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BREEDING BIOLOGY OF THE LITTLE BLUE HERON (*EGRETTA CAERULEA*) IN SOUTHEASTERN BRAZIL

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Resumo. – Biologia reprodutiva da Garça-azul (*Egretta caerulea)* no sudeste do Brasil. – A biologia reprodutiva da Garça-azul (*Egretta caerulea*) nidificando em Santos-Cubatão, sudeste do Brasil, foi estudada durante 1997 (75 ninhos monitorados) e 1998 (65 ninhos) em uma colônia (rio Saboó), e durante 1997 em outra colônia (58 ninhos) nas proximidades (rio Morrão). Ambas localizavam-se em uma área de manguezal bastante impactada pela poluição e atividades portuárias. As garças nidificam em colônias com várias espécies, construindo seus ninhos a alturas menores na colônia rio Morrão, localizada em uma área dominada por mangues-vermelhos (*Rhizophora mangle*) onde Guarás (*Eudocimus ruber*) eram a espécie com maior número de ninhos. Na colônia rio Saboó, localizada sobre mangues-brancos (*Laguncularia racemosa*) e dominada por Garças-azuis, os ninhos foram construídos a maior altura. A cronologia de reprodução foi similar ao reportado para populações norte-americanas mas as posturas (média de 2.21 a 2.57 ovos/ninho) e a produtividade (média de 0.53 a 0.98 filhotes/ninho construído) foram menores e os jovens parecem depender dos pais por um período maior. A queda de ninhos foi responsável pela maior parte das perdas, seguida pela predação. Parasitismo fatal por nematóides pode ser uma causa importante de mortalidade em alguns anos. Diferenças em sítios de nidificação entre as colônias resultam tanto da estrutura da vegetação como de interações com outras espécies nidificantes; aparentemente as garças selecionam territórios de exibição mais expostos (onde os ninhos serão construídos) se as condições permitem.

Abstract. – The breeding biology of Little Blue Herons (*Egretta caerulea*) nesting in Santos-Cubatão, southeastern Brazil, was studied during the 1997 (75 monitored nests) and 1998 (65 nests) breeding seasons in one colony (Saboó River), and during the 1997 season (58 nests) in another colony nearby (Morrão River). Both mixed-species colonies were in mangroves affected by pollution and port activities. Colonies were active in September–March (Saboó River), and November–March (Morrão River). Little Blue Herons built their nests lower in the red mangrove (*Rhizophora mangle*) Morrão River colony where Scarlet Ibises (*Eudocimus ruber*) were the commonest nesting species, and nested higher in trees of the white mangrove (*Laguncularia racemosa*) Saboó River colony, where they were most common. Breeding chronology was similar to North American populations but clutch sizes were smaller (mean 2.21 to 2.57 eggs/nest), productivity lower (mean 0.53 to 0.98 young/breeding attempt) and young remained with adults for longer. Nest collapse, followed by predation, accounted for most failures. Parasitism by nematode worms may be an important source of mortality in some years. Differences in nest-sites between colonies resulted both from the vegetation structure and interactions with other nesting species; male herons likely tend to select the more exposed display territories (where nests will be built). *Accepted 8 May 2001.*

Key words: Brazil, breeding biology, breeding success, clutch size, *Egretta caerulea,* Little Blue Heron, mangrove, Neotropics, nest failures, nest site location, productivity, South America.

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INTRODUCTION

Compared to northern hemisphere populations, Neotropical wading birds have been little studied. The breeding biology of the Little Blue Heron (*Egretta caerulea*) in North America is well known (reviewed by Rodgers & Smith 1995), but there is little information from locations farther south. The published data are limited to general descriptive information on the breeding period, clutch size and nesting habitat in Trinidad-Tobago, Costa Rica and Surinam (Stiles & Skutch 1989, ffrench 1991, del Hoyo *et al.* 1992, Haverschmidt & Mees 1994). Little Blue Herons are commonest in coastal habitats, especially mangroves in Brazil, which are their only known breeding habitat in the country, and seem to occur only as vagrants inland. There is little information on its breeding biology and ecology, despite being a common species in coastal Brazil (Sick 1997).

Like most Ardeidae, Little Blue Herons are colonial, often nesting in multi-species colonies. Nests are built inside a display territory established by the male early in the process of colony formation. These territories get smaller as pair-bonding and nest-building progress, allowing nesting to become denser (Rodgers & Smith 1995). Compared to other herons and egrets, Little Blue Heron nests are built lower and protected by the crowns of nest trees and bushes. In some localities, Little Blue Herons nest far from conspecifics compared to other herons, but distances between nests, as well as nest heights, are variable and depend on colony characteristics. In North America, clutch sizes tend to be larger in higher latitudes, compared to warmer ones (Rodgers & Smith 1995).

