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ARTICLE

Breeding biology review of White-backed Stilt *Himantopus melanurus* in Brazil and a case study in the largest restinga protected area (Aves, Charadriiformes, Recurvirostridae)

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Abstract. In Brazil, the White-backed Stilt *Himantopus melanurus* is distributed in the midwest, south and southeast but breeding information is scarce. In this study, species breeding information in the country was compiled from online platform (WikiAves, eBird) and literature. A case study describing nests and egg biometry were reported in Restinga of Jurubatiba National Park (RJNP), on the north cost of Rio de Janeiro state, as well potential threats to the species. Sampling was carried out in September and December 2018, monthly in 2019 and between January to March and September to December in 2020. Overall, 70 breeding records were compiled, between 1997 and November 2021, being 64 from WikiAves in all regions of Brazil, four records from eBird in São Paulo state (in 2021) and two records in literature (one from São Paulo state, in 2007 and one from Rio de Janeiro in 2012). In RJNP, 44 nests were identified being 34 active, with an average of 3.5 eggs per nest, and overall 118 eggs were measured. The main materials used to build the nests were the saltmarsh plant and mud. Around 60% of nests were degraded or predated. Predation was the main cause of egg loss. Successful nests (with chicks or hatching signs) represented 26% of the total nests monitored. This study reports the first information on the biometry of the species' eggs and nests, confirming the northern coast of Rio de Janeiro state as a nesting area for the species.

Keywords. Coastal lagoons; Recurvirostridae; Reproduction; Restinga de Jurubatiba; Shorebirds; Online platforms.

INTRODUCTION

Charadriiformes includes 19 families, 95 genera with 383 species, being one of the largest orders in the Aves group (Billerman *et al.,* 2020). Among the families, Recurvirostridae has three genera, with *Himantopus* and *Recurvirostra* considered cosmopolitan, and *Cladorhynchus* is monotypic and with distribution restricted to Australia (Pierce & Bonan, 2020; Winkler *et al.,* 2020). Among the three genera, *Himantopus* has the most controversial taxonomy (Robinson *et al.,* 2020). Some authors identify three to five subspecies (Iqbal *et al.,* 2010; AOU, 1998; Robinson *et al.,* 2020), others consider only one (Johnsgard, 1981), two (Pierce, 1996; Pierce & Bonan, 2020) or five global species, and the Black-backed Stilt *Himantopus mexicanus* (Statius Muller, 1776) is distributed in North and Central America while the White-backed Stilt *H. melanurus* Vieillot, 1817 occurs in South America (Gochfeld *et al.,* 1984; Robinson *et al.,* 2020). In Brazil, the occurrence of both species is recognized (Pacheco *et al.,* 2021). The White-backed Stilt is distributed in southern Peru, Bolivia, Argentina, Paraguay, Chile and Uruguay. In Brazil, the species occurs in the midwest, southeast and southern regions (Sick, 1997; Robinson *et al.,* 2020). It was considered short-distance migratory in southern Brazil, as it nests inland and lives on coastal beaches during the non-breeding period, generally seen in flocks of dozens of individuals (Belton, 1984; Vooren & Brusque, 1999). However, the White-backed Stilt is not listed as migratory or partially migratory in a comprehensive review of migratory birds in Brazil (Somenzari *et al.,* 2018; Jahn *et al.,* 2020).

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Recurvirostrids nest in colonies (Nicholson, 1929; Hamilton, 1975) and build their nests on the ground. The White-backed Stilt breeds on the muddy shores of lakes, lagoons, swamps, mangroves, rice paddies, estuaries, and river and sea beaches (Sick, 1997; Vooren & Brusque, 1999; Sigrist, 2009). The species breeding areas are little known in Brazil, as well as their breeding period, characterization and biometry of eggs and nests have not been described. In the literature, the nests of the species were previously recorded in Guarapiranga, SP, in 2007 (Schunck *et al.,* 2016) and in Quissamã, on the northern coast of the Rio de Janeiro state (Tavares & Siciliano, 2013). Breeding records of its cogeneric species (*H. mexicanus*) were reported in Rio Grande do Norte (Lunardi *et al.,* 2015; Mendonça *et al.,* 2019) and on the northern coast of Bahia (Santos & Lima, 2004).

Literature and online plataforms (WikiAves, E-bird) review has been widely used to update information of birds species occurrence (Martínez-Curci *et al.,* 2014; Frias *et al.,* 2020a; Barbosa *et al.,* 2021; Pinheiro *et al.,* 2021; Kaiser *et al.,* 2022), breeding (Scherer *et al.,* 2013; Guilherme & Lima, 2020; Tubelis, 2020; Tubelis & Sazima, 2020; Frias *et al.,* 2020b; Alexandrino *et al.,* 2022), and migration (Schubert *et al.,* 2019; Degroote *et al.,* 2020).

This study reviewed breeding records of the White-backed Stilt in Brazil compiled from literature review (scientific articles) and online platforms (WikiAves and eBird), from 1997 to April 2022. Furthermore, a local case study of breeding aspects and the identification of main threats to the species were carried out in Restinga of Jurubatiba National Park (RJNP), in the north coast of Rio de Janeiro state. These are essential information that may contribute to habitat management for species conservation, especially in protected areas as RJNP.

MATERIAL AND METHODS

Study area

The study area comprises the RJNP and its surroundings (Table 1), about 20 meters from the park's edge, called "Adjacent area". RJNP has 18 coastal lagoons, and is 44 km long, 2 to 4 km wide, totaling around 15,000 hectares, encompassing the municipalities of Macaé, Carapebus and Quissamã in the north coast of Rio de Janeiro state (Fig. 1). Restingas are characteristic habitats of the Atlantic Forest, located in coastal lowlands. They are composed of dunes and sandy ridges of recent formation, existing along thousands of kilometers of the Brazilian coast and with characteristic herbaceous plants (Rocha *et al.,* 2004). In the Rio de Janeiro state, few restinga areas are in protected areas and, among them, the RJNP is considered the largest restinga of the state and one of the largest in Brazil (Rocha *et al.,* 2004). However, all restingas are Permanent Preserved Areas according to Brazilian Forest Code (Law 12651/2012). The climate in the region is warm (annual average of 24°C) and rainy (35 and 180 mm), with the dry season in autumn and winter (Fischer *et al.,* 2007).

RJNP preserves sandbank and restinga habitats (Rocha *et al.,* 2004). However, it has some environmental conflicts, such as subsistence fishing, domestic effluents dumping in some lagoons, lack of sewage treatment plant in the Park area in Quissamã, agricultural and livestock activities (ICMBio, 2007).

Secondary data compilation

Search in scientific literature (scientific articles) and online platforms were carried out. For literature review it was used the following keywords in Google Academic: "Breeding", "reproduction", "biometry", "life history", *"Himantopus melanurus", "Himantopus himantopus mexicanus"* and *"Himantopus mexicanus".* On WikiAves (https://www.wikiaves.com/buscaavancada.php), an advanced search was carried out based on the species name (*Himantopus melanurus*) + photo content (egg; nest); or age (chicks) or observed action (mating; hatching; feeding the chicks; building the nest). We carefully check to avoid duplicate record of species breeding. On eBird, photos of the species were searched with the filter "reproducing" and all actions present, "age" – juvenile. The last search on online platforms was on April 18, 2022.

