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Breeding ecology of the Bare-Faced Ibis (*Phimosus infuscatus*) in Southern Brazil

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ABSTRACT. The Bare-faced Ibis is a gregarious bird found in South America. In the face of a rapid expansion in a southern state in Brazil and a lack of detailed information about the species' reproduction, two breeding areas were studied weekly for two consecutive seasons. We registered numbers and characteristics of adults, nests, eggs, and chicks, calculated success estimates, and assessed nest installation preferences. Chick morphology, age, and measurements served to define five growth stages. The species used the margins of two close rivers in Santa Catarina to build nests, lay eggs, and develop parental care between August and January, with success estimates as expected for the family. We observed a preference for the eastern margin of the rivers and proximity to bridges for nest installation, where the muddy margin provides resources for juvenile feeding. Two colony models were defined based on the near or far installation of the nests. Variations in egg and chick dimensions indicated higher adult investment in the second season, with negative allometric growth of the bill and tarsus of chicks related to weight. The results presented suggest favorable conditions for the species' reproduction in the region, a considerable factor in understanding its expansion in recent years.

Keywords: Aquatic birds; chicks; eggs; nests; reproductive success.

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Introduction

The Bare-Faced Ibis *Phimosus infuscatus* (Lichtenstein, 1823) is a gregarious aquatic bird with three recognized subspecies: *P. i. berlepschi* Helmayr 1903, found in Colombia, Ecuador, Brazil (northwest), Venezuela, the Guianas, and Surinam; *P. i. infuscatus* (Lichtenstein, 1823), in Bolivia, Paraguay, Argentina, and Uruguay; and *P. i. nudifrons* (Spix, 1825), in Brazil, south of Amazon (Sick, 1997; Matamala et al., 2020). The species inhabits open areas, wet meadows, pastures, savannas, marshes, rice fields, and margins of lagoons, swamps, and streams that are usually humid or flooded, where it feeds on small invertebrates and vegetable matter by probing part of its bill in the soil (Sick, 1997; Matamala et al., 2020).

Until 2003, surveys of the species in southern Brazil had been carried out in Paraná (Scherer-Neto & Straube, 1995) and Rio Grande do Sul (Belton, 1994; Sick, 1997; Dias & Burger, 2005; Guadagnin, Peter, Perello, & Maltchik, 2005; Silva, 2006; Acosta et al., 2010), but not in Santa Catarina, the state between them (Rupp et al., 2008; Piacentini et al., 2009), even though it was also expected to be found there (Rosário, 1996). However, *P. infuscatus* began to be reported in the state from 2003 onwards, in an accelerated colonization, with movement from south to north and east to west until the current occupation of almost the entire state (Rupp et al., 2008; Piacentini et al., 2009).

The main reasons for this rapid and recent territorial extension are not conclusive, but the replacement of natural areas for pastures and rice fields was considered by Rupp et al. (2008). On the other hand, Piacentini et al. (2009) reinforced the high importance of natural wetlands throughout the state as well, where the species was regularly observed in their research. This information demonstrates the need for more in-depth studies on the species, such as on its reproductive aspects, which were poorly studied until now (Miño & Del Lama, 2009), to assess breeding success estimates, which may help understand its potential for population expansion.

The current available information is from a few nests found in Mato Grosso (Almeida, Evangelista, & Silva, 2012) and studies focusing on other species in mixed colonies in Rio Grande do Sul (Petry & Hoffmann, 2002; Petry & Fonseca, 2005) and Santa Catarina (Grose, Cremer, & Moreira, 2012), as well as observations on nest

construction and the presence of chicks (Piacentini et al., 2009). These studies did not analyze the breeding ecology of the species in detail, which is important for understanding their colonization capacity and the development of conservation strategies (Quader, 2005; Miño & Del Lama, 2009).

After observing the daily movements of groups of *P. infuscatus* in the municipality of Itajaí, SC, we discovered a local population with reproductive sites on two close rivers in the city. The present study aimed to evaluate and provide information on the species' reproductive ecology, such as the breeding cycle, success estimates, incubation, parental care, nest site selection, and morphology of nests, eggs, and chicks.

Material and methods

Study area

The municipality of Itajaí (26°54'06" S, 48°39'40" W. Figure 1), located on the north-central coast of Santa Catarina, BR, presents a mesothermal humid climate of 21°C (Köppen classification), relative humidity of 80%, and rainfall from winter to summer (Schettini, 2002; Silva & Severo, 2018). Itajaí has around 100 km² of an urban area (Santa Catarina, 2016), where the final portions of the rivers Itajaí-Mirim (from now referred to as IM) and Itajaí-Açú (IA) are located. One of IA's margins belongs to the municipality of Navegantes.