The main recorded causes of nest failures in the studied populations are nest collapses, desertion and predation, which vary locally and annually. In Florida, Rodgers (1980a) found that 76% of the nest failures could be attributed to collapses due to poor construction, but winds may have contributed (Jenni 1969). Similar data are not available for the Neotropics.

Here we describe the breeding ecology of Little Blue Herons in a mangrove habitat in southeastern Brazil, including information on clutch size, breeding success, causes of nest failures and nest site characteristics.

STUDY AREA

We studied Little Blue Herons in the mangroves of Santos-Cubatão, between São Vicente Island and the mainland, on the coast of São Paulo state, southeastern Brazil (near 23°53'S, 46°23'W). This area is part of one of major mangrove ecosystems remaining in southeastern Brazil, covering 120.2 km^2. Roughly half of the mangrove area is located in the townships of Santos (30.69 km^2) and Cubatão (23 km^2; Lamparelli 1999).

Santos is the largest seaport in Latin America, while Cubatão is well known for its petrochemical, steel and fertilizer plants. Pollution levels were once so high that the town had the nickname of "Death Valley" in the 1980's (see Gutberlet 1996). Although the situation has somewhat improved, the estuary sediments are still laden with heavy metals and persistent organic pollutants, and oil slicks are common.

Climate in the area is hot and humid, monthly rainfall being commonly at or above 100 mm. Annual rainfall ranges from 2000 to over 2500 mm. Winter is the drier season, the lowest rainfall occurring in July–August, with higher amounts in September–March (Olmos & Silva e Silva in press). For a general description of the area's geography and environment, see Azevedo (1965), CETESB (1991), Gutberlet (1996) and Olmos & Silva e Silva (in press).

Five waterbird colonies, not active every year, are known from the study area. They are

TABLE 1. Variables for each Little Blue Heron nest studied. We did not take variables dist1can to dist4root at the Sabóo colony due to the different vegetation structure there (see Study area). These were substituted by the distances from the trunk of the nest-tree and the ones of the four nearest trees (tree 1 to tree 4, see Tables 3 and 4).

Codes	Description of variables
n eggs	Number of eggs per nest
height	Nest height from the ground
trunkper	Nest tree perimeter taken above its aerial roots
distrunk	Distance between the main trunk of the nest tree to the nest edge
nest 1	Distance to the nearest nest
nest 2	Distance to the second nearest nest
nest 3	Distance to the third nearest nest
nest 4	Distance to the fourth nearest nest
tree height	Nest tree height
n nests	Number of nests on nest tree
dist edge	Distance from the nest tree to the mangrove-dry land interface, with *Acrostichum* spp. thickets
dist open	Distance from the nest tree to an open area (clearing, river or tidal channel)
dist1can	Distance from the outermost branches of the nest tree to the crown of the nearest tree
dist2can	Distance from the outermost branches of the nest tree to the crown of the second nearest tree
dist3can	Distance from the outermost branches of the nest tree to the crown of the third nearest tree
dist4can	Distance from the outermost branches of the nest tree to the crown of the fourth nearest tree
dist1root	Distance from the outermost aerial roots of the nest-tree to the aerial roots of the nearest tree
dist2root	Distance from the outermost aerial roots of the nest-tree to the aerial roots of the second nearest tree
dist3root	Distance from the outermost aerial roots of the nest-tree to the aerial roots of the third nearest tree
dist4root	Distance from the outermost aerial roots of the nest-tree to the aerial roots of the fourth nearest tree
nests t1	Number of nests in the nearest tree
nests t2	Number of nests in the second nearest tree
nests t3	Number of nests in the third nearest tree
nests t4	Number of nests in the fourth nearest tree
sp1	Species of the nearest nest
sp2	Species of the second nearest nest
sp3	Species of the third nearest nest
sp4	Species of the fourth nearest nest
cover	Degree of exposure: 3 = wholly shaded by overhanging branches and leaves; 1 = wholly exposed to the sun, no overhanging branches; 2 = intermediate between 1 and 3.

the only ones so far recorded in coastal São Paulo. Data were collected at the Morrão (23°52'S, 46°21'W) and Saboó (23°55'S, 46°20'W) colonies, both in Santos township. For a description of waterbird colonies in the area, see Olmos and Silva e Silva (in press).

When active, the Morrão colony is used by Scarlet Ibises (*Eudocimus ruber*; the nuclear species first arriving at the site), Little Blue Herons, Snowy Egrets (*Egretta thula*) and Black-crowned Night-Herons (*Nycticorax nycticorax*). This colony, in a red mangrove (*Rhizophora mangle*) swamp, has been active from early November to early March during the 1994–97 period. From late 1997 to 2000, the ibises deserted the colony while building the nests, following vandalism and disturbance from fishermen, and the herons nested successfully only in 2000. Birds built their nests on red mangrove trees, characterized in this area by a squat appearance and multiple trunks and roots, which made their lower branches quite stable during storms and windy spells.