Field sampling

Two expeditions per month were carried out in eight RJNP lagoons: Garças, Maria Menina, Robalo, Visgueiro, Catingosa, Pires, Barrinha, Casa Velha, Ubatuba and adjacent area (temporary wetlands, see details in "study area" section, Table 1). Observations were carried out between 07:00 and 15:00, totaling 25 h in the field in 13 days of observations (Table S1).

The identification of White-backed Stilt colonies was done through active search in areas with many individuals or when they were seen incubating. The sighting was carried out by two observers with the aid of binoculars (Nikon Prostaff 10 × 42) and spottingscope (Celestron 22-66 × 100). Nests were approached when the adult birds were not close. Each nest was marked with a numbered label, photographed (Nikon P600) and geo-referenced (ViewRanger App). Searches and sampling occurred in September and December 2018, monthly in 2019, and between January to March and September to December in 2020. After identifying the colonies, weekly expeditions were carried out during September and October, which comprised the breeding period at the sites between 2018 and 2020. For each nest in the colonies were recorded: (i) type of nesting microhabitat; (ii) distance between the nest and the edge of the water body; (iii) distance from the next closest nest; (iv) types of materials used to build the nest; (v) outer and inner diameter of the nest; (vi) number, height and width of eggs (according Pinho & Marini, 2014; Mendonça *et al.,* 2019). Egg measurements were performed with a caliper rule (accuracy of 0.01 mm) and nest measurements

Table 1. Characterization of areas (lagoons) with colonies of the species White-backed Stilt *Himantopus melanurus* in Restinga of Jurubatiba National Park and adjacent area.

Area (Colonies)	Characterization
Visgueiro (1, 5)	Presence of undergrowth (grass and saltmarsh plant); muddy and exposed (permanent) area near the lagoon; livestock (cattle and horses); domestic animals (birds and dogs); urbanization.
Maria Menina (2)	Presence of undergrowth (grass); permanent islet in the interior of the lagoon; livestock (cattle and horses).
Robalo (3)	Presence of undergrowth (grass and saltmarsh plant); livestock (cattle and horses); domestic animals (birds); urbanization.
Ubatuba (4)	Presence of undergrowth (grass and saltmarsh plant); islet in the posterior interface of the lagoon; livestock (cattle and horses).
Adjacent area (6)	Presence of undergrowth (grass and saltmarsh plant); livestock (cattle and horses); muddy and exposed area near the wetland).

were made with a tape measure and ruler (accuracy of 1 mm). Each registered nest was identified with a numbered blue tag. The nests were classified as: (i) active nest (with an egg and without hatching or predation traces), (ii) predated nest (when at least one egg was damaged or had disappeared, and/or when predator footprints were close to the nest), and (iii) successful nest (presence of at least one chick inside or close to the nest) (Fonseca, 2013).

Data analysis

The biometric parameters of nests and eggs were compared between colonies through analysis of variance to identify potential differences. Only colonies with more than three nests (colonies 1, 2, 3 and 4) were tested. Data normality and homoscedasticity were evaluated by the Shapiro-Wilk and Levene tests, respectively. For the parametric data (outer diameter of the nests), One-Way ANOVA was used, followed by the Tukey test. For the non-parametric data (nest height and internal diameter; distance from water; distance from the closest nest; height and width of eggs), the Kruskal-Wallis and Dunn tests were performed, adjusted with the Holm method. Tests were considered significant when $p < 0.05$. One-Way ANOVA and Mann-Whitney were used to evaluated if the distance from water and distance from the closest nest differed between "successful" and "not successful" nests. R software and the FSA package were used in all analysis (Ogle & Wheeler, 2020). The relative frequency of occurrence of the materials used to build the nests was calculated summing the total number of nests with a certain material used, divided by the total number of nests, and multiplied by 100.

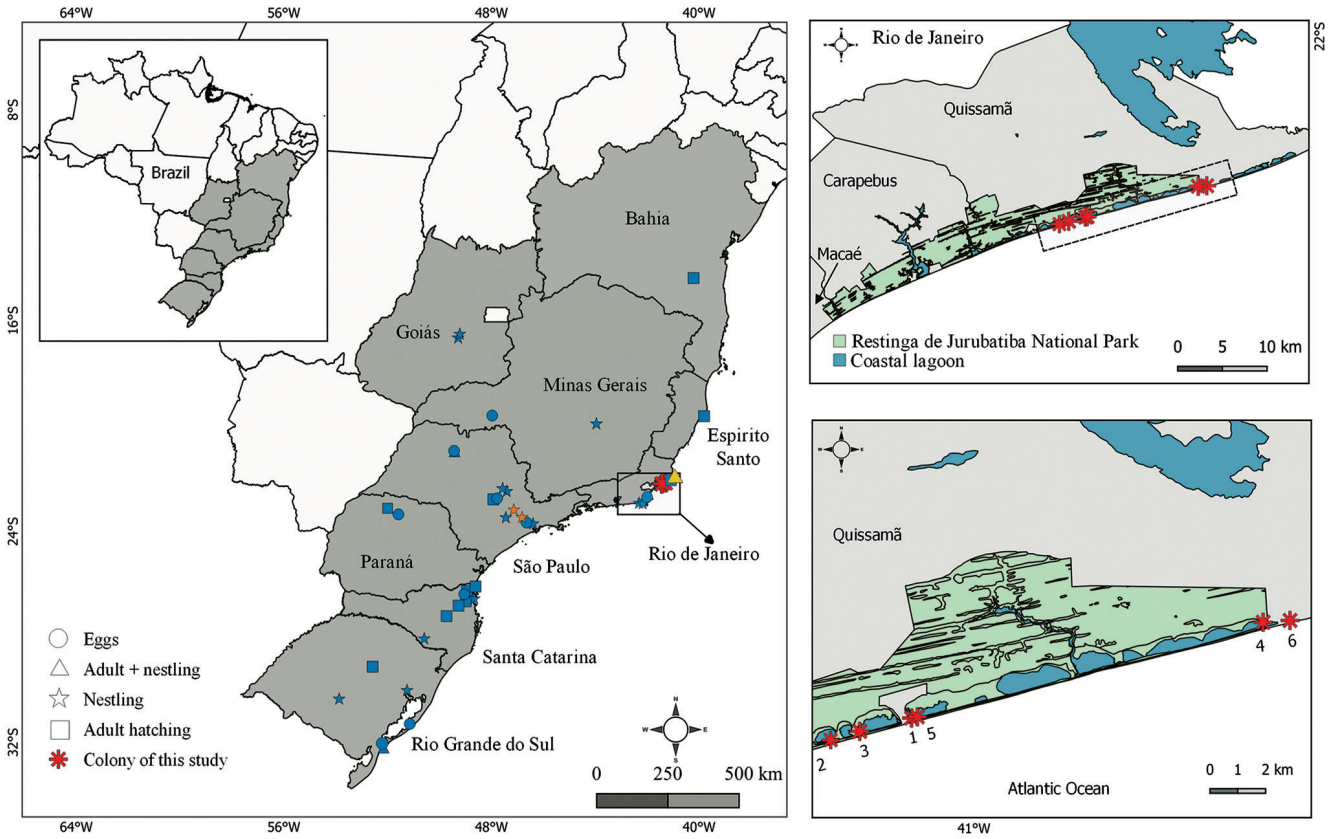

Figure 1. Breeding records of White-backed Stilt *Himantopus melanurus* in Brazil (WikiAves – blue, eBird – orange and literature – yellow, Table 2) and this study area (red) with colonies identified in the Restinga de Jurubatiba National Park and adjacent area, in 2018, 2019 and 2020, in the northern coast of Rio de Janeiro state. *Colonies: 1 = Visgueiro/2018; 2 = Maria Menina/2018; 3 = Robalo/2018; 4 = Ubatuba/2019; 5 = Visgueiro/2020; 6 = Adjacent Area/2020.