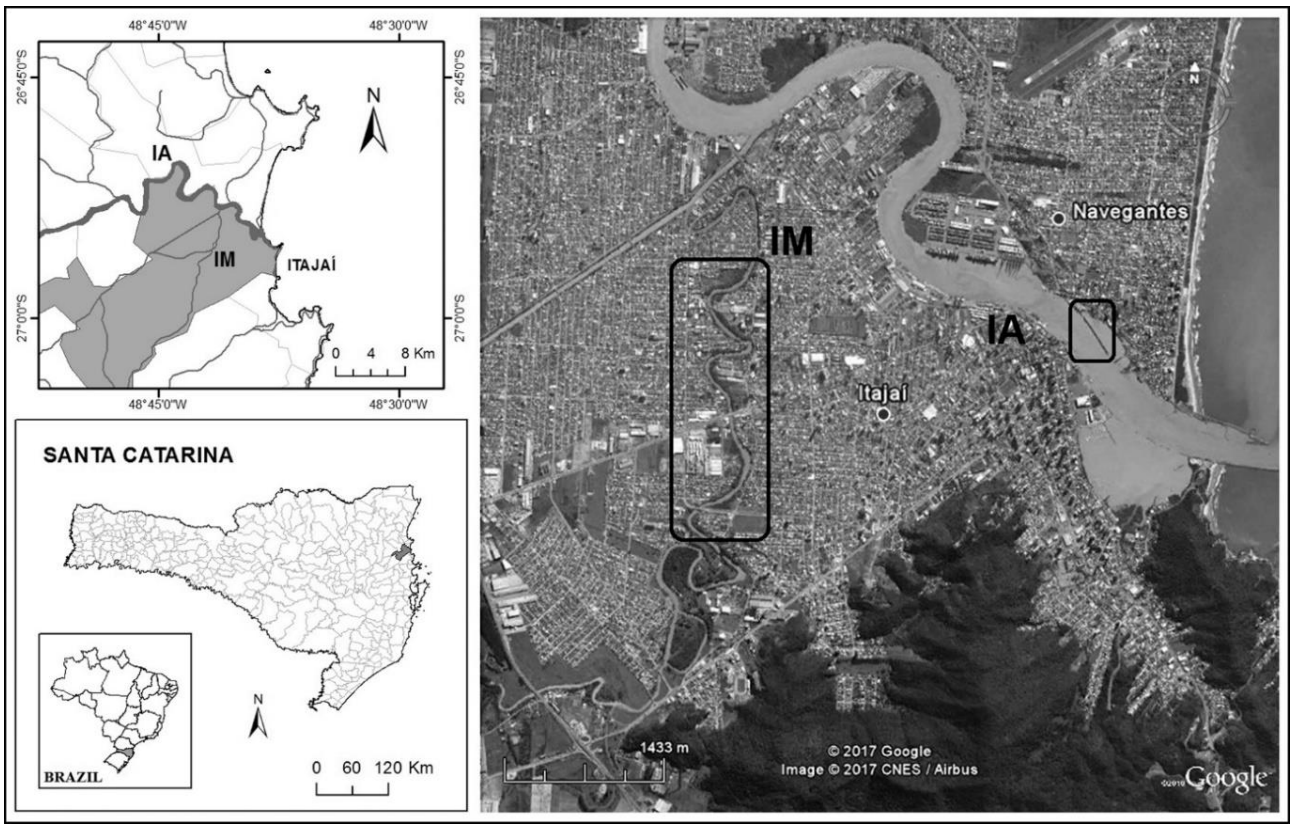


Figure 1. Maps of the study area focusing on breeding sites of *Phimosus infuscatus* in the final portions of the rivers Itajaí-Mirim (IM) and Itajaí-Açú (IA), researched in the breeding seasons of 2015 and 2016. Satellite image from Google Earth Pro.

The IM, between highway BR101 and its connection with the IA, is approximately 11 km long, 20–100 m wide, and has muddy margins with ciliary and bamboo vegetation where *P. infuscatus* installed nests to breed. From the connection of the rivers, the IA extends for 7 km into the sea, with around 250–450 m of width and margins predominated by urban areas (Figure 1). The breeding site was found near its mouth, in breakwaters with mangrove vegetation (Figure 1). The colony is close to the Saco da Fazenda, an estuarine environment important for local biodiversity (Branco, 2000). The rivers are impacted by port companies, the passage of small and large ships, ferry boats, marinas, and fishing (Schettini, 2002, 2008).

Methods

The breeding sites were discovered through the observation of daily movements of *P. infuscatus* above Itajaí and near both rivers. We visited the margins of the rivers weekly with a small, silent boat in search of

nests from August 2015 to January 2016 and August 2016 to January 2017. Sampling in the IA started in December 2015, when its site was found.

On each weekly visit, we registered number of nests, adults, eggs, and chicks, their characteristics, GPS coordinates, courtship (also in dormitories and feeding areas nearby), nest reuses, and chick losses. This data allowed us to assess the development of the breeding cycle and hatching success, chick survival, and reproductive success. We also recorded nearby vegetation and potential predators. Google Earth Pro software was used to obtain distances between nests and from nests to bridges, where we defined proximity up to 300 m.

We also recorded measurements of nests, chicks, and eggs. The length, width, height, and installation height of nests were obtained with a tape measure. The bill and right tarsus of chicks and the length and width of eggs were measured with a caliper ruler (± 1.0 mm). The weight of chicks and eggs were obtained with a Pesola dynamometer (± 1.0 g). The growth stages of chicks were defined according to morphology, age, mobility, and measurements. Chick capture was evaluated before the approach to avoid escapes and falls when they showed enough mobility to escape from the researcher, with accommodation in cloth bags to reduce stress. The eggs were marked with non-toxic paint, and in 2016 chicks were marked with metallic rings provided by CEMAVE. Each nest was researched in under 10 minutes to avoid abandonment by adults.

