extended from September, when the birds started nest occupation, to January–February, when they left the colonies after the young had fledged (Table 2). The colony at Itacorubi was the largest, containing 70% of the total of 106 active nests found at the three study sites, while that at Patos Lagoon was the smallest, with 5.7% of nests (Table 2). At Patos Lagoon the number of breeding pairs remained constant in 2004–06, with an increase of two pairs in 2007 (Fig. 2). In February 2009, 33 adults and four juveniles were

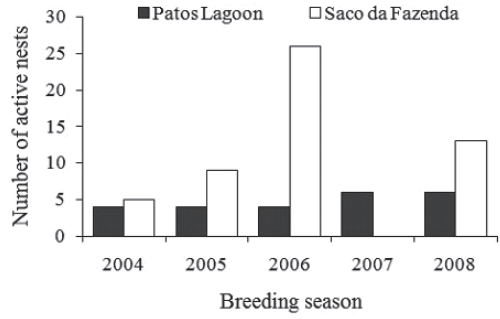

Figure 2. Number of breeding pairs of Yellow-crowned Night Herons *Nyctanassa violacea* at Saco da Fazenda and Patos Lagoon in 2004–08.

Table 2. Characteristics of the breeding sites of Yellow-crowned Night Heron *Nyctanassa violacea* studied in Rio Grande do Sul (RS) and Santa Catarina (SC).

Characteristic	Site		
	Patos Lagoon (RS)	Saco da Fazenda (SC)	Itacorubi Mangrove (SC)
Max. number of breeding pairs	6 (2007 and 2008)	26 (2006)	74* (2007)
Breeding period	September–February	September–January	September–January
Breeding habitat	Infrequently flooded saltmarsh[1]; grove of *Pinus elliottii*[2]; swamp forest[3]	Periodically flooded saltmarsh, with patches of mangrove	Mangrove
Nest height range (m)	1.4–1.81 6.0–11.52 1.2–1.63	1.8–6.0	1.5–3.0
Nest vegetation	*Myrsine parvifolia*[1], *Pinus elliottii*[2], *Cephalanthus glabratus*[3]	*Laguncularia racemosa*	*Avicennia schaueriana*, *Laguncularia racemosa*
Other Ciconiiformes breeding at the site	*Butorides striata*[1], *Syrigma sibilatrix*[2], *Ardea alba*[3], *Ardea cocoi*[3], *Egretta thula*[3], *E. caerulea*[3], *Bubulcus ibis*[3], *Nycticorax nycticorax*[3], *Platalea ajaja*[3]	*Butorides striata*, *Nycticorax nycticorax*	None confirmed
Potential predators	*Phylodrias patagonensis*[1,2], *Coragyps atratus*[3], *Caracara plancus*[1,3], *Milvago chimango*[1–3] *M. chimachima*[3], *Circus buffoni*[1,3], *Bubo virginianus*[2,3], *Rhinoptynx clamator*[2], *Procyon cancrivorus*[3], *Lutreolina crassicaudata*[3], *Didelphis albiventris*[3], *Leopardus geoffroyi*[3]	*Coragyps atratus*, *Caracara plancus*	*Coragyps atratus*, *Caracara plancus*, *Milvago chimachima*

* Estimated as the % of active nests (90%) of the 40 sampled, projected to the total number of nests (n=83).

[1] Pólvora Island [2]Oceanographic Museum [3] Marinheiros Island

counted, suggesting that numbers had increased, although only five nests were found on Marinheiros Island in 2008–09. There was a gradual increase in the number of breeding pairs at Saco da Fazenda in 2004–06, despite that in 2007 none nested, although in 2008 the species bred there again (Fig. 2).

Breeding site characteristics.—The colony at Itacorubi was established in a mangrove forest dominated by *Avicennia schaueriana*, while that at Saco da Fazenda was in a mangrove / saltmarsh mosaic. Although there were differences between these two colonies, all nests were built on mangroves in the inter-tidal zone. However, in Patos Lagoon, where there are no mangroves, all nests were above the inter-tidal zone. On Pólvora Island Yellow-crowned Night Herons nested in rarely flooded saltmarsh, building their nests on *Myrsine parvifolia* bushes. The species also nested in a grove of *Pinus elliottii* at the Oceanographic Museum (Fig. 3), where there is daily movement of people and vehicles. In 2008, Yellow-crowned Night Herons nested on Marinheiros Island, in a swamp forest on the shore dominated by *Sebastiana brasiliensis*, *Sapium glandulosum*, *Erythrina crista-galli* and *Ficus cestrifolia*. At this site, all nests were built on a *Cephalanthus glabratus* (Tables 2–3), in an area permanently flooded by fresh water.