RESULTS

Literature review and online searches

In the literature, only two studies recorded nests and/or nestlings of *H. melanurus* in Guarapiranga, SP in 2007 (Schunck *et al.,* 2016) and in Rio de Janeiro in 2012 (Tavares & Siciliano, 2013), but none described breeding details of the species in Brazil (Table 2). The record of Schunck *et al.,* (2016) was also in the WikiAves platform, so we considered it only one time as literature review.

On WikiAves and eBird 68 breeding records of the species were found in Brazil, between 1997 and November 2021 (Table 2, Fig. 1). These records were concentrated mainly in the south (n = 29) and southeast (n = 28), in addition to six in the midwest (Goiás), one in the northeast (Bahia), and one in the north (Rondônia). The breeding period in almost all regions was similar to this study, except in Rio de Janeiro state (Cabo Frio in March, and Campos dos Goytacazes and São Pedro da Aldeia in May). Nearly 90% of breeding records occurred between August and November (Table 2).

Field sampling

In RJNP and adjacent area, six colonies were identified between 2018 and 2020 in Visgueiro, Maria Menina, Robalo, Ubatuba lagoons, and adjacent area (Fig. 1, Table 3). Only in Visgueiro two colonies were registered in different years (2018 and 2020). Overall, 44 nests of the species were identified, being 34 active.

Table 2. Breeding records of the White-backed Stilt (*Himantopus melanurus*) on WikiAves, eBird and literature. Local (municipallity and state): RS = Rio Grande do Sul; SP = São Paulo; MG = Minas Gerais; SC = Santa Catarina; PR = Paraná; RJ = Rio de Janeiro; GO = Goiás; RO = Rondônia Records listed chronologically from 1997 to 2021. NA = Not applicable. * = Same record on literature and WikiAves.

Nº	Local	Date (day/month/year)	Nest Content/Action	Author	Record Number
1	Rio Grande/RS	02/12/1997	4 eggs	Rafael A. Dias	WA715827
2	Tavares/RS	04/10/2006	3 eggs	Rafael A. Dias	WA715825
3	São Paulo/SP	07/11/2007	4 eggs	Fabio Schunck*	WA1456938
4	Capão Alto/SC	01/10/2008	2 nestlings	José Branco	WA184114
5	Schroeder/RS	29/08/2009	3 eggs	Sidney Vargas	WA51671
6	Piracicaba/SP	11/09/2010	2 eggs	Luciano Monferrari	WA202887
7	Joinville/SC	27/08/2011	Adult hatch.	Vilde E. Florencio	WA428939
8	Piracicaba/SP	08/10/2011	4 eggs	Luciano Monferrari	WA466799
9	Quissamã/RJ	20/06/2012	1 nest, 2 nestling	Tavares & Siciliano, 2013	NA
10	Cordeiropólis/SP	20/09/2012	2 nestling	Ademir Costa	WA967223
11	Porto Alegre/RS	23/11/2012	1 nestling	Veridiana Tamiozzo	WA812287
12	Belo Horizonte/MG	15/08/2013	1 nestling	Myriam Castro	WA1059655
13	Laurentino/SC	31/08/2013	Adult hatch	Miguel A. Biz	WA1067995
14	Sabáudia/PR	07/09/2013	4 eggs	Sérgio R. Rossi	WA1083013
15	Sabáudia/PR	14/09/2013	3 eggs	Demétrio Lorin	WA1087182
16	Sabáudia/PR	05/10/2013	4 eggs	Augusto Constantini	WA1109422
17	Sabáudia/PR	12/10/2013	4 eggs	Aluisio Ribeiro	WA1116220
18	C. Goytacazes/RJ	20/05/2014	Adult hatch.	Denison Cordeiro	WA1388099
19	Ribeirão Pires/SP	07/10/2014	1 nestling	Felipe P. Santos	WA1475289
20	Piracicaba/SP	28/10/2014	4 eggs	Luiz E.R. Silva	WA1509229
21	Itapoá/SC	24/10/2015	Adult hatch.	Adilson Constantini	WA1888303
22	Araruama/RJ	20/11/2015	1 nestling	Eduardo Pimenta	WA1919672
23	Jardim Alegre/SC	12/10/2016	3 eggs, 1 hatch.	Adilson Constantini	WA2321235
24	Piracicaba/SP	12/10/2016	4 eggs	Júlio Machado	WA2327423
25	Uberaba/MG	12/11/2016	3 eggs	Rafael Nogueira	WA2362783
26	Massaranduba/SC	12/08/2017	Adult hatch.	Eduardo Rodrigues	WA2657352
27	Piracicaba/SP	05/10/2017	Adult hatch.	Fernanda Pacheco	WA3793026
28	São Pedro Aldeia/RJ	07/05/2018	1 nestling	Sandro Paixão	WA2965778
29	Goiânia/GO	18/10/2017	1 nestling	André Mendonça	WA2741513
30	Goiânia/GO	21/10/2017	1 nestling	Jose M.V. Franco	WA2771145
31	Boa Nova/BA	22/10/2017	Adult hatch	Dêner V. Souza	WA2753481
32	Goiânia/GO	25/10/2017	1 nestling	Jayrson Araújo	WA2759096
33	Goiânia/GO	27/10/2017	2 nestlings	Maurício Poletti	WA2753925
34	Goiânia/GO	29/10/2017	2 nestlings	Ivo Zecchin	WA2771955
35	Goiânia/GO	24/10/2018	1 nestling	Igor Oliveira	WA3156716
36	Bady Bassitt/SP	25/11/2018	1 adult +1 nestling	Dina Lucas Bessa	WA4285750
37	Praia do Cassino/RS	02/12/2018	1 adult +1 nestling	Carlos E. Soares	WA3227230
38	Timbó/SC	30/08/2019	Adult hatch	Luiz Anjos	WA3476184