Data analysis

The Chi-square Test was used to assess differences in breeding cycle numbers between rivers in 2016, seasons for the IM, nest number by margin, and proximity to bridges ($p < 0.05$). Hatching success, chick survival, and reproductive success were analyzed as the percentage of hatched eggs per total laid eggs, flying capable chicks per hatched eggs, and flying chicks per total eggs, respectively (Belhadj, Chabi, Chalabi, & Gauthier-Clerc, 2007; Neigh et al., 2007).

Measurements of the distance between nests, installation height, nest size, number of eggs and chicks, and the number of days of incubation and parental care were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Bartlett's test) (Zar, 1999). According to the results, Student's t or Mann-Whitney U Tests were used to assess differences between rivers and seasons ($p < 0.05$). Curves were adjusted to verify the relationship between chicks' bills and right tarsus growth with their weights.

Results

Breeding seasons began in August and ended in December, except for 2016 in the IA, where it continued into January, 2017 (Table 1). Pairs of *P. infuscatus* developed courtship, copulation, nest building, laid and incubated eggs, and cared for chicks throughout this period (Table 1). During courtship, individuals with or without reddish throats and legs were observed sharing light pecks while walking on the ground in feeding areas. When perched in dormitory or reproductive areas, both individuals pecked vegetation branches in front of each other before starting copulation.

Table 1. Data from breeding events of *Phimosus infuscatus* recorded in the breeding seasons of 2015 and 2016 in the rivers Itajaí-Mirim and Itajaí-Açú in Itajaí, Santa Catarina, Brazil.

		Itajaí-Mirim				Itajaí-Açú			
		Period	Nests	Eggs	Chicks	Period	Nests	Eggs	Chicks
2015	Start	Aug	17 Aug	17 Aug	04 Sep	-	-	-	-
	End	Dec	07 Dec	07 Dec	07 Dec	Dec	15 Dec	01 Dec	15 Dec
	Duration (days)	120	113	113	95	-	-	-	-
2016	Start	Aug	24 Aug	24 Aug	19 Sep	Aug	30 Aug	08 Sep	04 Oct
	End	Jan/17	04 Jan	05 Dec	04 Jan	Dec	27 Dec	27 Nov	27 Dec
	Duration (days)	139	134	113	108	125	120	81	85

Numbers from seasons and comparisons between rivers and years determine the breeding cycle in the region in the research period (Table 2). Between seasons in the IM, the number of lost eggs was higher in 2016 (Table 2). Numbers were significantly higher in the IM than in the IA in 2016, except for nests with two eggs and inactive ones, which did not vary. Nest reuses occurred within a season (Table 2), but it was not possible to confirm couple fidelity. However, some reutilizations happened during late parental care, which suggests the persistence of the same couple. Ten nest sites from 2015 were reused in 2016, even though nests totally or almost vanished between seasons.

The mean number and standard deviation of clutch size, days of incubation, and parental care showed few differences between rivers and years (Table 2). Between seasons in the IM, parental care was longer in 2015 ($t = 7.49$, $df = 28$, $p < 0.05$). Adults took turns foraging in the daytime during incubation and parental care, which occurred in a total time of 59.96 ± 7.38 days.

Table 2. Data from the breeding of *Phimosus infuscatus* with differences assessed through Chi-square Tests (χ^2, degrees of freedom and p significance), and mean number and standard deviation of clutch size (CS), days of incubation (DI), and parental care (DC), recorded in 2015 and 2016 in the rivers Itajaí-Mirim (IM) and Itajaí-Açú (IA) in Itajaí, Santa Catarina, Brazil.

	Itajaí-Mirim		Itajaí-Açú		IM 2015 vs 2016			IM vs IA 2016		
	2015	2016	2015	2016	χ^2	d.f.	p	χ^2	d.f.	p
Adults	66	76	20	28	0.57	1	> 0.05	21.24	1	< 0.05
Nests	33	38	10	14	0.35	1	> 0.05	11.08	1	< 0.05
Nests with 1 egg	4	4	2	0	-	-	-	-	-	-
2 eggs	6	6	4	6	0.00	1	> 0.05	0.00	1	> 0.05
3 eggs	12	22	3	6	2.38	1	> 0.05	0.04	1	< 0.05
4 eggs	11	6	1	2	0.94	1	> 0.05	-	-	-
Number of Eggs	96	106	23	34	0.40	1	> 0.05	36.01	1	< 0.05
Inactive Nests	3	7	17	8	-	-	-	0.00	1	> 0.05
Lost Eggs	12	31	0	4	7.53	1	< 0.05	19.31	1	< 0.05
Reused Nests	3	6	0	1	-	-	-	-	-	-

	Itajaí-Mirim				Itajaí-Açú			
	2015		2016		2015		2016	
	N	$\bar{x}$ ± SD	N	$\bar{x}$ ± SD	N	$\bar{x}$ ± SD	N	$\bar{x}$ ± SD
CS	33	2.91 ± 1.01	38	2.79 ± 0.84	10	2.30 ± 0.95	14	2.43 ± 0.73
DI	10	22.00 ± 0.82	21	21.67 ± 0.91	0	-	9	21.89 ± 0.78
DC	11	46.18 ± 3.97	19	34.63 ± 4.13	0	-	6	36.00 ± 2.45