The Saboó colony is a mixed-species colony used by Little Blue Herons, Yellow-crowned Night-Herons (*Nyctanassa violacea*), Great Egrets (*Ardea alba*), Black-crowned Night-Herons and Snowy Egrets, in a broad mangrove fringe backed by container and car storage areas for the Santos port. The Saboó River is bordered by > 12 m tall black mangrove (*Avicennia schaueriana*), which are used by nesting night herons. A belt of young white mangrove (*Laguncularia racemosa*), 3–6 m high, with a few red mangrove trees, grows in an outer fringe in two "inlets" and is the place of choice for nesting Little Blue Herons and Snowy Egrets, plus a few night herons. Little Blue Herons built their nests mostly on the thin, young white mangrove trees. Those trees had few lateral branches compared to red mangroves, and would bend and shake during windy spells.

The tallest red mangroves (over 8 m high), which form "islands" surrounded by the lower trees, are used by Great Egrets. There are between 600 and 800 active nests each year. The colony is active from September to February–March, and in the 1998–1999 nesting season, we censused 615 nests made by Little Blue Herons (470), Yellow-crowned Night-Herons (80), Great Egrets (35), Snowy Egrets (22) and Black-crowned Night-Herons (8).

METHODS

We monitored the Saboó colony in October–November 1996 and 1997, and the Morrão colony from October 1996 to March 1997. Prior to monitoring, colony sites were checked regularly for displaying birds. During the nest-building period (September–early October for Saboó, late October–early November for Morrão), we visited the colonies at least twice a week to check for incubating birds. When most nests were believed to have complete clutches, a variable number of nests were marked with numbered vinyl tape (Saboó) or metal tags (the nesting Scarlet Ibises took the pink vinyl tape as nesting material). In both 1996 and 1997, we marked nests in the same part of the Saboó colony, many in the same trees.

As Little Blue Heron colonies may have nests in different stages of the breeding cycle at a given time, our results for the Saboó colony refer to the early breeders nesting at the beginning of the breeding season. We marked and monitored Morrão nests throughout the breeding season, allowing comparisons between early and late breeders. Clutch size is here defined as the maximum number of eggs recorded in a given nest. Nesting cycle for the Saboó colony is described in detail only for the 1997 season.

Each nest was checked twice a week until the young reached 18–20 days old, when they were able to move about the trees and became hard to locate. Nestlings were banded with metal bands and plastic numbered or color bands in unique combinations to allow individual identification.

We tried to spend as little time in the colony as possible in order to minimize disturbance, and avoided rainy days or periods of high temperature. Two people were able to check all nests during a visit lasting about one hour. Herons and ibises soon habituated to us and would return to the nests a few minutes after we climbed down the nest tree or moved to other part of the colony. It was common to see ibises and herons waiting for us to leave, perching on trees beside the one we were working, or even on the same tree.

We measured 29 variables from each nest at the Morrão colony and 25 at Saboó (Table 1). The difference is due to the different architectures of red mangrove (dominant at Morrão) and white mangrove trees (dominant at Saboó). Measurements were taken with poles and tapes and are given as means and standard deviation. Distances between nests were taken from their edges and calculated with Pythagoras theorem. Statistical tests were made using the packages SYSTAT 5.0 (Systat 1992) and STATISTICA 4.3 (StatSoft 1993). A nest was considered successful if at least one nestling reached age 18 days, when they became independent from their nests, and failed if it or its eggs, or nestlings < 18 days old, disappeared.

We defined factors of nest failure as follows: 1) Predation: intact nests with vanished eggs or nestlings, none found on the ground (although nests from where eggs had vanished commonly had yolk stains); half-collapsed nests, with some material still in the nest tree but with no trace of contents on the ground; 2) Fall: nests partly or completely collapsed with their contents on the ground; fallen eggs would stuck in the very soft mud for long periods; 3) Desertion: intact nests with contents not attended by adults for two consecutive visits; deserted nests commonly retained their contents for weeks; 4) Breakage: eggs broken, apparently due to thin shells; 5) Fight: nests abandoned, or collapsed and contents falling to the ground due to inter or intraspecific fights. Nests were included in this category only if actual evidence of take-over was found; 6) Disease: dead, emaciated nestlings otherwise intact, in nests. Based on the symptoms of some young observed before death and autopsies, we believe those birds were infested by the worm *Eustrongylides ignotus* (Wiese *et al.* 1977), but some may have starved.