Nº	Local	Date (day/month/year)	Nest Content/Action	Author	Record Number
39	Bady Bassitt/SP	12/09/2019	4 eggs	Kris Rodrigues	WA3510899
40	Sorocaba/SP	07/10/2019	1 nestling	Lucas A.C. Silva	WA3528359
41	Rio Claro/SP	03/11/2019	1 nestling	Luiz Ramassotti	WA362205
42	Cabo Frio/RJ	07/03/2020	3 eggs	Eduardo Pimenta	WA3721076
43	Linhares/ES	04/07/2020	Adult hatch	Justiniano Magnago	WA3865922
44	Barros Cassal/RS	01/08/2020	Adult hatch	Jairo Ortiz Costa	WA3907932
45	Vila Nova do Sul/RS	29/10/2020	1 nestling	Giancarlo Pozzebon	WA4048388
46	Araruama/RJ	02/11/2020	1 nestling	Eduardo Pimenta	WA4054638
47	Arraial do Cabo/RJ	21/11/2020	1 nestling	Eduardo Pimenta	WA4085454
48	Araruama/RJ	18/07/2021	1 nestling	Eduardo Pimenta	WA4399193
49	Araquari/SC	01/08/2021	1 nestling	Valmir L. Nicolletti	WA4421331
50	Araquari/SC	14/08/2021	Adult hatch	Valmir L. Nicolletti	WA4439460
51	Massaranduba/SC	15/08/2021	1 nestling	Eduardo Rodrigues	WA4439460
52	Rio do Oeste/SC	17/08/2021	Adult hatch	Miguel Angelo Biz	WA4439460
53	Massaranduba/SC	28/08/2021	1 nestling	Eduardo Rodrigues	WA4439460
54	Araruama/RJ	04/09/2021	1 nestling	Eduardo Pimenta	WA4439460
55	Valinhos/SP	08/09/2021	Adult hatch	Pedro Behne	WA4439460
56	Florianópolis/SC	11/09/2021	4 eggs	Renné Araújo	WA4439460
57	Rio Claro/SP	26/09/2021	2 nestling	Carlos Gussoni	WA4439460
58	Rio Claro/SP	26/09/2021	2 nestling	Carlos Gussoni	ML372750681
59	São Pedro da Aldeia/RJ	02/10/2021	1 nestling	Sandro Paixão	WA4439460
60	Candeias do Jamari/RO	02/10/2021	2 nestling	Álisson Albino	WA4439460
61	Valinhos/SP	03/10/2021	1 nestling	Arthur Gomes	ML374654861
62	Valinhos/SP	03/10/2021	1 nestling	Arthur Gomes	ML374654851
63	Valinhos/SP	03/10/2021	3 nestling	Arthur Gomes	ML374654881
64	Jaboticabal/SP	09/10/2021	4 eggs	Donizete Carvalho	WA4439460
65	Mostardas/RS	31/10/2021	Adult hatch	Jair Ortiz Costa	WA4439460
66	Uruguaiana/RS	02/11/2021	1 nestling	Ricardo O. Oliveira	WA4439460
67	Sabáudia/PR	09/11/2021	Adult hatch	Lauril Krawczun	WA4439460
68	Tramandaí/RS	14/11/2021	1 nestling	Paulo Fenalti	WA4439460
69	Uberaba/MG	15/11/2021	1 nestling	Rodrigo M. Loures	WA4439460
70	Rio do Oeste/SC	15/11/2021	1 nestling	Miguel Angelo Biz	WA4439460

Table 3. Biometry of the nests of the White-backed Stilt *Himantopus melanurus* registered in the Restinga of Jurubatiba National Park and adjacent area. *Colony 1: Visgueiro/2018; Colony 2: Maria Menina/2018; Colony 3: Robalo/2018; Colony 4: Ubatuba/2019; Colony 5: Visgueiro/2020; Colony 6: Adjacent Area/2020. N = Number of nests. DCN = Distance from closest nest; DW = Distance from water; ODN = Outer diameter of the nest; ID = Internal diameter; HN = Height of the nest. Mean ± standard deviation; (min-max. value).

Colony	(N)	DCN (m)	DW (m)	ODN (cm)	ID (cm)	HN (cm)
1	14	6.8 ± 2.1 (2.9-10.9)	26 ± 18.9 (17-33)	19.4 ± 17.2 (14.5-24.5)	9.1 ± 7.4 (7.5-13)	4.9 ± 2.2 (1.5-8.5)
2	8	7.3 ± 3.6 (1.7-11.4)	3.1 ± 2.8 (0.45-9.4)	15.8 ± 15 (12-18)	7.3 ± 7.1 (4.5-9.5)	2.6 ± 1.3 (1.5-5)
3	8	6.2 ± 2.6 (3.6-11)	5.3 ± 5.4 (5.2-7.7)	21.6 ± 20.8 (17-23.5)	10.7 ± 7.2 (6.5-18.5)	3.2 ± 1.1 (2.0-5.0)
4	7	17 ± 12.3 (5.5-34)	16.6 ± 9.1 (0-32)	18.4 ± 17.9 (13-24)	8.4 ± 8.6 (6-11)	20.5 ± 14.9 (9.2-27.5)
5	2	20 ± 17.1 (20-20)	1.1 ± 1 (1-1.3)	16.5 ± 16 (16-17)	8.5 ± 8 (8-9)	11.0 ± 9.8 (9-13)
6	3	25.6 ± 22.1 (21-35)	14.5 ± 19.2 (6.5-28)	12.7 ± 11.1 (12-13.4)	4.6 ± 3.7 (4.4-5)	8.0 ± 6.7 (6-11)
Total	42	10.8 ± 18.9 (0.45-35)	13.5 ± 8.4 (1.7-38)	18.2 ± 21.3 (12-24)	8.6 ± 7.9 (4.4-18.5)	7.4 ± 6.1 (2-27.5)

Table 4. Dunn test results, pairwise comparisons in relation to nest height, distance from water and distance to the closest nest in colonies recorded in the Restinga of Jurubatiba National Park and adjacent area. Z = Z test statistic values for each comparison; P.unadj = unadjusted p-values for each comparison; P.adj = Adjusted p values for each comparison. * = Significant difference.

Colonies	Nests Height			Distance from water			Distance from the closest nest		
	Z	P.unadj	P.adj	Z	P.unadj	P.adj	Z	P.unadj	P.adj
1 – 2	1.915	5.54e-02	0.166	4.651	3.29e-06	1.97e-05*	-0.379	0.704	0.704
1 – 3	1.232	2.17e-01	0.435	3.662	2.49e-04	1.24e-03*	0.832	0.405	0.810
2 – 3	-0.604	5.45e-01	0.545	-0.902	3.66e-01	3.66e-01*	1.054	0.291	0.874
1 – 4	-2.913	3.57e-03	0.014*	1.143	2.52e-01	5.05e-01*	-2.195	0.028	0.140
2 – 4	-4.245	2.17e-05	0.001*	-3.051	2.27e-03	9.10e-03*	-1.535	0.124	0.498
3 – 4	-3.661	2.50e-04	0.001*	-2.179	2.93e-02	8.79e-02*	-2.751	0.005	0.035*

The breeding season of the species in the colonies occurred mainly in September and October 2018, 2019, and 2020. In 2018, during these months, 32 nests were registered. In 2019, seven nests and in 2020 five nests in September were observed (Table 3). In July 2019, one single nest was identified on an islet in the middle of a flooded, in an inaccessible area.

Most of the nests (95%) were built on the ground, close to water. Nests biometry and measurements parameter in each colony are shown in Table 3. The outer diameter of the nest did not differ significantly between colonies (ANOVA, $F = 0.099$; $p = 0.755$), neither did the internal diameter (Kruskal-Wallis $X^2 = 2.891$, $p = 0.408$). Nest height differed among colonies (Kruskal-Wallis $X^2 = 20.805$, $p = 0.001$), with higher nests in colony 4 (Dunn Test, $p < 0.05$) (Table 4), which the highest average height of 20.5 cm.

The nest distance from water also differed between colonies (Kruskal-Wallis $X^2 = 27{,}138$, $p = 5.5*10\text{-}6$) and all comparisons showed significant differences (Dunn Test, $p < 0.005$) (Tables 3 and 4). Colonies 1 and 2, for example, had different distances from the water, 26 cm and 3.1 cm, respectively. The distances of the closest nests were different (Kruskal-Wallis $X^2 = 8.1176$, $p = 0.043$), and only colony 3 differed from colony 4 (Dunn Test, $p = 0.035$) (Table 4).