Hatching success presented a small decrease between years in both rivers, while chick survival and reproductive success increased in the second year (Table 3). We registered six animal species with potential to predate eggs and chicks of *P. infuscatus* near the colonies in both rivers and seasons: Tegu lizards, *Salvator merianae* (Duméril and Bibron 1839); domestic cats, *Felis catus* (Linnaeus 1758); Swallow-tailed Kites, *Elanoides forficatus* (Linnaeus 1758); Yellow-headed Caracaras, *Milvago chimachima* (Vieillot 1816); Kelp Gulls, *Larus dominicanus* (Lichtenstein 1823); and Black-crowned Night-Herons, *Nycticorax nycticorax* Linnaeus 1758. However, no acts of predation were observed during the study.

Table 3. Hatching success, chick survival, and reproductive success of *Phimosus infuscatus* recorded in the breeding seasons of 2015 and 2016 in the rivers Itajaí-Mirim and Itajaí-Açú in Itajaí, Santa Catarina, Brazil.

Success	Itajaí-Mirim		Itajaí-Açú	
	2015	2016	2015	2016
Hatching	85.54%	71.29%	100%	89.47%
Chick Survival	47.88%	66.23%	43.47%	70.58%
Reproductive	40.96%	47.22%	43.47%	63.15%

Phimosus infuscatus built nests above water in 11 different tangled vegetation species. Ten were recorded in the IM: Brazilian peppertrees, *Schinus terebinthifolius* (58.54%); Giant Leather Ferns, *Acrostichum danaeifolium* (10.98%); Bamboos, *Bambusa sp.* (9.76%); Black Mulberries, *Morus nigra* (7.32%); Jumbays, *Leucaena leucocephala* (6.10%); Asian bamboos, *Phyllostachys sp.* (2.44%); Jamaican nettletrees, *Trema micrantha* (1.22%); candlenut trees, *Aleurites moluccana* (1.22%); Chinese hibiscus, *Hibiscus rosa-sinensis* (1.22%); and common lantanas, *Lantana camara* (1.22%); but in only one species in the IA: white mangroves, *Laguncularia racemosa* (100%).

The mean number and standard deviation of the distance between nests and their installation height showed few differences between rivers and years (Table 4). Comparing values from rivers in 2015, the nest distance was higher in the IM ($U = 52.00$, $p < 0.05$) and the installation height in the IA ($U = 246.50$, $p < 0.05$), while in 2016 only the distance between nests remained higher in the IM ($U = 131.00$, $p < 0.05$). Isolated pairs in one river and near each other in the other define two colony models in the same region. Between seasons in the IM, the installation height was higher in 2015 ($U = 787.00$, $p < 0.05$).

Table 4. Mean number and standard deviation of the distance (in meters) between nests (DN), and their installation height (IH) during *Phimosus infuscatus* breeding recorded in 2015 and 2016 in the Itajaí-Mirim and Itajaí-Açú rivers in Itajaí, Santa Catarina, Brazil.

	Itajaí-Mirim				Itajaí-Açú			
	2015		2016		2015		2016	
	N	$\overline{x}$ ± SD	N	$\overline{x}$ ± SD	N	$\overline{x}$ ± SD	N	$\overline{x}$ ± SD
DN	25	72.52 ± 52.14	32	59.89 ± 55.91	24	14.25 ± 35.03	17	21.35 ± 35.27
IH	36	1.83 ± 0.81	46	1.73 ± 0.93	26	2.44 ± 0.91	14	2.00 ± 0.48

We found 22 nests in the eastern margin of the IM and 11 in the western in 2015, while 15 and 11 were recorded, respectively, in the IA. In 2016, 33 and 13 were found in the eastern and western margins of the IM and 10 and eight in the IA, respectively. There was a preference for the eastern margin in the IM (χ^2 = 12.16, df = 1, $p < 0.05$), mainly in 2016 (χ^2 = 7.95, df = 1, $p < 0.05$, Figure 2). Also, more nests were built near bridges than away from them in the IM (2015: 23 and 10, χ^2 = 4.36, df = 1, $p < 0.05$; 2016: 37 and 12, χ^2 = 11.75, df = 1, $p < 0.05$, Figure 2).

Figure 2. Nests of *Phimosus infuscatus* according to margins and proximity to bridges (center of the transparency circles) recorded in 2015 and 2016 in the Itajaí-Mirim and Itajaí-Açú rivers in Itajaí, Santa Catarina, Brazil.

Nests were built in a basket shape, using leaves and other flexible items in the center and resistant sticks in the periphery, sometimes with thorns. The means and standard deviations of the dimensions had few variations between rivers and years (Table 5). Comparing rivers, the length and width of the nests were higher in the IM in 2015 ($t = 3.63$, df = 60, $p < 0.05$; $t = 2.18$, df = 60, $p < 0.05$), as well as the width between breeding seasons ($U = 403.50$, $p < 0.05$).