Table 3. Number of breeding pairs of Yellow-crowned Night Heron *Nyctanassa violacea* at the three sites in Patos Lagoon over five consecutive breeding seasons.

Location	2004	2005	2006	2007	2008
Pólvora Island	4	4	1	-	-
Oceanographic Museum	-	-	3	6	1
Marinheiros Island	...	...	...	-	5

(-) = species absent; (...) = lack of sampling

Nests were concave platforms of dry sticks, supported by branches of a tree or a bush, always

Figure 3. Yellow-crowned Night Heron *Nyctanassa violacea* fledglings close to a nest on *Pinus elliottii* in Rio Grande do Sul (Dimas Gianuca)

below the canopy. Some green branches of mangrove were also used in nests at Itacorubi and Saco da Fazenda.

Other Ciconiiformes were not observed breeding at Itacorubi, while at Saco da Fazenda nests of Yellow-crowned Night Herons were scattered along the banks with nests of Striated Herons *Butorides striata* and Black-crowned Night Herons. In Patos Lagoon, Striated Herons nested alongside Yellow-crowned Night Herons on Pólvora Island, while at the Oceanographic Museum, Whistling Herons *Syrigma sibilatrix* bred in the same pine grove. On Marinheiros Island Yellow-crowned Night Herons nested in a mixed colony with seven other species of Ciconiiformes totalling c.3,000 breeding pairs (Table 2).

At Itacorubi and Saco da Fazenda, Southern *Caracara plancus* and Yellow-headed Caracaras *Milvago chimachima*, and Black Vulture *Coragyps atratus* were identified as potential predators of eggs and nestlings, while at Patos Lagoon an additional four bird species, four terrestrial mammals and one snake were potential predators (Table 2).

Egg and chick size.—At Patos Lagoon, volume of C eggs (third egg laid) was significantly smaller than A and B (W=7538, P=0.01, n=3), with a mean difference of -12.5% relative to eggs A and B, and -8.7% compared to the mean volume of all eggs. However, at Saco da Fazenda volume of A, B and C eggs was not significantly different (W=1062, P=0.05, n=10). C eggs had a mean difference of

Table 4. Egg volume of Yellow-crowned Night Herons *Nyctanassa violacea* at Patos Lagoon and Saco da Fazenda.

Site	Laying order	N	Egg volume (ml^3)		
			Mean	SD	Range
Patos Lagoon	A	3	38.90 a[1]	1.37	37.28–40.33
	B	3	38.55 a	1.31	36.91–39.73
	C	3	33.87 b	0.92	33.25–35.06
	Grouped	9	37.11 c	2.62	33.25–40.33
Saco da Fazenda	A	10	35.72 c	1.91	33.08–38.24
	B	10	35.53 c	2.10	31.17–38.02
	C	6	34.72 c	1.26	31.09–36.26
	Grouped	26	34.85 c	3.77	31.09–38.24

[1]Significant difference in mean egg volumes between laying order are denoted by different letters (ANOVA, P<0.05).

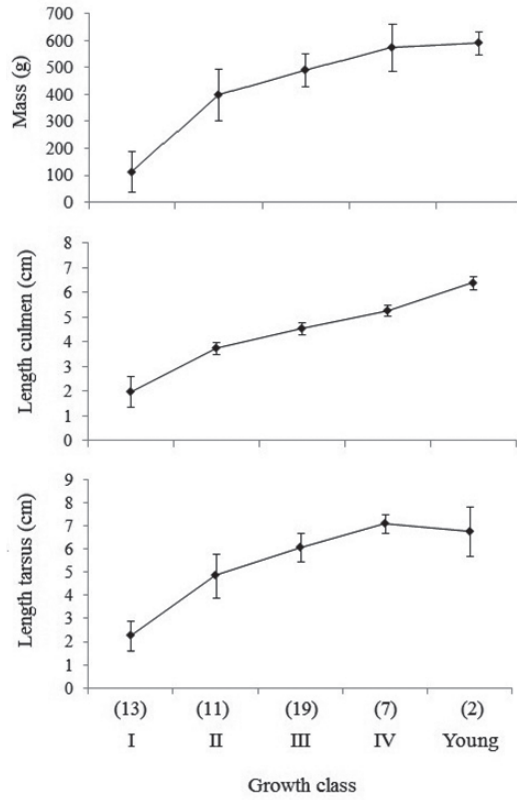

Figure 4. Mean values (and standard deviation bars) for the mass and culmen and tarsus lengths of Yellow-crowned Night Heron *Nyctanassa violacea* nestlings of different growth classes at the Saco da Fazenda colony. Numbers in parentheses indicate the number of nestlings measured in each class.

only -2.5% relative to A and B eggs, and only -1.7% compared to the mean volume of all eggs (Table 4).