RESULTS

Nesting cycle

The herons started gathering at Saboó by the end of August, mostly for roosting, their numbers increasing by September–October. The first to build their nests were Great Egrets and Yellow-crowned Night-Herons.

By mid-September 1997, we found displaying Little Blue Heron males in full breeding plumage, and the first nests were started in early October. On 15 October, there were already Great Egret nestlings 1–2 weeks old and Yellow-crowned Night-Heron nestlings in their first week. Little Blue Heron clutches were mostly complete but we also found some nests with their first egg.

The incubation period was estimated to 20–24 days (n = 5 clutches), the latter value from a nest where we recorded the laying of the first egg. On 22 October, 2 of 63 active monitored nests had nestlings, this proportion increasing to 26 out of 56 on 1 November. On 1 November, we observed the first young climbing branches near their nests as a reaction to our approach. On 8 November, only 2 out of 54 active nests still had eggs, and both were deserted. On 17 November, all surviving young of the monitored nests were able to climb up the nest trees and move between trees with agility. By 22 November, several of the banded birds were able to make short flights between trees.

The 1996 chronology at Saboó was about 10 days late compared to 1997. During 1996, we tagged the nests on 26 October and found

TABLE 2. Clutch size and nest success of the three nest groups (i.e., Salboó 1997, Saboó 1998, and Morrão 1997). Data refer only to nests with known clutch size.

Clutch size (Mean ± SD)	Number of nests	Success	Number of young	Young/breeding attempt	Young/successful nest
Saboó 1996					
1	1	0	0	0	0
2	32	20 (62%)	25 (37 % of all nests)	0.78	1.25
3	42	25 (60%)	43 (63% of all nests)	1.02	1.72
(2.55 ± 0.53)					
Total	75	45	68	0.91	1.51
Saboó 1997					
1	1	0	0	0	0
2	26	17 (65%)	24 (38% of all nests)	0.92	1.41
3	38	24 (66%)	40 (62% of all nests)	1.05	1.67
(2.57± 0.53)					
Total	65	41	64	0.98	1.56
Morrão 1996					
1	6	0	0	0	0
2	34	13 (38%)	21 (68% of all nests)	0.62	1.61
3	18	6 (33%)	10 (32% of all nests)	0.56	1.67
(2.21± 0.61)					
Total	58	19	31	0.53	1.63

the first newly hatched nestlings on 6 November, ending the individual checking by 30 November.

The chronology of the Morrão colony (also monitored in 1996) was even later than the Saboó one, and Little Blue Herons had their first eggs by 9 November 1996. We monitored 15 nests of these early breeders, including one made by a pair of a bird in the normal adult plumage and a bird in the white coat (but with bright blue facial skin). The first nestlings were found on 30 November and all surviving nests had young on 10 December. On 21 December, some young were mobile enough to climb to the crowns of the nest trees and, on 29 December, all young were able to jump between trees trying to fly.

On 3 January 1997, we again observed Little Blue Herons gathering nesting material. On 5 January we checked most the active nests in the colony, including 55 that had not been monitored. Of these, three were being built, 22 had only eggs, and 30 had young with ages ranging from one day to four weeks. We monitored 46 of those late nests found with eggs and young nestlings. One day later, we observed the first young herons in sustained flight. Their age was estimated to 30–35 days. On 15 January, the first young were foraging along the river margins together with adults, their number increasing greatly between 25 and 29 January. At this time, young from late nests found with eggs on 5 January were already able to climb up their nest trees when we approached.

On 1 February, we again found Little Blue Heron nests with newly hatched nestlings. The young hatched in January were already able to make short flights between trees on 5

TABLE 3. Nest site characteristics for 75 Little Blue Heron nests studied during the 1996 breeding season in the Saboó colony. See Table 1 for codes. Measurements are in centimeters. The numbers between parentheses in the first column refer to the valid cases.

Variables	Mean	Minimum	Maximum	SD
height (74)	264.32	120	390	56.18
trunkper (74)	15.85	5	46	9.46
distrunk (74)	37.03	0	320	70.76
nest 1 (72)	148.04	22	635	100.10
nest 2 (72)	199.32	51	679	107.15
nest 3 (72)	243.74	54	718	109.33
nest 4 (72)	295.83	104	855	120.05
treeheight (74)	468.65	170	1000	194.96
nnests (74)	2.78	1	8	1.85
distedge (74)	901.08	150	1800	504.91
distopen (74)	414.19	0	1400	348.94
tree 1 (74)	77.09	15	250	48.98
tree 2 (74)	107.84	25	250	55.53
tree 3 (74)	146.89	30	400	74.43
tree 4 (74)	182.90	40	500	95.34
nestst1 (74)	0.62	0	6	1.09
nestst2 (74)	1.03	0	6	1.52
nestst3 (74)	1.26	0	6	1.93
nestst4 (74)	1.57	0	6	2.62
spn1	Great Egret: n = 1; Little Blue Heron: n = 69; Yellow-crowned Night-Heron: n = 2; Unknown: n = 3			
sp2	Little Blue Heron: n = 72; Unknown: n = 3			
sp3	Great Egret: n = 2; Little Blue Heron: n = 68; Black-crowned Night-Heron: n = 2;			
sp4	Great Egret: n = 2; Little Blue Heron; n = 66; Black-crowned Night-Heron: n = 3; Yellow-crowned Night-Heron: n = 1; Unknown: n = 3			
sp5	1: n = 14; 2: n = 40; 3: n = 20; Unknown: n = 1			