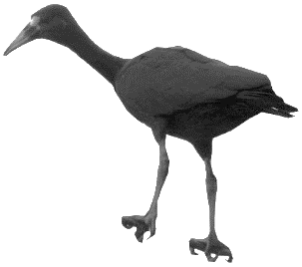
Table 5. Mean number and standard variation of the length (Lt), width (Wi), height (Ht), and weight (Wt) of nests and eggs of *Phimosus infuscatus* recorded in the breeding seasons of 2015 and 2016 in the rivers Itajaí-Mirim and Itajaí-Açú in Itajaí, Santa Catarina, Brazil.

		Itajaí-Mirim				Itajaí-Açú		
Nests	N	Lt (cm) $\overline{x}$ ± SD	Wi (cm) $\overline{x}$ ± SD	Ht (cm) $\overline{x}$ ± SD	N	Lt (cm) $\overline{x}$ ± SD	Wi (cm) $\overline{x}$ ± SD	Ht (cm) $\overline{x}$ ± SD
2015	36	33.65 ± 6.07	28.85 ± 6.59	14.10 ± 4.59	26	27.88 ± 6.31	25.11 ± 6.72	13.35 ± 3.57
2016	46	30.89 ± 5.71	24.59 ± 5.71	14.00 ± 3.29	14	30.50 ± 3.86	26.00 ± 4.22	13.28 ± 2.58
Eggs	N	Lt (mm) $\overline{x}$ ± SD	Wi (mm) $\overline{x}$ ± SD	Wt (g) $\overline{x}$ ± SD	N	Lt (mm) $\overline{x}$ ± SD	Wi (mm) $\overline{x}$ ± SD	Wt (g) $\overline{x}$ ± SD
2015	89	47.92 ± 1.99	34.95 ± 1.80	32.54 ± 2.98	8	47.07 ± 1.65	31.42 ± 1.24	23.19 ± 9.80
2016	196	48.47 ± 2.00	34.79 ± 1.12	31.19 ± 2.93	51	48.32 ± 1.38	34.80 ± 1.15	32.61 ± 2.49

Eggs showed coloration ranging from green to light blue and were laid asynchronously, and were always found dirty with mud. The mean values and standard deviations of their dimensions presented some variations between rivers and years (Table 5). Comparing seasons in the IM, eggs were heavier in 2015 ($U = 6726.50$, $p < 0.05$) and longer in 2016 ($t = 2.15$, $df = 283$, $p < 0.05$); while in the IA, length, width, and weight were higher in 2016 ($t = 2.32$, $df = 57$, $p < 0.05$; $t = 7.66$, $df = 57$, $p < 0.05$; $U = 60.50$, $p < 0.05$). Between rivers in 2015, width and weight were higher in the IM ($t = 5.42$, $df = 95$, $p < 0.05$; $U = 71.50$, $p < 0.05$).

The age and overall characteristics of chicks were used to define five growth stages (described in Table 6), recorded simultaneously during breeding seasons. During the juvenile stage, chicks were observed requesting food from parents in flight. This dependency decreased until they began gathering to forage in the margins before joining adults and leaving the reproductive area at the ends of the seasons.

Table 6. Growth stages, ages, and characteristics of chicks of *Phimosus infuscatus* defined during the breeding seasons of 2015 and 2016 in the Itajaí-Mirim and Itajaí-Açú rivers in Itajaí, Santa Catarina, Brazil.

Stage	Age (days)	Picture	Characteristics
F1	1 to 7		Sparse plumage, pin feathers on wings and tail, distended abdomen, fragile white-pink legs with no mobility, nails dark at base and white at the tip, dark blue forehead, closed eyes (initially), black transversal strip at the bill, egg tooth.
F2	8 to 14		Similar to F1, with developed feather shafts, little mobility, bill strip also visible internally, and no egg tooth.
F3	15 to 25		Dense body plumage, wing and tail feathers emerging from shafts, reduced abdomen distension, elongated black legs with good mobility, black nails, fading blue on the forehead, thicker bill strip, chases adult through branches near nest.
F4	26 to 36		Fully developed wings and tails, strong legs with perfect mobility, whitish forehead, small bill losing the stripe, wing exercises, and flight training.
Juvenile	37 +		Full juvenal plumage, flight capability, forehead, and bill approximate to adult's color, the bill still growing, independent feeding.

The number of chicks gradually decreased between stages (Table 7). Comparisons of quantities between rivers presented differences (Table 7). In 2016, all values were higher in the IM, but no variation was found between seasons for the river.

Table 7. Data from chicks of *Phimosus infuscatus* with differences assessed through Chi-square Tests (χ^2, degrees of freedom and p significance) recorded in the breeding seasons of 2015 and 2016 in the Itajaí-Mirim (IM) and Itajaí-Açú (IA) rivers in Itajaí, Santa Catarina, Brazil.