The volume of A (t=2.615, P=0.024, gl=11) and B eggs (t=2.286, P=0.043, gl=11) in Patos Lagoon was significantly higher than in Saco da Fazenda, despite the volume of eggs C was lower (t=1.368, P=0.213, gl=7). Mean volume in Patos Lagoon and Saco da Fazenda did not differ significantly (t=2.022, P=0.051, gl=33) (Table 4).

Nestlings in growth class III were on average 83% of the mass of juveniles, which are similarly sized to adults. The tarsus had a mean growth rate slightly greater than that of the bill, and reached 91% of juvenile length in stage IV while the bill reached 82% (Fig. 4).

Discussion

Breeding period and abundance.—The breeding period of Yellow-crowned Night Heron in Rio Grande do Sul and Santa Catarina is similar to that in coastal Paraná[58] and São Paulo[55]. It coincides with increased availability of crabs (e.g. *Neohelice*, *Erythium*, *Aratus*, *Goniopsis*, *Cardisoma*, *Armases*, *Uca*, *Callinectes*) in the spring / summer[5,6,22,55], which provide a constant prey supply while the nestlings are growing. In northern Brazil (02°26'S), the breeding period is the opposite of that in south-east Brazil, but it also commences in the local wet season, when crab abundance reaches its peak[16,33,48]. In the Northern Hemisphere, the seasonal breeding pattern is similar to that in southern South America, i.e. commencing in spring (April–June) and extending until late summer (June–September)[1,10,35,44].

The seasonal presence of Yellow-crowned Night Heron at Patos Lagoon[30] differs from that observed elsewhere in Brazil[7,16,50,55], as well as in Colombia[52] and in Guatemala[23], where the species is resident. Northward migration following breeding at Patos Lagoon is presumably related to the high energy costs of maintaining the body temperature during winter[15,62], a situation exacerbated by low food availability.

The main prey of Yellow-crowned Night Herons at Patos Lagoon is the crab *Neohelice* (=*Chasmagnathus*) *granulata*, which represented 85% of 282 prey items collected in the 2005 and 2007 breeding seasons (pers. obs.). According to D'Incao *et al*.[22], these crabs practically disappear from the surface of mudflats in winter, remaining in their burrows due to the cold temperatures, and thus unavailable to a visual predator like this heron. Yellow-crowned Night Herons breeding in the northern USA also migrate in late summer to subtropical and tropical regions, where crab availability remains high all year[9,44].

The principal Yellow-crowned Night Heron breeding sites in Brazil are the mangroves of Santos / Cubatão (SP), with c.180 breeding pairs[55], and those in coastal Maranhão and Pará, with c.200 breeding pairs[48]. Itacorubi, which holds at least 74 pairs, represents the third most important breeding site for the species in Brazil, reinforcing the importance of urgent and effective protective against human impact there[56,61,68].

Breeding site characteristics.—Patos Lagoon was recently colonised by Yellow-crowned Night Heron, 400 km beyond the southernmost limit of Neotropical mangroves[11], and is the only known locality in South America where the species does not breed in mangrove. The nests were constructed on pines (*Pinus elliottii*) at the Oceanographic Museum, unlike elsewhere in South America, but in coastal Virginia, USA, pines (*P. taeda*) were the substrate for 95% of 257 nests sampled by Watts[72].

That Yellow-crowned Night Herons mainly use mangroves for nesting is related to the high abundance of crabs in such habitat[5,48,55], as the proximity of available food resources is the main factor used to select breeding sites by Ardeidae[25,27,37]. Yellow-crowned Night Herons will construct their nests in other trees or bushes in the absence of mangroves, if they are close to areas of high prey availability, as was observed at Patos Lagoon. At least 14 tree species were used by this heron for nesting in North America[9,19,32,46,72], whilst in the Gulf of Panama, they nested on coastal islands where shrubs and herbaceous vegetation were dominant[1].

The larger number of predators in Patos Lagoon reflects the diversity of habitats used by Yellow-crowned Night Herons for nesting there. The colony on Marinheiros Island was the only place where mammalian predators were recorded, it being located within partially flooded forest, with no surrounding water thereby granting access to terrestrial predators. Furthermore, Marinheiros possesses several fragments of native forest, whereas dense urban areas surround the Oceanographic Museum, Saco da Fazenda and the Itacorubi mangrove.