Different materials were used in to build the nests, such as saltmarsh plant *Sesuvium portulacastrum* L., grass, mud, shells; and cattle feces (Figs. 2 and 3).

Thirty-five nests (79%) had the saltmarsh plant as one of the main items, in addition to mud in a smaller proportion (34%). Within the shell group, gastropods represented 5% (Fig. 3).

In total 118 eggs were registered in the 34 active nests of the six colonies. Twenty-six nests contained

Figure 2. Nests of White-backed Stilt *Himantopus melanurus* monitored in Restinga de Jurubatiba National Park and adjacent area. A = Nest built with saltmarsh plant *Sesuvium portulacastrum* L. and suspended over cattle feces; B = Nest with dry saltmarsh plant and mud fragments; C = Nest with shells, saltmarsh plant and mud; D = Nest with mud and dry saltmarsh plant fragments. Photos: Lucas R.M. Porto.

Table 5. Biometry of eggs of the White-backed Stilt (*Himantopus melanurus*) recorded in the Restinga de Jurubatiba National Park and adjacent area. Mean ± standard deviation; (min-max. value). *N = number of eggs; EH = eggs height; EW = eggs width.

Year	Colony	Lagoon	N	EH (cm)	EW (cm)
2018	1	Visgueiro	46	3.2 ± 0.11 (3.1-3.6)	4.6 ± 0.14 (4.4-4.9)
2018	2	M. Menina	22	3.2 ± 0.12 (3.1-3.6)	4.5 ± 0.15 (4.3-4.8)
2018	3	Robalo	4	3 ± 0.54 (2.9-3.9)	4.5 ± 0.22 (4.3-4.8)
2019	4	Ubatuba	26	3.2 ± 0.09 (3.1-3.3)	4.4 ± 0.16 (4.1-4.9)
2020	5	Visgueiro	8	3.1 ± 0.05 (3.1-3.2)	4.6 ± 0.2 (4.5-4.9)
2020	6	Adjacent area	12	3.2 ± 0.11 (3.1-3.5)	4.6 ± 0.09 (4.5-4.7)
Total	—	—	118	3.2 ± 0.14 (2.9-3.9)	4.5 ± 0.16 (4.1-4.9)

four eggs, three nests had three eggs, two nests had two eggs, and three nests had only one egg. Eggs biometry are in Table 5. Egg height did not differ between colonies (Kruskal-Wallis X^2 = 8.482, p = 0.131), however there was a difference in egg width (Kruskal-Wallis X^2 = 16.848, p = 0.004), between colony 4 and colonies 1 and 6 (4 and 1, Dunn Test, p = 0.014) (4 and 6, Dunn Test, p = 0.006) (Table 6).

Egg predation was identified in 21 active nests (61.7%, Fig. 4). During monitoring, footprints of wild animals such as the crab-eating foxes *Cerdocyon thous*

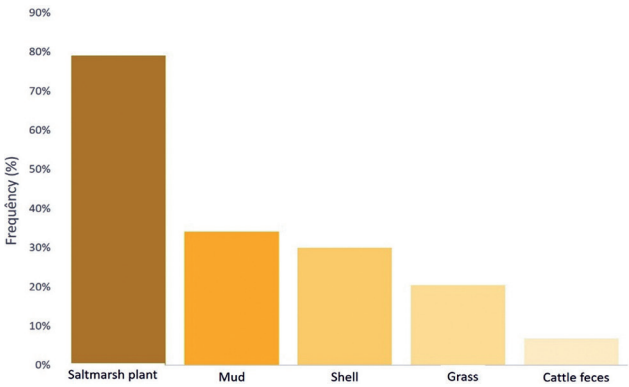

Figure 3. Frequency of occurrence of the materials used to build the nests of the White-backed Stilt *Himantopus melanurus* in the Restinga de Jurubatiba National Park and adjacent area.

Linnaeus, 1766, crab-eating raccoon *Procyon cancrivorus* (Cuvier, 1798) and domestic animals (cattle and domestic dog) were recorded close to the nests (Fig. 4). Besides predation, two nests (5.8%) were trampled by cattle and two other nests were flooded.

Of the 34 active nests monitored, nine (26.4%) were successful, as there was a record of egg hatching or chicks close to the nest (Fig. 6), two in colonies 1 and 2, and three in colony 4. Successful and unsuccessful nests