	Itajaí-Mirim		Itajaí-Açú		IM vs IA 2016			IM 2015 vs 2016		
	2015	2016	Dec 2015	2016	χ^2	df	p	χ^2	df	p
Chicks F1	71	77	23	38	12.56	1	< 0.05	0.17	1	> 0.05
F2	62	76	20	38	12.01	1	< 0.05	1.22	1	> 0.05
F3	52	55	18	32	5.56	1	< 0.05	0.08	1	> 0.05
F4	34	51	16	32	3.90	1	< 0.05	3.01	1	> 0.05
Juveniles	34	51	10	24	9.01	1	< 0.05	3.01	1	> 0.05
Lost Chicks	37	26	13	14	6.25	1	< 0.05	1.59	1	> 0.05

The means and standard deviations of the bill, right tarsus, and weight of the first three stages of chicks showed small variations between rivers and years (Table 8) and completed the growth stages definitions. Comparing seasons in the IM, the tarsus of the F2 was higher in 2015 ($t = 2.34$, $df = 88$, $p < 0.05$), while the F1 and F2 bills and weight of the F1 were higher in 2016 ($t = 2.79$, $df = 107$, $p < 0.05$; $t = 2.21$, $df = 88$, $p < 0.05$; $t = 2.48$, $df = 107$, $p < 0.05$); and in the IA, the F3 tarsus and weight were higher in 2016 ($U = 0.00$, $p < 0.05$; $U = 1.50$, $p < 0.05$). Between the rivers in 2016, the tarsus of the F1 and F3 were higher in the IA ($t = 1.99$, $df = 74$, $p < 0.05$; $t = 2.05$, $df = 28$, $p < 0.05$). The growth of the bill and tarsus was considered negatively allometric in relation to weight (Figure 3).

Table 8. Mean number and standard deviation of the length of the bill (B), right tarsus (T), and weight (W) of the first growth stages (F1, F2, F3) of *Phimosus infuscatus* chicks in 2015 and 2016 in the Itajaí-Mirim and Itajaí-Açú rivers in Itajaí, Santa Catarina, Brazil.

		Itajaí-Mirim				Itajaí-Açú			
		N	B (mm) $\bar{x} \pm SD$	T (mm) $\bar{x} \pm SD$	W (g) $\bar{x} \pm SD$	N	B (mm) $\bar{x} \pm SD$	T (mm) $\bar{x} \pm SD$	W (g) $\bar{x} \pm SD$
2015	F1	50	18.20 ± 4.51	21.34 ± 5.20	78.40 ± 40.25	8	20.19 ± 4.71	24.42 ± 3.90	91.25 ± 36.81
	F2	40	26.93 ± 2.71	35.95 ± 3.73	185.37 ± 22.46	0	-	-	-
	F3	18	42.32 ± 4.97	52.48 ± 5.61	302.78 ± 34.90	3	36.03 ± 2.63	45.40 ± 3.55	256.67 ± 28.87
2016	F1	59	20.40 ± 3.70	22.56 ± 5.40	97.63 ± 40.43	17	22.04 ± 2.22	25.44 ± 4.66	118.23 ± 31.67
	F2	50	28.29 ± 3.04	34.17 ± 3.50	188.10 ± 24.51	17	29.42 ± 2.90	34.99 ± 4.12	198.82 ± 26.43
	F3	22	39.31 ± 5.45	51.04 ± 4.84	296.36 ± 36.29	9	37.90 ± 7.54	54.80 ± 2.91	310.00 ± 20.70

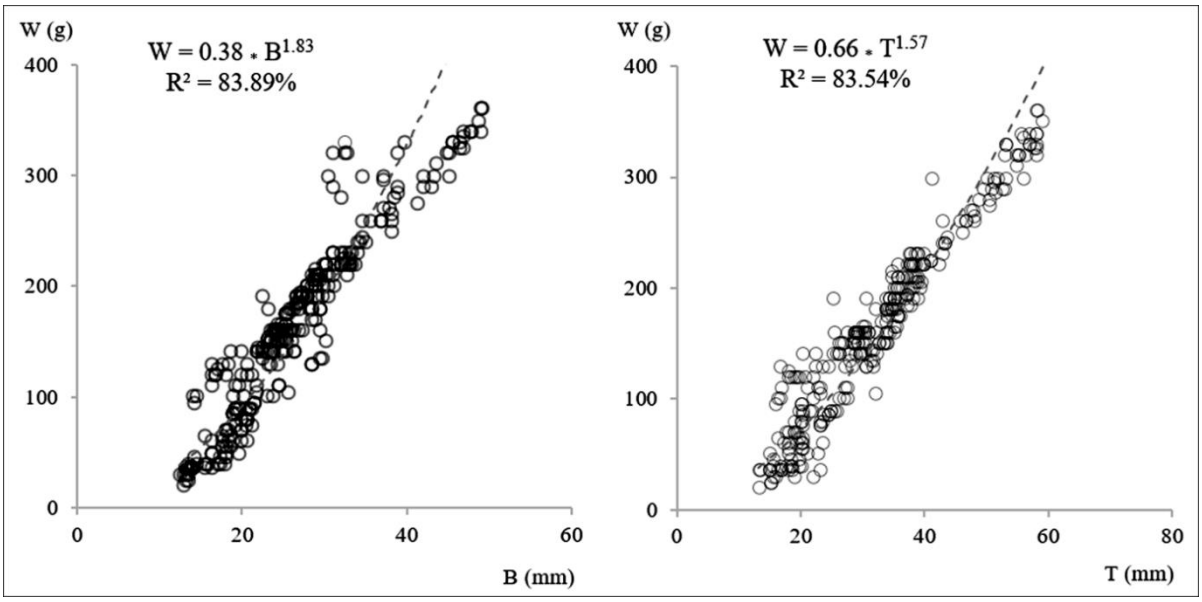


Figure 3. Adjusted curves between measurements of the bill (B), right tarsus (T), and weight (W) of the three first growth stages of *Phimosus infuscatus* chicks recorded in 2015 and 2016 in the Itajaí-Mirim and Itajaí-Açú rivers in Itajaí, Santa Catarina, Brazil.