February. Meanwhile, the young hatched in late November–early December kept on the river margins foraging and actively soliciting food from adult herons passing by.

On 12 February, we observed over 30 young Little Blue Herons on the mudflats of the Morrão River by the colony. The number of young herons increased three days later. On 19 February, the latest young from monitored nests (about 20 days old) were able to climb their nest trees, but their flight feathers were still emerging from the sheaths. On 12 March, there were no active nests and only a few immature herons were associated with a Scarlet Ibis crèche on the river margins.

In short, Little Blue Heron young are able to amble on the branches around their nests when 15 days old. At 20–25 days, they are nimble enough to climb up to the canopy of the nest-tree and some may jump to neighboring trees if pressed. At this age, they can be found a fair distance from their nests. The first short flights are made by 30-day herons, although some (underfed ?) young only acquire this ability when 35–38 days old. After flying, the young begin looking for food around the colony site, but are still dependent on adults and beg for food for at

TABLE 4. Nest site characteristics for 75 Little Blue Heron nests monitored during the 1997 breeding season in the Saboó colony. See Table 1 for codes. Measurements are in centimeters. The numbers of valid cases id 65 for all variables, except sp1, sp2, sp3, sp4, and cover.

Variables	Mean	Minimum	Maximum	SD
height	299.69	150	520	78.34
trunkper	13.76	6	45	4.91
distrunk	13.31	0	300	46.66
nest 1	104.17	30	200	46.27
nest 2	156.58	30	427	64.78
nest 3	205.37	100	616	91.46
nest 4	241.48	111	753	97.81
treeheight	4.03	1	15	154.54
n nests	4.03	1	15	5.06
distedge	1548.46	0	3000	814.80
distopen	348.62	0	1500	396.03
tree 1	106.62	0	400	136.22
tree 2	185.08	20	700	236.77
tree 3	224.77	40	800	264.97
tree 4	328.62	50	1200	399.75
neststl	0.52	0	3	0.85
nestst2	0.69	0	4	1.10
nestst3	0.59	0	4	1.12
nestst4	0.51	0	3	0.89
sp1	Little Blue Heron: n = 57; Yellow-crowned Night-Heron: n = 5; Snowy Egret: n = 3			
sp2	Little Blue Heron: n = 60. Yellow-crowned Night-Heron: n = 3; Snowy Egret: n = 1			
sp3	Little Blue Heron: n = 63; Yellow-crowned Night-Heron: n = 2; Unknown: n = 3			
sp4	Little Blue Heron: n = 61; Yellow-crowned Night-Heron: n = 4; Unknown: n = 3			
cover	1: n = 16; 2: n = 28; 3: n = 21; Unknown: n = 1			

least another two weeks.

Clutch size and breeding success

All the eggs we observed were smooth, light blue and without markings. Measurements of fresh eggs from nine nests were 43.2 ± 1.49 x 31.7 ± 0.97mm and weight 23.1 ± 2.2 g (n = 21).

At the Saboó colony, we found a significant positive association between clutch size and the number of young reaching 18 days during the 1996 breeding season (χ^2 = 7.9, df = 2, P = 0.02), but not in the following year (χ^2= 0.93, df = 2, P = 0.63). There were no differences in clutch size (χ^2 = 0.08, df = 1, P = 0.77) and the number of young produced per nest (χ^2 = 0.41, df = 2, P = 0.81) between 1996 and 1997 (Table 2).

Heron nests were checked throughout the period the Morrão colony was active. Although clutch size of nests built in early November was somewhat larger (2.46 ± 0.52 eggs, n = 15 nests) compared to nests built in early December or later (2.13 ± 0.63 eggs, n = 43 nests), this difference was not significant (χ^2 = 3.12, df = 2, P = 0.21). We also found no difference in the number of young produced by early (0.69 ± 0.85 young/nest) and late breeders (0.65 ± 0.87 young/nest, χ^2 = 0.79, df = 2, P = 0.67), and no significant association between clutch size and the number of young reaching 18 days (χ^2 = 3.67, df =

TABLE 5. Nest site characteristics for 66 Little Blue Heron nests studied during the 1996-1997 breeding season in the Morrão colony. See Table 1 for codes. Measurements are in centimeters. The number of valid cases is 66 for all variables.