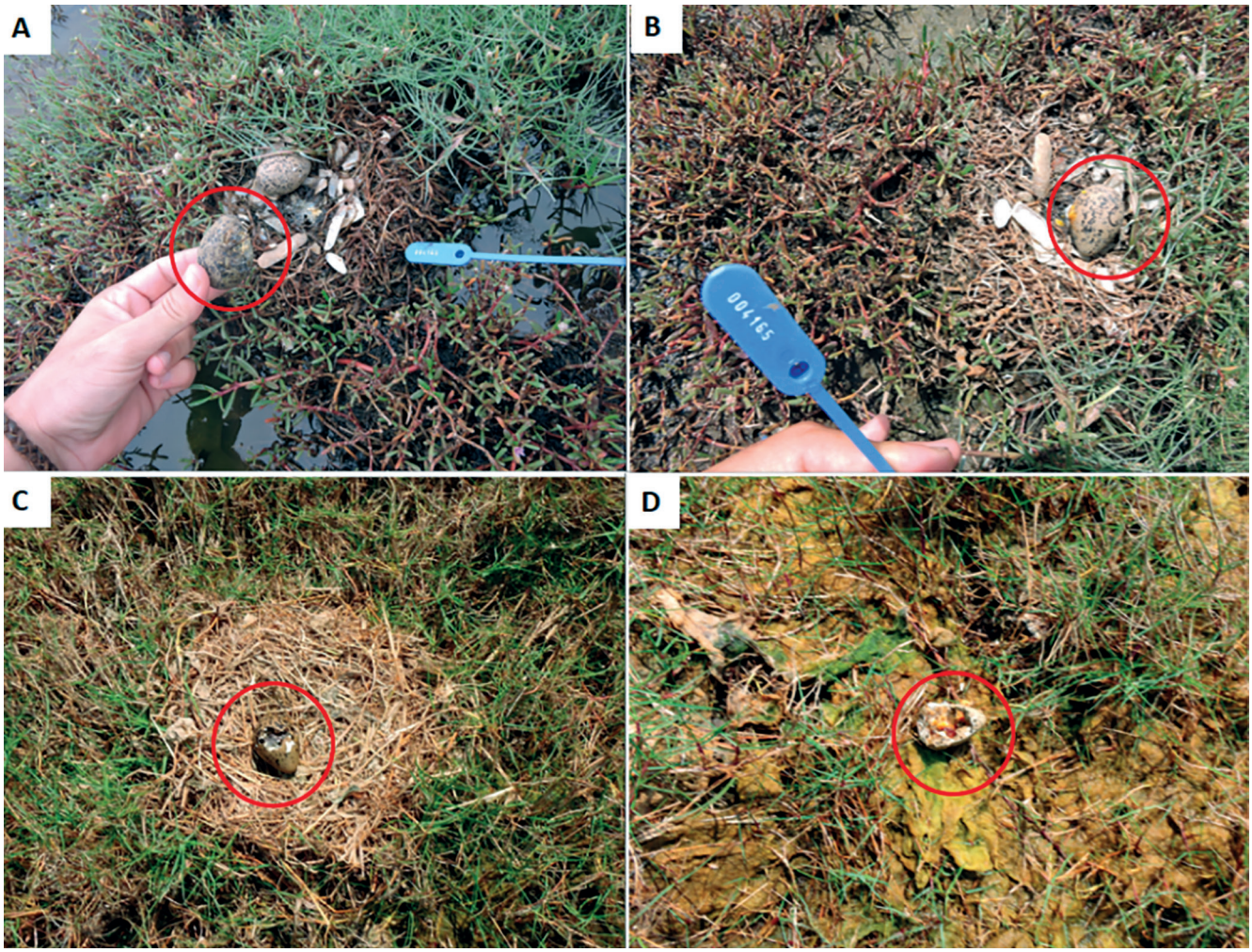

Figure 4. Predated/degraded eggs of White-backed Stilt *Himantopus melanurus* in Restinga de Jurubatiba National Park in October 2018. A, B and C: Colony 1 (Visgueiro), D: Colony 2 (Maria Menina). Photos: Lucas R.M. Porto.

had no significant differences for the parameters analyzed: outer diameter of the nest (ANOVA, F = 1.477; p = 0.231), internal diameter (Man-Whitney U = 115; p = 0.308), nest height (ManWhitney U = 127; p = 0.517), and the distance from the water (Man-Whitney U = .101; p = 0.618). However, in the distance to the closest nest, there was a significant difference (Man-Whitney U = 9.5; p < 0.005).

Table 6. Result of the Dunn Test, pairwise comparisons, in relation to egg width, of colonies in the Restinga of Jurubatiba National Park and adjacent area. Z = Values the Z-test statistic for each comparison; P.unadj = unadjusted p-values for each comparison; P.adj = Adjusted p values for each comparison. * = Significant difference.

Colony	Z	P.unadj	P.adj
1 – 2	0.469	0.638	1.000
1 – 3	0.418	0.675	1.000
2 – 3	0.176	0.859	0.859
1 – 4	3.289	0.001	0.014*
2 – 4	2.413	0.015	0.205
3 – 4	1.140	0.253	1.000
1 – 5	-0.318	0.749	1.000
2 – 5	-0.531	0.594	1.000
3 – 5	-0.544	0.585	1.000
4 – 5	-1.854	0.063	0.764
1 – 6	-1.458	0.144	1.000
2 – 6	-1.658	0.097	1.000
3 – 6	-1.251	0.210	1.000
4 – 6	-3.501	0.000	0.006*
5 – 6	-0.610	0.541	1.000

DISCUSSION

On Wikiaves, 90% of breeding records of the White-backed Stilt were from August to November. Based in the WikiAves records, the main breeding areas of the species are concentrated in the southeast and south, which corroborates with literature (Belton, 1984; Lima *et al.*, 2009; Tavares & Siciliano, 2013). However, these data could be bias because southeast is the most populated region in the country, with great number of birdwatchers (n = 21935, 37%) and together with south region sums 53% of the observers registered in this platform (WikiAves, 2022). Species breeding records in other regions are reported for the first time, including the northeast (Bahia), midwest (Goiânia) and north (Rondônia). On eBird, the records in São Paulo state were in September and October, similar to the data recorded in the RJNP col-

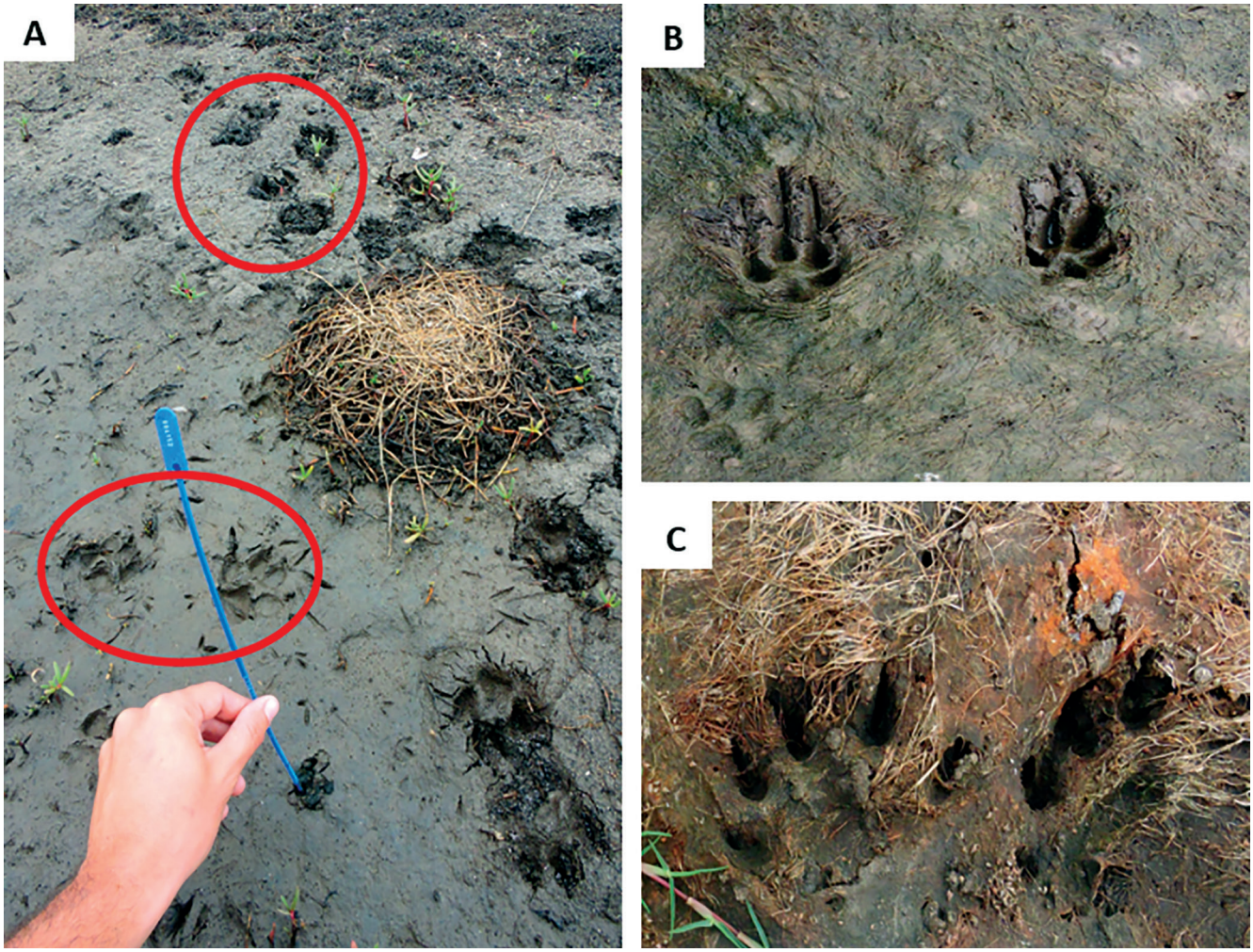

Figure 5. Footprints records of possible predators and cattle trampling near nests of White-backed Stilt *Himantopus melanurus* in Restinga de Jurubatiba National Park. (A) Footprints of domestic dogs and trampling of cattle in the Visgueiro lagoon (2018). (B) crab-eating fox (*Cerdocyon thous*) footprints, and (C) crab-eating raccoon (*Procyon cancrivorus*) footprints in adjacent area (2020). Photos: Lucas R.M. Porto.

ony. The breeding period differences in some states may be linked to distinct rainfall regimes and consequently the availability of food resources.