Discussion

According to Piacentini et al. (2009), the first observation records of *P. infuscatus* in Itajaí occurred on August 8, 2008, on Highway SC486 and in the IM. Since then, there has been no more detailed information for the municipality, even though the species presents a local population, daily movements, forages in urban and rural areas, and breeds in local rivers, aspects here documented for the first time. The data presented here contributes to the knowledge of the species and its recent expansion, recorded by Rupp et al. (2008) and Piacentini et al. (2009).

The breeding cycles presented in this study occurred from winter to summer, which is when there is rainfall and a consequent increase in food resources for aquatic birds (Branco, 2003). *Phimosus infuscatus* also started breeding in August for two seasons in Rio Grande do Sul (Petry & Hoffmann, 2002; Petry & Fonseca, 2005). However, in the observations of Piacentini et al. (2009) and in the season studied by Grose et al. (2012), both in Santa Catarina, breeding occurred later, between September and December and October and February, respectively, close to what Matamala et al. (2020) reported in the Brazilian southeast. In Mato Grosso, nests were reported before October (Almeida et al., 2012). These differences suggest some degree of adaptability of the species to start the breeding cycle, where it waits for periods of rainfall and available food resources (Branco, 2003).

Courtship and copulation are still poorly studied in aquatic birds (Miño & Del Lama, 2009), but the behaviors recorded for *P. infuscatus* in this study correspond to those of other threskiornithids (Winkler, Billerman, & Lovette, 2020). The asynchronous laying and hatching of eggs, as well as biparental care during incubation and feeding offspring, have been documented for the family (Winkler et al., 2020), but not specifically for *P. infuscatus*. The species may exhibit these behaviors because it also visits distant areas to forage, which takes prolonged time and leaves the offspring vulnerable, similar to what is discussed by Cockburn (2006) for nine waterbird families that forage at sea and return to land to breed and feed offspring. The incubation time was also the same as reported in the literature, but parental care had a longer duration in our study, similar to what was recorded for another aquatic bird, *Egretta caerulea* (Linnaeus, 1758), by Olmos and Silva (2002). This result may indicate juvenile resistance to leaving the nest region if it presents favorable conditions, such as food resources and protection by the presence of adults and other chicks (Geffen & Yom-Tov, 2000).

The numbers of adults, nests, eggs, and chicks recorded here were higher than in the above studies. Petry and Hoffmann (2002) and Petry and Fonseca (2005) found 31 nests, of which 23 produced 72 eggs, but only 15 contributed 42 chicks in two seasons combined; Grose et al. (2012) recorded six nests in one season; Almeida et al. (2012) seven nests; and Piacentini et al. (2009) reported a colony with more than 54 individuals. Some of these studies were developed in mixed colonies (Petry & Hoffmann, 2002; Petry & Fonseca, 2005; Grose et al., 2012), where threskiornithids are generally found in higher abundance (Winkler et al., 2020). These differences may suggest that the population here had better conditions to breed in the region for that period, possibly with lower species competition for resources while breeding in a monospecific colony. Monitoring of these colonies could help identify other variables influencing these numbers.

Considering the numbers discussed above, as well as lost eggs and reused nests here in this study, variations between rivers indicate a better situation in the IM than in the IA for the second season. The differences in the number of lost eggs for the IM between the two seasons also point to a better condition for the population in 2016. This circumstance may indicate the participation of new reproductive individuals from the season before or coming from other populations in the region, as the colony increased between years (Branco, 2003; Efe, 2004). Also, the rivers may be influenced by different aspects in their proximity, with possibly lower negative impacts in the second year. Availability of food resources and vegetation for nest installation, and the influence of predation, floods, and anthropic impacts need to be better assessed in the future through monitoring these and other breeding populations (Branco, 2003; Kushlan & Hancock, 2005; Kelly, Stralberg, Etienne & McCaustland, 2008). For example, the small number of nests in the IA may be related to disturbances caused by port undertakings carried out in the region during the period, which can increase the daily pressure on the area (Schettini, 2002, 2008).

The clutch size found here also followed the family and species pattern (Matamala et al., 2020). Petry and Fonseca (2005) registered similar variations between one and four eggs, as well as Almeida et al. (2012), with nests with two to three eggs. It is also possible that these oscillations happen according to the quality of the feeding areas and other variables near the breeding site (Martin, 1995; Kushlan & Hancock, 2005; Kelly et al., 2008).