Variables	Mean	Minimum	Maximum	SD
height	215.30	110	420	57.79
trunkper	16.09	8	29	5.01
distrunk	59.62	0	300	70.85
nest 1	83.89	0	283	53.66
nest 2	116.96	30	301	61.11
nest 3	156.64	40	310	65.45
nest 4	194.47	76	390	73.67
treeheight	459.70	280	650	71.92
n nests	15.06	2	36	11.87
dist edge	934.62	0	1680	574.66
dist open	35.60	0	1650	210.63
dist1can	0.46	0	30	3.69
dist2can	10.61	0	270	36.33
dist3can	142.05	0	500	127.36
dist4can	292.58	0	1100	201.02
dist1root	159.49	0	500	126.57
dist2root	210.00	65	700	131.18
dist3root	412.50	90	800	171.62
dist4root	489.52	100	1600	238.53
nests t1	8.61	0	18	6.29
nests t2	10.15	0	47	11.69
nests t3	9.01	0	24	8.09
nests t4	4.68	0	20	6.81
spn1	Scarlet Ibis: n = 16; Little BlueHeron: n = 42. Snowy Egret: n = 1; Black-crowned Night-Heron: n = 6; Unknown: n = 1			
sp2	Scarlet Ibis: n = 27; Little blue Heron: n = 32; Black-crowned Night-Heron; n = 4; Snowy Egret: n = 3			
sp3	Scarlet Ibis: n = 25; Little Blue Heron: n = 38; Black-crowned Night-Heron: n = 1; Snowy Egret: n = 2			
sp4	Scarlet Ibis: n = 28; Little Blue Heron: n = 29. Black-crowned Night-Heron: n = 5; Snowy Egret: n = 2; Unknown: n = 2			
cover	1: n = 20; 2: n = 22; 3: n = 24			

4, *P* = 0.45). That was true both for the 13 early breeders (χ^2= 1.89, df = 2, *P* = 0.39) as well as for the 46 late breeders whose clutch size was known (χ^2= 6.36, df = 4, *P* = 0.17).

There was no significant association between clutch size and success for any of the monitored nest groups (Saboó 1997 and 1998, and Morrão 1997; all *P* > 0.8). Comparing the Saboó and Morrão colonies data for 1996, clutch size in the latter was significantly smaller (χ^2 = 11.6, df = 2, *P* = 0.003), but the difference in number of young produced per nest was not significant (χ^2 = 5.72, df = 2, *P* = 0.06; Table 2).

Causes of mortality and nest loss

Saboó colony. No nest raised three young to their 18th day in 1996, and only one did so in

1997 (Table 2). The youngest nestlings usually died or disappeared soon after hatching.

In 1996, of 30 unsuccessful nests, 16 failed when they had eggs and 14 after at least one nestling had hatched. Known causes of nest failure were predation (20 nests, 67%), desertion (five, 17%), nest collapse (two, 6.7%), fight (one, 3.3%) and disease (one, 3.3%). All deserted nests had eggs. The nest we believe was taken over through fight had a young 10–15 days old already able to move about the nearby branches; three days after this young was last seen the nest had three freshly laid eggs. It is possible the young bird survived, we did not find it or its corpse. The nestlings found dead at the nest were 3–5 days old.

Eleven depredated nests had nestlings, while nine had only eggs. Two of these nests had new eggs 10 days after losing their contents. We were unable to determine if these were replacement clutches or came from different pairs re-using a deserted nest.

The main cause of nest losses in 1997 was collapse (nine nests, 43%), followed by disease (seven, 33%), predation (three, 13%) and desertion (two, 9.5%). One nest failed due to egg breakage, and another nest contained one infertile egg. Eleven nests failed when they contained only eggs, and 12 with at least one nestling. As in 1996, all deserted nests had only eggs. Six fallen nests had only eggs, while the remaining nests contained nestlings.

Two depredated nests had two nestlings each, while the other one had only eggs. This nest had two new eggs 11 days after being found empty, suggesting a replacement clutch.

In 1997, we found an adult heron and several young, including some fledglings, weak and unable to walk or control their movements, and prone to die suddenly when handled, apparently with the same disease that killed nestlings at the monitored nests. Autopsy of six Little Blue Heron and one Black-crowned Night-Heron young found them to be very emaciated and with nematode infestations in the pre-ventriculus and ventriculus (E. R. Matushima, Faculdade de Medicina Veterinária/USP, pers. com.).