The White-backed Stilt breeding in RJNP and adjacent area were recorded mainly between September and October. This period includes the dry season (June, July, August, September and October) in the northern region of Rio de Janeiro state. The dry season may also explain the nest recorded in July 2019 in this study, similar to the breeding record of the species in RJNP in June 2012 (Tavares & Siciliano, 2013). Water levels in wetlands are determined by a variety of factors including the effect of tides, river overflows and the level of local precipitation (Burger *et al.,* 1977; Collazo *et al.,* 2002). These factors determine the water depth in shorebird foraging areas, which affects both bird access to these areas and invertebrate abundance (Marín *et al.,* 2006; Giner & Pérez-Emán, 2016), influencing the availability of food resources and adequate breeding sites. These environmental conditions, together with the availability of exposed areas, influence the establishment of nesting areas for the species.

In 2018, 32 nests were recorded while in 2020 only five were found in the same area. Several factors may have influenced the species' breeding in the area. In 2018, the annual average of rainfall (115 mm) was lower than in 2019 (128 mm) and 2020 (136 mm) (INMET, 2020). Open areas with a smaller flooded surface are essential for the establishment of breeding colonies, thus the higher rainfall may explain the differences in the number of nests between the sampling years (Hamilton, 1975). Only the Visgueiro lagoon was used in more than one breeding season (2018 and 2020). This lagoon has a larger and

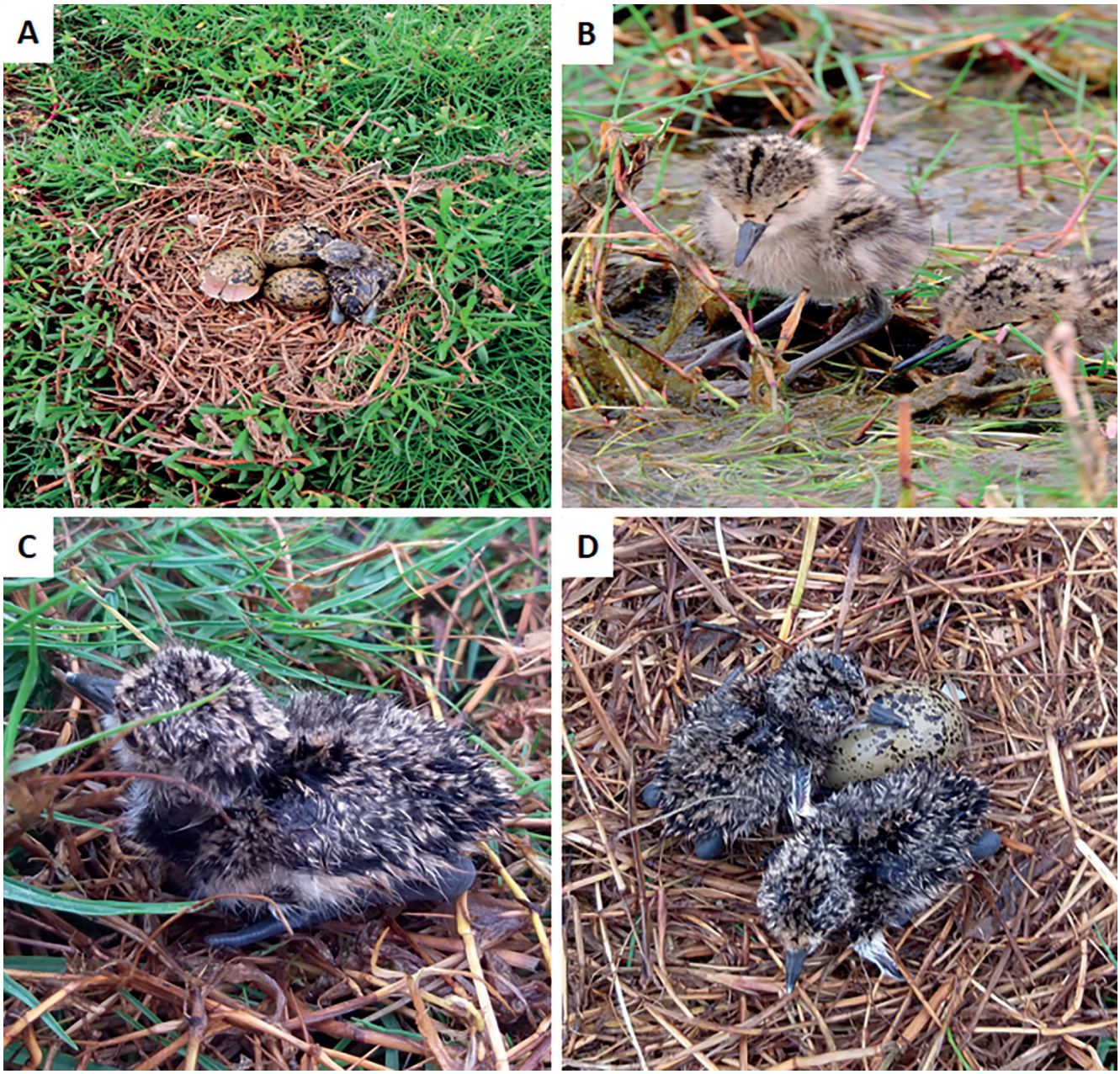

Figure 6. Successful nesting records of the White-backed Stilt *Himantopus melanurus* in Restinga de Jurubatiba National Park and adjacent area. (A) White-backed Stilt chicks found in Visgueiro lagoon (September 2018); (B) Hatchling and eggs in the Maria Menina Lagoon (October 2018); (C and D) Chicks in the nests in Ubatuba lagoon (September 2019). Photos: Lucas R.M. Porto.

exposed lateral area, with muddy substrate and close to water, which is a favorable environment for the establishment of the species. Another possibility is that in 2019 and 2020 White-backed Stilt couples may have nested in different areas than those monitored. In 2020, the expedition occurred from January to March and September to December, thus only for seven months compare to 2019. The distances between the closest nests differed between colonies, mainly between colony 3 and 4. These differences can be explained because colony 4 is mixed with nests of the Gray-hooded Gull (*Chroicocephalus cirrocephalus* Swainson, 1837), where the nests were further apart. The spacing between Recurvirostridae nests varies between 5 and 30 m (Nicholson, 1929; Hamilton, 1975). No pattern was identified regarding the nest distribution in the colonies. They can be located close or far apart, according to habitat conditions (Gibson, 1920), such as size of available area, availability of resources and number of breeding couples.

The distance between the nests and water differed significantly between colonies. Most of the nests were built on the ground around the lagoon, while in colony 4 there were nests built on the water. Proximity to water is often an important predictor of nest viability because, although water can make the presence of terrestrial predators more difficult, the further away from the water, the lower the risk of flooding (Cuervo, 1993; Polak & Kasprzykowski, 2013; Harmon *et al.,* 2021). Only two flooded nests were recorded in the study area. Regarding the height of the nests, the highest one was in colony 4 (Ubatuba, height = 27.5 cm) and was suspended over the water in a large tangle of vegetation. During this period (September and October 2019), the volume of water in the lagoon was increasing. Considering all colonies, the average nest height was 7.4 cm. The external and internal diameters of the nests were smaller than *H. mexicanus* nests (Lunardi *et al.,* 2015; Mendonça *et al.,* 2019). As in North America (Saito, 1975; Dinsmore, 1977; Coleman, 1981; Grant, 1982), such differences can be determined by the type of habitat and materials used in the construction of nests in each area.