Mammals, especially nocturnal species, may cause high predation rates[27,28], as with the four species recorded on Marinheiros Island. Such predation may have been responsible for the fact that only five active nests were found on Marinheiros Island, despite 37 adults and juveniles being observed. These five nests were sited at 1.2–1.8 m on shrubs, and were predated during the egg laying and incubation periods, leading to their being abandoned. In addition, just one of the 37 birds observed at the end of the breeding period was in first-year plumage (pers. obs.), offering further evidence of low breeding success in 2008/2009.

Predation events may also have induced the small population at Patos Lagoon estuary to switch breeding sites. In 2006 on Pólvora Island, three

breeding pairs abandoned their nests after the eggs were predated, but subsequently nested at the Oceanographic Museum (pers. obs.). None nested on Pólvora Island in 2007 and 2008.

Eggs and chicks.—In Ardeidae hatching is asynchronous and the death of the final nestling is common due to competition for food and aggressive interactions with their siblings (siblicide), especially in nests with more than two young[17,27]. Custer & Frederick[17] noted that in three-egg clutches of Great Egrets *Ardea alba*, Snowy Egrets *Egretta thula* and Black-crowned Night Herons, the last egg (C) tended to be smaller, which may contribute to the low survival rate of the youngest nestling.

The difference between the mean volume of C eggs and that of A and B eggs (-2.5%) at Saco da Fazenda was lower than that observed in three heron species in Texas and Florida, where the difference varied between -3.9% and -6.5%[17]. At Patos Lagoon, despite the smaller relative size of C eggs (-12.5%), all nestlings survived unless predated or the nest collapsed[30], as was also the case at Santos / Cubatão[55]. Such low mortality rates in successful nests of Yellow-crowned Night Herons contrasts with the pattern observed in other Ardeidae (e.g. Great Egret, Little Blue Heron, Snowy Egret, Cattle Egret *Bubulcus ibis* and Black-crowned Night Heron) in which siblicide is very common[17,27,55], and is probably due to the 'calm' behaviour of the nestlings, among which aggressive interaction is rare[55].

The lower volume of C eggs at Patos Lagoon (but not at Saco da Fazenda) is perhaps due to lower ambient temperatures during egg formation. A positive correlation between egg volume and ambient temperature during this period has been observed in several bird species, with the last egg to be laid affected most markedly. This pattern is probably due to the higher energy cost of body maintenance, exacerbated by low food availability, which reduces the energy allocated for breeding and contributes to smaller egg size[12,36,47]. Mean temperature during egg laying (September, 2005) was 14.6°C with a minimum 6.0°C (Meteorological Station, FURG) in Patos Lagoon, while at Saco da Fazenda mean and minimum temperatures during September (2006) were 18.3°C and 7.2°C, respectively (Meteorological Station of the Brazilian Institute of Meteorological Research). In addition, crab availability during the colder months at Patos Lagoon is very low.

Clutch size in the states of Rio Grande do Sul and Santa Catarina (max. three) was lower than in coastal Paraná, São Paulo and Maranhão, where up to five eggs were recorded[55,58]. This might be related to the unfavourable temperatures and food availability during the early breeding period, which compromise female reserves and foraging during egg formation[12,36,47]. This pattern is the reverse of what is noted in birds generally, including some Ardeidae, in which clutch size tends to be lower nearer the tropics[41,49,59].

The growth pattern of nestlings at Saco da Fazenda was the same as in Maranhão[16] and for Black-crowned Night Heron young in Santa Catarina[8]. Generally, this pattern varies little among populations and species of Ardeidae[16,18], with swift growth of tarsi and feet considered an adaptation to acquire locomotive ability, increasing their chances of escaping from predators[24,74].

Conservation.—The nesting areas of Yellow-crowned Night Herons at Patos Lagoon (except Marinheiros Island), Saco da Fazenda, and Itacorubi mangrove were sited in areas heavily impacted by humans, as is also true at Santos / Cubatão[55] and the rio Perequê[58], the other breeding sites in south-east Brazil. This illustrates that the proximity of high-quality foraging areas is the most important factor determining where Ciconiiformes breed[25,27,37], with isolation from human-impacted areas generally secondary[27]. Nevertheless, high concentrations of pollutants near urban and industrial areas are associated with the formation of fragile eggs, atrophy, slow growth, deformation and nestling death in aquatic birds that nest and forage in such areas[20,45,53,55,65,67].