Morrão colony. As in the Saboó colony, no nest at the Morrão colony raised three young. Thirty-eight of the monitored nests failed. The main cause of failure was nest collapse due to bad construction or winds (23 nests, 59%). Another 12 nests (31%) were found empty or destroyed, suggesting the action of predators. Two nests with eggs were deserted. One nest was apparently destroyed due to interference of Scarlet Ibises. This nest was first found with one ibis and one heron egg and, six days latter, was found destroyed on the ground with three heron eggs.

Predation

No predation event was directly observed, the evidence presented here being circumstantial. A nestling Black-crowned Night-Heron regurgitated parts of a Little Blue Heron nestling, confirming that species as a predator (Davis 1993). A young night-heron was also observed causing a Little Blue nestling to fall from the nest when it fled from our approach.

On 13 November 1996, we observed a Yellow-headed Caracara (*Milvago chimachima*) flying low over the Saboó colony. Immediately the nesting birds began to call loudly and tens of Little Blue Herons and a few Great Egrets flew towards the raptor, calling and mobbing it until it left. This was the sole occasion we witnessed such behavior. On other occasions the birds were indifferent to Black Vultures (*Coragyps atratus*), Crested Caracaras (*Caracara plancus*) and Roadside Hawks (*Rupornis magnirostris*) perched next the colony. Grey-necked Rails *Aramides cajanea* were commonly seen in both colonies and may have stolen eggs, taking one at a time, a common pattern in depredated nests (Olmos & Silva e Silva 2001).

Harris´ Hawks (*Parabuteo unicinctus*) caused immediate desertion by attending herons of the Morrão colony which flew calling in alarm, not facing the predator, but this species was not observed at the Saboó colony during the study period. Harris´ Hawks attacked only Scarlet Ibis young at the Morrão colony, sparing the herons (Silva e Silva & Olmos 1997, Olmos & Silva e Silva 2001). Dead nestlings at Saboó had been eaten on the ground by brown rats (*Rattus norvegicus*), probably instances of scavenging or predation on fallen young. A depredated nest at the Morrão colony was very low on the nest tree and we found crab-eating raccoon (*Procyon cancrivorus*) footprints under it.

Nesting ecology

Little Blue Heron nests at the Saboó colony were built higher in 1997 compared to 1996 ($t_{137} = 3.08$, $P = 0.0025$) and were closer to each other as assessed from distances to the nearest nest ($t_{135} = -3.234$, $P = 0.0015$), second nearest nest ($t_{135} = -2.79$, $P = 0.0061$), third nearest nest ($t_{135} = -2.21$, $P = 0.03$) and fourth nearest nest ($t_{135} = -2.89$, $P = 0.0045$). However, distances between a given nest-tree and its second (dist 2; $t_{137} = 2.72$, $P = 0.084$), third (dist 3; $t_{137} = 2.42$, $P = 0.007$) and fourth (dist 4; $t_{137} = 3.04$, $P = 0.003$) nearest neighbors were larger in 1997 (Tables 3 and 4).

The nests in 1996 were lower and in denser vegetation, but in 1997 higher and closer to each other. Tree height ($t_{137} = 3.08$, $P = 0.002$), distance to the nearest tree ($t_{137} = 1.74$, $P = 0.08$) and number of nests per tree ($t_{137} = 1.98$, $P = 0.05$) did not differ between years.

Little Blue Heron nests at the Morrão colony were significantly lower ($t_{139} = 4.90$, $P < 0.0000$) compared to Saboó nests, although mean nest-tree height did not differ between colonies ($t_{139} = 0.19$, $P = 0.84$, also Tables 3–5). Nests at the Saboó colony, numerically dominated by Little Blue Herons, were farther from each other compared to the Morrão colony, where Scarlet Ibises were dominant (nest 1: $t_{137} = 4.69$, $P < 0.0000$; nest 2: $t_{137} = 5.56$, $P < 0.0000$; nest 3: $t_{137} = 5.73$, $P < 0.0000$; nest 4: $t_{137} = 5.92$, $P < 0.0000$). The number of nests per tree at Saboó (a mean of 2.78 against 15 nests/tree, $t_{139} = 8.88$, $P < 0.0000$) was much smaller than at Morrão.

Saboó heron nests were significantly lower compared to Scarlet Ibis nests (2.17 versus 3.42 m; $t_{264} = 8.39$, $P < 0.000$), indicating a preference for lower trees (4.59 against 5.25 m; $t_{264} = -4.62$, $P < 0.0000$). Also, compared to the ibises, heron nests were more distant from their neighbors of any species (nest1: $t_{264} = 6.83$, $P < 0.0000$; nest2: $t_{264} = 4.85$, $P < 0.0000$; nest3: $t_{264} = 4.47$, $P < 0.0000$; nest4: $t_{264} = 4.13$, $P < 0.0000$). We found no significant differences between ibis and heron nests in other spatial variables.