Both areas presented success estimates as expected for the family, where up to 80% of couples are successful in the best years (Winkler et al., 2020), a good indication for the species' permanence and expansion in the area. *Phimosus infuscatus* is considered to present medium sensitivity (Parker III, Stotz, & Fitzpatrick, 1996), being affected, for example, by the use of pesticides (Sick, 1997). However, resource supplies, floods, and predation are best known for influencing reproduction (Fasola, 1998; Kushlan & Hancock, 2005; Kelly et al., 2008). In Venezuela, more than 80% of eggs and juveniles were lost to predation in one season (Matamala et al., 2020), which was also recorded by Almeida et al. (2012) in Mato Grosso. Even though we didn't witness acts of predation in this study, *S. merianae* and *F. catus* are known to affect bird populations in urban areas (Kiefer & Sazima, 2002; Baker, Bentley, Ansell, & Harris, 2005), and were the potential predators seen the closest to nests.

The construction of most nests on *S. terebenthifolius* is probably related to the entanglement of the its branches, as also occurs in some of the other recorded plant species. This aspect helps with camouflage by reducing visibility to aerial predators, while the position above water makes nests difficult to reach for terrestrial ones (Kushlan & Hancock, 2005). The installation height of the nests is also thought to be related to the susceptibility of the family to floods (Winkler et al., 2020), as well as to the presence of different vegetation recorded between rivers, where *P. infuscatus* may benefit from areas where the vegetation is taller.

Waterbird colonies generally involve large numbers of individuals in close nests (Sick, 1997; Frederick, 2002; Gianuca, Branco, & Vooren, 2011). The two colony models found here, based on the distance between nests, demonstrates flexibility on intraspecific relations during breeding. This dynamic was different from the isolation on reeds reported for the species by Sick (1997), but corresponded to the slight aggregation mentioned by Matamala et al. (2020) for the family. Grose et al. (2012) observed a group of three nests and another with two, which is insufficient for characterization. The proximity between nests is generally related to the distance, quantity, and quality of food available in foraging areas (Erwin, Haig, Stotts, & Hatfield, 1996; Frederick, 2002).

The preference for the eastern margin suggests a relation to higher sunlight incidence, as observed for nests of *Theristicus melanopis* (Gmelin, 1789) built pointing southwest in Chile (Hoekman, Ball, & Fondell, 2002; Raimilla, Rau, & Niklitschek, 2015; Gantz & Yañez, 2016). On the other hand, *P. infuscatus* built more nests in the center of a mixed colony in Rio Grande do Sul, which may have been influenced by the presence of other species (Petry & Fonseca, 2002; Petry & Hoffmann, 2005). The nest proximity to bridges suggests a search for reference points in their construction and a greater extension of a visible margin with food available for juveniles, even though such buildings represent anthropic pressure and possible negative influence on reproductive success. However, juvenile aggregations foraging in these visible margins next to bridges indicates favorable conditions, as well as protection, by the presence of adults and other chicks, which can monitor the group together (Geffen & Yom-Tov, 2000).

The nest format and building materials, as well as the color of eggs, correspond to the literature on the family, presenting some degree of camouflage in the vegetation (Simon & Pacheco, 2005; Almeida et al., 2012; Winkler et al., 2020). The specific description for *P. infuscatus* is important for a wider knowledge of its biology (Simon & Pacheco, 2005; Miño & Del Lama, 2009). Considering nest dimensions, there was only one report of a 26 cm diameter nest in Mato Grosso (Almeida et al., 2012), similar to what was recorded here. Differences in the nest sizes between rivers in 2015 reflect the measurement at the end of the period in the IA, when they may be less elaborate or shattered by the activity of young and adults. Almeida et al. (2012) recorded egg dimensions of 46.41 x 33.48 mm, which is also close to what was found in our study. Variations in egg measurements may indicate better use of food resources by adults during the second season (Branco, 2003; Efe, 2004). The availability of food resources is considered essential for quality during breeding (Martin, 1995; Fasola, 1998; Kelly et al., 2008).

The literature presents only simple descriptions of dark plumage in chicks (Matamala et al., 2020), without distinctions of growth stages, variations, and measurements. A better definition of chick growth stages will help future studies on the species' reproduction have better assessment of success estimates. This camouflage plumage, as well as the juveniles gathering to forage in the margins before joining the adults, is important for their defense against predators, increasing survival chances in the first weeks of life (Efe, 2004; Matamala et al., 2020). Grose et al. (2012) also found juvenile aggregations near the studied mixed colony, but did not specify the presence of *P. infuscatus*.

Variations found in the morphometry of chicks suggest a better resource investment by adults in their offspring during the second year (Branco, 2003; Efe, 2004). The quantity and quality of food resources is essential at this moment, providing efficiency for the reproductive season (Olmos & Silva, 2002; Kelly et al.,

2008). The chicks' bills and tarsi fast growth associated with their weight reflects the rapid development of these body parts for them to join adults and the reproductive population as soon as possible (Branco et al., 2010; Matamala et al., 2020). Additions of new reproductive individuals each season represents a growing population and furthers the species' stabilization in the area. We hope that chicks banded in this study can be recorded again in future monitoring research and observations on feeding areas and dormitories to understand even more about their presence in the region.

Conclusion

This research describes important information on the breeding of *P. infuscatus*. The results suggest favorable conditions for nesting in coastal areas of Santa Catarina, an important factor in the understanding of its population expansion in recent years as recorded by Rupp et al. (2008) and Piacentini et al. (2009). The existence of other reproductive areas on the coast of the state is probable, and study of those areas will contribute even further to the knowledge of this species.

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