Yellow-crowned Night Heron may become at greater risk in southern Brazil because the main colonies (Santos / Cubatão and Itacorubi) are in areas subject to marked human influence, with high levels of environmental pollution, including metals[4,34,55,56,61,68,69]. The Paranaguá (Paraná) estuarine complex has 551.8 km^2 of well-preserved mangrove[54], and thus has the potential to support a significant population of Yellow-crowned Night Heron. However, Mestre *et al.*[50] observed that the species was infrequent in mangrove in the south of bay, where Rechetelo[58] recorded just 20 pairs breeding on the rio Perequê. Surveys of the large estuaries of southern Brazil for breeding Yellow-crowned Night Herons are needed. Special attention should be afforded the mangroves of Araquari / São Francisco do Sul and Ilha de Santa Catarina (Santa Catarina), Guaratuba Bay and the Paranaguá estuary (Paraná) and Cananéia (São Paulo).

Acknowledgements

We thank Lauro Barcellos, Director of the Complexo de Museus e Centros Associados da FURG, for assistance with access to Pólvora Island, and the Universidade Federal do Rio Grande (FURG) for logistical support on Marinheiros Island. DG receives a Master's scholarship from the Conselho Nacional de Pesquisa e Desenvolvimento (CNPq). The English version of this manuscript was prepared by Rodrigo da Rosa Pereira through the Program of Support to Student Scientific

Production at FURG, and subsequently revised by Eric Hoddy. We also thank Fábio Olmos, Clay Green and Guy Kirwan for comments and suggestions on the submitted manuscript.

References

1. Angehr, G. R. & Kushlan, J. A. (2007) Seabird and colonial wading bird nesting in the Gulf of Panamá. *Waterbirds* 30: 335–357.
2. Asmus, M. L. (1997) Coastal plain and Patos Lagoon. In: Seeliger, U., Odebrecht, C. & Castello, J. P. (eds.) *Subtropical convergence environments: the coast and sea in the southwestern Atlantic*. Berlin: Springer-Verlag.
3. Bellrose, F. C. (1938) Yellow-crowned Night Heron breeding in northern Illinois. *Auk* 55: 122.
4. Braga, E., Bonetti, C. V. D. H., Burone, L. & Filho, J. B. (2000) Eutrophication and bacterial pollution caused by industrial and domestic wastes at the Baixada Santista estuarine system. *Brazil. Mar. Pollut. Bull*. 40: 165–173.
5. Branco, J. O. (1991) Aspectos ecológicos dos *Brachyura* (Crustacea: Decapoda) no manguezal do Itacorubi, SC. *Brasil. Rev. Bras. Zool*. 7: 165–179.
6. Branco, J. O. (1993) Aspectos bioecológicos do caranguejo *Ucides cordatus* (Linnaeus, 1763) (Crustacea Decapoda) no manguezal do Itacorubi, Santa Catarina, BR. *Arq. Biol. Tecnol*. 36: 133–148.
7. Branco, J. O. (2007) Avifauna aquática do estuário do Saco da Fazenda (Itajaí, Santa Catarina, Brasil): uma década de monitoramento. *Rev. Bras. Zool*. 24: 873–882.
8. Branco, J. O. & Fracasso, H. A. A. (2005) Reprodução de *Nycticorax nycticorax* (Linnaeus) no litoral de Santa Catarina, Brasil. *Rev. Bras. Zool*. 22: 424–429.
9. Brown, K. M., Tims, J. L., Erwin, E. M. & Richmond, M. E. (2001) Changes in nest population of colonial waterbirds in Jamaica Bay Wildlife Refuge, New York, 1974–1998. *Northeast. Nat*. 8: 275–292.
10. Capul-Magdaña, F. G. (2003) Reproducción avanzada de *Nyctanassa violacea* (Ardeidae) en el estero El Salado, Jalisco, México (junio a julio de 2001). *Cienc. Mar*. 7 21: 43–49.