DISCUSSION

Little Blue Herons lack synchronous nesting, contrasting with the very synchronous Scarlet Ibises nesting nearby (Olmos & Silva e Silva 2001) Nests with eggs occur with young from all ages. Our observations suggest there are inter-annual variations in breeding periods of the herons probably due to climate, as low temperatures and persistent rains discouraged displaying by the males, which set the beginning of activities in the colony, and possibly food availability. During 1996, strong winds caused the death of at least one heron, found with a broken leg at the Saboó colony.

The development schedule we found in southeastern Brazil is very similar to that described for North American populations (Rodgers & Smith 1995), including incubation period and age of first flight, but young Brazilian birds seem to remain around the colony area for longer periods. Young herons in our study area seem to rely on their parents for almost two months, compared to five weeks for northern populations (Rodgers & Smith 1995). This difference is probably related to the migratory habits of northern birds.

The clutch sizes of Brazilian Little blue Herons (Table 2) seem small when compared to data from Trinidad (2–5 eggs; ffrench 1973) and Costa Rica (2–4 eggs; Stiles & Skutch 1989) but meaningful comparisons are not possible. North American populations (n = 29, Rodgers & Smith 1995) have mean clutch size ranging from 2.67 to 4.4 eggs, with a mode of three or four eggs. The only Little Blue Herons with a similar clutch size to the Brazilian ones live in freshwater and mangrove habitats in Florida (2.67 and 2.7 eggs, respectively) and Georgia (2.3 eggs; Rodgers & Smith 1995). In all other localities, mean clutch size was equal or greater than three.

Brazilian herons also produce fewer young compared to northern birds. Frederick & Collopy (1989) found 2.38 and 2.71 young/successful nest in the Everglades. In Lake Okeechobee, mean clutch sizes of 3.2 and 3.4 eggs produced 1.8 and 2.5 young/successful nest (Smith & Collopy 1995). Little Blue Herons breeding in all-white plumage have also been recorded in Florida (Rodgers 1980b). Besides one individual at the Morrão colony in 1996, another was observed incubating eggs and latter with small young in another colony in 1997.

Little Blue Herons in southeastern Brazil thus have smaller clutch sizes, lower productivity and an apparently longer dependence period compared to North American populations, where the species has larger clutches in higher latitudes and in freshwater habitats (Rodgers & Smith 1995). It would be interesting to verify if those life-history characteristics are linked to factors such as food supply and adult survivorship (see Ricklefs 2000). As the colonies in Santos-Cubatão are the southernmost reported in Brazil (I. Nascimento, CEMAVE, pers. com.), it would be interesting to get data on populations from northern Brazil where other mangrove-dwelling populations are known.

Although the proximate cause of death of starved birds could not be verified, symptoms are similar to those caused by the worm *Eustrongylides ignotus* (Spalding *&* Forrester 1993) which result in anorexia and behavioral changes which can lead to death. Fish are the intermediate hosts for *Eustrongylides ignotus*, a parasite favoring freshwater with high organic pollution (Spalding *et al.* 1993). During 1997, we observed leakages from a local garbage heap into the mangroves of the Saboó colony, increasing the high levels of organic pollution prevalent all over the area. The possibility of pollution-mediated parasitism being an important source of heron mortality deserves further research, as almost every estuary in southeastern Brazil is subject to increasing levels of pollution by sewage.

Little Blue Herons used nest-sites with different characteristics in the two studied colonies. Much of the variation is probably due to the different vegetation structures, as the Morrão colony was established in an area dominated by red mangroves with broad canopies and multiple trunks with aerial roots, causing them to be more stable and have more nest-sites, compared to the slender white mangroves common in the Saboó colony.

However, interaction with other species and the selection of display territories by males may also play a role in nest site characteristics. Scarlet Ibises seem dominant over Little Blue Herons as, in the absence of ibises, nests were higher on the trees of the Saboó colony. Ibises may appear to have monopolized higher nest sites, leaving the lower ones for the herons, but in fact the ibises congregated in only a few of the available trees (Olmos & Silva e Silva 2001). The reasons for herons building higher, more exposed (and more successful nests) at Saboó are unclear, but they may be related to the nearby Great Egrets nesting in even higher sites, and their engagement in anti-predator behavior. On the other hand, there were no Great Egrets in Morrão colony, frequently raided by Harri's Hawks, which took ibis nestlings from their higher nests (Olmos & Silva e Silva 2001). Lessened competition and a perceived lower vulnerability to predation may be a stimulus for Little Blue Heron males selecting more exposed display territories to attract mates, and eventually building nests.

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