White-backed Stilt nests on muddy soil or in very shallow waters, in open areas (Ridgely & Tudor, 2016), corroborating with this study. Several types of materials were used as nest structure, with the saltmarsh plant and mud being the most frequent. These materials were also abundant in the colonies areas and the saltmarsh plant is a native vegetation found in other wetlands, which the cogeneric species *H. mexicanus* breeds (Robinson *et al.,* 2020). Nest composition for Recurvirostidae ranges from small, simple tangles with almost no material, to clumps of stems and branches (up to 40 cm high) (Wetmore, 1925; Wheeler 1955; von Frisch, 1961; Palmer, 1967). Sometimes, nests are built over a mound of vegetation, in water and on floating vegetation (Hamilton, 1975).

On average, the number of eggs per nest was four eggs, similar to *H. mexicanus* (Lunardi *et al.,* 2015). However Mendonça *et al.* (2019), reported an average of three eggs in the Apodi-Mossoró River estuary, Rio Grande do Norte. Overall, nests are composed of 3-4 eggs for the genus *Himantopus* (Gibson, 1920; Sick, 1997). The eggs of Recurvirostrids, on average measure 4.5 × 3.3 cm, in height and width, respectively (Gibson, 1920), values similar to those recorded in this study. The diameter of the eggs, considering all colonies, had an average similar to *H. mexicanus,* (3.1 cm) (Lunardi *et al.,* 2015), and different considering the other study (2.8 cm) (Mendonça *et al.,* 2019).

Predation and trampling by cattle seem to be the main threats to the species' nesting in RJNP and in the adjacent area. The Maria Menina and Visgueiro lagoons are close to urbanized areas, where there are domestic animals, such as dogs (*Canis familiaris*). Furthermore, tracks of natural predators such as crab-eating fox and raccoon were recorded close to the nests. The main predators of Recurvirostrid eggs are terrestrial vertebrates, which can either ingest the eggs (dogs, snakes) or trample them (cattle and horses) (Cuervo, 1993; Arroyo, 2000). In addition to mammals and reptiles, some birds also prey on eggs and chicks, such as herons, vultures and falcons that are abundant in the area (Teunissen *et al.,* 2008; Andrade *et al.,* 2020; Canabarro & Fedrizzi, 2010; Frias *et al.,* 2020b). Despite the high number of preyed nests, about a quarter of them (26%) were successful, considering hatched eggs. The characteristics of successful and unsuccessful nests did not differ, only the distance between the closest nests. The average distance between the nests was greater for the successful ones (22 m) with a maximum distance of 34 m. Breeding neighbors are known to reduce predator pressure on waterbird species, both because of their occupation of nearby space (dilution effect), and in the case of nest-defending species, because of their defensive behavior against predators (Brzeziński *et al.,* 2018). In this study, colonies were relatively small and nests were rarely very close (smallest distance was 1.7 m). However, it is not clear whether colonial breeding always reduces predation, there may be a negative relationship between nest predation risk and colony aggregation or size (Varela *et al.,* 2007), but some studies have found differences (Rolland *et al.,* 1998, Picman *et al.,* 2002).

Due to the human occupation of the coastal zone, natural breeding areas for the White-backed Stilt and several other shorebird species have been constantly destroyed (Weber *et al.,* 1999; Rais *et al.,* 2010). Livestock is one of the main activities responsible for the destruction of breeding areas for many shorebird species (Powers & Glimp, 1996). As a result, shorebird species have sought alternative breeding habitats such as rice fields, pastures and artificial salt pans in some locations (Masero, 2003; Dias, 2009; Rocha *et al.,* 2016; Barnagaud *et al.,* 2019). Nest trampling by cattle was recorded as another impact for the species, affecting two nests in the Visgueiro lagoon (colony 1, 2018) and has already been observed previously in other species, in Long-billed Curlew *Numenius americanus* (Gregory *et al.,* 2011), *Calidris alpina schinzii* (Pakanen *et al.,* 2011), *Tringa totanusa* (Sharps *et al.,* 2017), *Bartramia longicauda* (Bowen & Kruse, 1993). In addition, two nests built on feces and inside cattle tracks were observed at the same site. Some advantages of building the nests on the feces are: (1) increase in

the nest temperature when unprotected by the parents; (2) increase of the height of the nest reducing potential flooding; and (3) "disguising" nests from predators, due to feces color and odor (Grau, 1975). Cattle grazing may also favor shorebird species in other aspects during breeding, decreasing vegetation height and facilitating foraging, and may allow birds to better see predators (Colwell & Dodd, 1995; Rottenborn, 1996). Although there are possible positive and negative factors between livestock and shorebirds, to avoid other types of impacts, some strategies, such as installation of signs with bird's biology information, monitoring populations size, access restriction in breeding areas frequently use by birds and installation of bird watching platforms are indicate to conservation management of the species (Burger *et al.,* 2004).

RJNP and its adjacent areas are considered annual breeding sites for the White-backed Stilt, on the northern coast of the state of Rio de Janeiro, in southeastern Brazil. The area is also home to a large population (nearly 112.4 birds/km) of the White-backed Stilt during most of the year (authors obs.). More aspects of the breeding biology and ecology of the species, that were not the focus of this study, should be evaluated, such as incubation period, details of parental care and breeding success rate along the years in the colonies in Brazil.

CONCLUSION

White-backed Stilt in Brazil breeds mainly from August to November, and most of the breeding records were in southeast and south regions. Domestic animals and livestock may represent some threats and potential predators during species breeding period in RJNP. Management and mitigation actions, as restrict the access of domestic animals and livestock near the breeding areas should be implement, targeting specie conservation. Furthermore, this study brings the first data on the nest and egg biometry of this species in Brazil, highlighting the northern coastal region of Rio de Janeiro state as a breeding area in the largest protected restinga area in Brazil.

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SUPPLEMENTARY MATERIAL

Table S1. Data from sampling fields from monitoring the nests of Himantopus melanurus in the Restinga de Jurubatiba National Park and adjacent areas between 2018 and 2020.

Date	Hours	Area
11/09/2018	10:00 – 12:30	Visgueiro
20/09/2018	11:30 – 13:30	Visgueiro
26/09/2018	10:00 – 11:30	Visgueiro
26/09/2018	13:00 – 14:30	Maria Menina
28/09/2018	08:30 – 9:30	Visgueiro
18/10/2018	11:20 – 13:40	Visgueiro
18/10/2018	11:20 – 13:40	Maria Menina
24/10/2018	10:00 – 11:30	Robalo
05/09/2019	09:30 – 11:00	Ubatuba
10/09/2019	08:40 – 11:30	Ubatuba
19/09/2019	08:20 – 11:30	Ubatuba
29/09/2019	12:40 – 14:50	Ubatuba
03/09/2020	08:45 – 11:00	Visgueiro
08/09/2020	08:30 – 10:40	Visgueiro
17/09/2020	09:10 – 11:50	Adjacent area

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