11. Cintrón-Molero, G. & Schaeffer-Novelli, Y. (1992) Ecology and management of New World mangroves. In: Seeliger, U. (ed.) *Coastal plant communities of Latin America*. San Diego, CA: Academic Press.
12. Cooper, C. B., Hochachka, W. M., Andre, G. B. & Dhondt, A. (2005) Seasonal and latitudinal trends in clutch size: thermal constraints during laying and incubation. *Ecology* 86: 2018–2031.
13. Costa, C. S. B. (1997) Tidal marshes and wetlands. In: Seeliger, U., Odebrecht, C. & Castello, J. P. (eds.) *Subtropical convergence environments: the coast and sea in the southwestern Atlantic*. Berlin: Springer-Verlag.
14. Costa, C. S. B., Seeliger, U. & Kinas, P. G. (1988) The effect of wind velocity and direction on the salinity regime in the lower Patos Lagoon estuary. *Cienc. Cult*. 40: 909–912.
15. Cox, W. G. (1985) The evolution of avian migration systems between temperate and tropical areas of the New World. *Amer. Nat*. 126: 451–474.
16. Cunha, A. H. F., Rodrigues, A. A. F. & Martínez, C. (2000) Desenvolvimento dos filhotes de Taquiri (*Nyctanassa violacea*, Aves: Ardeidae) na Ilha do Cajual, Alcântara - MA. *Bol. Mus. Para. Emílio Goeldi* 16: 7–11.
17. Custer, T. W. & Frederick, P. C. (1990) Egg size and laying order of Snowy Egrets, Great Egrets and Black-crowned Night-Heron. *Condor* 92: 772–775.
18. Custer, T. W. & Peterson, D. W. (1991) Growth rate of Great Egret, Snowy Egret and Black-crowned Night Heron chicks. *Colonial Waterbirds* 14: 46–50.
19. Custer, T. W., Osborn, R. G. & Stout, W. F. (1980) Distribution, species abundance, and nesting-site use of Atlantic Coast colonies of herons and their allies. *Auk* 97: 591–600.
20. Custer, T. W., Custer, C. M., Eichhorst, B. A. & Warburton, W. (2007) Selenium and metal concentrations in waterbird eggs and chicks at Agassiz National Wildlife Refuge, Minnesota. *Arch. Environ. Contam. Toxicol*. 53: 103–109.
21. Diegues, A. C. (1999) Human populations and coastal wetlands: conservation and management in Brazil. *Ocean Coast. Manag*. 42: 187–210.
22. D'Incao, F., Ruffino, M., Grubel, L. K. S. & Braga, A. C. (1992) Responses of *Chasmagnathus granulata* Dana (Decapoda: Grapsidae) to salt-marsh environmental variations. *J. Exp. Mar. Biol. Ecol*. 161: 179–188.
23. Eisermann, K. (2006) *Evaluation of waterbirds populations and their conservation in Guatemala, final report*. Guatemala City: BirdLife International, Salvanatura & US Fish & Wildlife Service.
24. Erwin, R. M., Haig, J. G., Stotts, D. B. & Hatfield, J. S. (1996) Reproductive success, growth and survival of Black-crowned Night-Heron (*Nycticorax nycticorax*) and Snowy Egret (*Egretta thula*) in coastal Virginia. *Auk* 113: 119–130.
25. Fasola, M. & Barbieri, F. (1978) Factors affecting the distribution of heronries in northern Italy. *Ibis* 120: 537–540.
26. Fleury, B. C. & Sherry, T. W. (1995) Long-term populations trends of colonial wading birds in southern United States: the impact of crayfish aquaculture on Louisiana population. *Auk* 112: 613–632.
27. Frederick, P. C. (2002) Wading birds in the marine environment. In: Schreiber, E. A. & Burger, J. (eds.) *Biology of marine birds*. Boca Raton, FL: CRC Press.
28. Frederick, P. C. & Callopy, M. W. (1989) The role of predation in determining reproductive success of colonially nesting wading birds in the Florida Everglades. *Condor* 91: 860–867.
29. Frederick, P. C., Bjork, R., Bancroft, G. T. & Powell, G. V. N. (1992) Reproductive success

of three species of herons relative to habitat in southern Florida. *Colonial Waterbirds* 15: 192–201.
30. Gianuca, D. (2007) Ocorrência sazonal e reprodução do socó-caranguejeiro *Nyctanassa violacea* no estuário da Lagoa dos Patos, novo limite sul da sua distribuição geográfica. *Rev. Bras. Orn*. 15: 464–467.
31. Gianuca, D., Quintela, F. M., Barros, J. A., Gomes, A. & Gianuca, N. M. (2008) Ocorrência regular da garça-azul *Egretta caerulea* (Ciconiiformes, Ardeidae) no estuário da Lagoa dos Patos, Rio Grande do Sul, Brasil. *Pan. Amer. J. Aquatic Sci*. 3: 328–334.
32. Harford, H. M. (1951) Nest of the Yellow-crowned Night Heron, *Nyctanassa violacea*, in Kansas City, MO. *Auk* 68: 235–236.
33. Hass, A., Matos, R. H. R. & Marcondes-Machado, O. (1999) Ecologia reprodutiva e distribuição espacial da colônia de *Eudocimus ruber* (Ciconiiformes: Threskiornithidae) na Ilha do Cajual, Maranhão. *Rev. Bras. Orn*. 7: 41–44.
34. Hortellani, M. A., Sarkis, J. E. S., Bonetti, J. & Bonetti, C. (2005) Evaluation of mercury contamination in sediments from Santos - São Vicente estuarine system, São Paulo state, Brazil. *J. Braz. Chem. Soc*. 16: 1140–1149.
35. Hoyt, D. F. (1979) Practical methods of estimating volume and fresh weight of bird eggs. *Auk* 82: 507–508.
36. Järvinen, A. & Ylimaunu, J. (1986) Intraclutch egg-size variation in birds: physiological responses of individuals to fluctuations in environment conditions. *Auk* 103: 235–237.
37. Kelly, J. P., Stralberg, D., Etienne, K. & MacCaustland, M. (2008) Landscape influences on the quality of heron and egret colony sites. *Wetlands* 28: 257–275.
38. Kim, J. & Koo, T. H. (2007) The use of feathers to monitor heavy metals contamination in herons, Korea. *Arch. Environ. Contam. Toxicol*. 53: 435–441.
39. King, D. T. & LeBlanc, D. (1995) Foraging behaviors of Snowy Egrets (*Egretta thula*) and Yellow-crowned Night-Herons (*Nyctanassa violacea*) in south Louisiana. *Colonial Waterbirds* 18: 224–225.
40. Klein, A. H. F. (1997) Regional climate. In: Seeliger, U., Odebrecht, C. & Castello, J. P. (eds.) *Subtropical convergence environments: the coast and sea in the warm-temperate southwestern Atlantic*. Berlin: Springer-Verlag.
41. Koenig, W. D. (1984) Geographical variation in clutch size in the Northern Flicker (*Colaptes auratus*): support for Ashmole's hypothesis. *Auk* 101: 698–706.
42. Kushlan, J. A. (1993) Colonial waterbirds as bioindicator of environmental change. *Colonial Waterbirds* 16: 223–251.
43. Kushlan, J. A. (1997) The conservation of wading birds. *Colonial Waterbirds* 20: 129–137.
44. Kushlan, J. A. & Hancock, J. A. (2005) *The herons*. Oxford: Oxford University Press.
45. Lam, J. C. W., Shinsuke, T., Wong, B. S. F. & Lam, P. K. S. (2004) Trace element residues in eggs of Little Egret (*Egretta garzetta*) and Black-crowned Night Heron (*Nycticorax nycticorax*) from Hong Kong, China. Mar. *Pollut. Bull*. 48: 390–396.
46. Laubhan, M. K. & Reid, F. A. (1991) Characteristics of Yellow-crowned Night-Heron nests in lowland hardwood forests of Missouri. *Wilson Bull*. 103: 486–491.
47. Magrath, R. D. (1992) Seasonal changes in egg-mass within and among clutches of birds: general explanations and a field study of the Blackbird *Turdus merula*. *Ibis* 134: 171–179.
48. Martinez, C. (2004) Food and niche overlap of the Scarlet Ibis and the Yellow-crowned Night Heron in a tropical mangrove swamp. *Waterbirds* 27: 1–8.
49. Maxwell, G. R. & Kale, H. W. (1977) Breeding biology of five species of herons in coastal Florida. *Auk* 84: 689–700.
50. Mestre, L. A. M., Krul, R. & Moraes, V. S. (2007) Mangrove bird community of Paranaguá Bay - Paraná, Brazil. *Braz. Arch. Biol. Technol*. 50: 75–83.
51. Mock, D. W. T., Lamey, T. C. & Ploger, B. J. (1987) Proximate and ultimate roles of food amount in regulating egret sibling aggression. *Ecology* 68: 1760–1772.
52. Moreno-Bejarano, L. M. & Álvarez-León, R. (2003) Fauna asociada a los manglares y otros humedales en el delta-estuario del río Magdalena, Colombia. *Rev. Acad. Colombiana Cienc*. 27: 517–534.
53. Newman, S. H., Padula, V. M., Cray, C. & Kramer, L. D. (2007) Health assessment of Black-crowned Night-herons (*Nycticorax nycticorax*) of the New York Harbor estuary. *Comp. Biochem. Physiol*. 148: 363–374.
54. Noernberg, M. A., Lautert, L. F. C., Araújo, A. D., Marone, E., Angelotti, R., Netto, J. P. B. & Krug, L. A. (2004) Remote sensing and GIS integration for modeling the Paranaguá estuarine complex – Brazil. *J. Coast. Res*. 39: 1627–1631.
55. Olmos, F. & Silva e Silva, R. (2003) *Guará: ambiente, fauna e flora dos manguezais de Santos-Cubatão*. São Paulo: Empresa das Artes.
56. Pagliosa, P. R. & Barbosa, F. A. R. (2006) Assessing the environment–benthic fauna coupling in protected and urban areas of southern Brazil. *Biol. Conserv*. 129: 408–417.
57. Patten, M. A. (2007) Geographic variation in calcium and clutch size. *J. Avian Biol*. 38: 637–643.
58. Rechetelo, J. (2009) Biologia reprodutiva e dieta do socó-do-mangue *Nyctanassa violacea* no Parque Natural Municipal do Manguezal do Rio Perequê, no Estado do Paraná, Brasil. M.Sc. thesis. Pontal do Sul: Universidade Federal do Paraná.
59. Ricklefs, R. E. (1980) Geographical variation in clutch size among passerine birds: Ashmole's hypothesis. *Auk* 97: 38–49.

60. Riegner, M. F. (1982) The diet of Yellow-crowned Night Herons in the eastern and southern United States. *Colonial Waterbirds* 5: 173–176.
61. Rivail da Silva, M., Lamotte, M. O., Donard, F. X., Soriano-Sierra, E. J. & Robert, M. (1998) Contaminação por metais presentes em sedimentos de superfície de mangues, lagoas e da Baía Sul na Ilha de Santa Catarina. In: Soriano-Sierra, E. J. & Sierra de Ledo, B. (eds.) *Ecologia e manejo do manguezal de Itacorubi*. Florianópolis: Nemar-CCB-UFSC.
62. Root, T. (1998) Energy constraints on avian distributions and abundances. *Ecology* 69: 330–339.
63. Salle, G. W. (1982) Mixed heronries of Oklahoma. *Proc. Oklahoma Acad. Sci*. 62: 53–56.
64. Sokal, R. R. & Rohlf, F. J. (1969) *Biometry, the principles and practices of statistics in biological research*. San Francisco, CA: W. H. Freeman & Co.
65. Spanh, S. A. & Sherry, T. W. (1999) Cadmium and lead exposure associated with reduced growth rates, poorer fledging success of Little Blue Heron chicks (*Egretta caerulea*) in south Louisiana wetlands. *Arch. Environ. Contam. Toxicol*. 37: 377–384.
66. Straube, F. C., Urben-Filho, A. & Kajiwara, D. (2004) Aves. In: Mikich, S. B. & Bérnils, R. S. (eds.) *Livro vermelho da fauna ameaçada no estado do Paraná*. Curitiba: Instituto Ambiental do Paraná.
67. Thompson, H. M., Alwyn, F., Rose, M., White, S. & Blackburn, A. (2006) Possible chemical causes of skeletal deformities in Grey Herons nestling (*Ardea cinerea*) in north Nottinghamshire, UK. *Chemosphere* 65: 400–409.
68. Torres, M. A., Testa, C. P., Gáspari, C., Masutti, M. B., Panitz, C M. N., Curi-Pedrosa, R., Almeida, E. A., Di Mascio, P. & Filho, D. W. (2002) Oxidative stress in the mussel *Mytella guyanensis* from polluted mangroves on Santa Catarina Island, Brazil. *Mar. Pollut. Bull*. 44: 923–932.
69. Umbuzeiro, G. A., Kummrow, F., Roubicek, D. A. & Tominaga, M. Y. (2006) Evaluation of the water genotoxicity from Santos Estuary (Brazil) in relation to the sediment contamination and effluent discharges. *Environ. Intern*. 32: 359–364.
70. Valiela, I., Bowen, J. L. & York, J. K. (2001) Mangrove forests: one of the world's threatened major tropical environments. *BioScience* 51: 807–815.
71. Watts, B. D. (1988) Foraging implications of food usage patterns in Yellow-crowned Night-Herons. *Condor* 90: 860–865.
72. Watts, B. D. (1989) Nest-site characteristics of the Yellow-crowned Night-Herons in Virginia. *Condor* 91: 979–983.
73. Wayne, A. T. (1906) A contribution to the ornithology of South Carolina, chiefly the coastal region. *Auk* 23: 56–68.
74. Werschkul, D. F. (1979) Nestling mortality and adaptive significance of early locomotion in the Little Blue Heron. *Auk* 96: 116–130.

Dimas Gianuca
Programa de Pós-graduação em Oceanografia Biológica, Instituto de Oceanografia, Universidade Federal do Rio Grande, CP747, Rio Grande, Rio Grande do Sul, Brazil. E-mail: dmsgianuca@hotmail.com.

Joaquim O. Branco
Centro de Ciências Tecnológicas da Terra e do Mar, Universidade do Vale do Itajaí, CP150, Itajaí, Santa Catarina, Brazil. E-mail: branco@univali.br.

Carolus Maria Vooren
Laboratório de Elasmobrânquios e Aves Marinhas, Instituto de Oceanografia, Universidade Federal do Rio Grande, CP747, Rio Grande, Rio Grande do Sul, Brazil. E-mail: doccmv@furg.br.