SEASONAL ABUNDANCE OF THE NEOTROPIC CORMORANT (*PHALACROCORAX BRASILIANUS*) AT LAGOA DOS PATOS ESTUARY, SOUTHERN BRAZIL

VIVIANE BARQUETE [1,2,4], CAROLUS MARIA VOOREN [1] AND LEANDRO BUGONI [1,3]

[1] *Laboratório de Elasmobrânquios e Aves Marinhas, Instituto de Oceanografia, Universidade Federal do Rio Grande (FURG). CP 474, CEP 96201-900, Rio Grande, RS, Brazil.*
[2] *Percy FitzPatrick Institute, DST/NRF Centre of Excellence, University of Cape Town. Private Bag X3, Rondebosch 7701, South Africa.*
[3] *Institute of Biomedical and Life Sciences, University of Glasgow. Glasgow G12 8QQ, United Kingdom.*
[4] *vibarquete@yahoo.com.br*

ABSTRACT.— Censuses of the Neotropic Cormorant (*Phalacrocorax brasilianus*) were carried out at a power tower near the mouth of Lagoa dos Patos estuary, southern Brazil, from November 2001 to October 2002. At this major roosting site, a total of 309 counts over 47 days of census were performed to estimate monthly variation in the abundance of the Neotropic Cormorant. The highest abundance occurred in January (1390 birds), and the lowest in May (117 birds). The tower was a roosting site for cormorants at night, which arrived around 15:30 h onward, with numbers increasing near dusk. Birds preferentially used the lower levels of the tower (including the concrete base and levels 1 and 2) throughout the year and this preference could be partially due to strong winds in the area. Migrating cormorants arrived at the estuary in winter and spring, increasing throughout the summer and severely decreasing in autumn months, when they probably moved to inland breeding grounds.

KEY WORDS: *abundance, Neotropic Cormorant,* Phalacrocorax brasilianus*, roosting site, seasonal variation.*

RESUMEN. ABUNDANCIA ESTACIONAL DEL BIGUÁ (*PHALACROCORAX BRASILIANUS*) EN EL ESTUARIO DE LA LAGUNA DOS PATOS, SUR DE BRASIL.— Se realizaron censos de Biguá (*Phalacrocorax brasilianus*) en una torre de transmisión de energía eléctrica cerca de la barra de la laguna dos Patos, en el sur de Brasil, entre noviembre de 2001 y octubre de 2002. Se realizaron un total de 309 conteos en 47 días de censos para estimar la variación mensual en la abundancia del Biguá. La mayor abundancia se observó en enero (1390 aves) y la menor en mayo (117 aves). La torre fue un importante sitio de descanso nocturno al cual las aves llegaban alrededor de las 15:30 h, aumentando el número de aves cerca del atardecer. Las aves utilizaron preferentemente los niveles inferiores de la torre (la base de hormigón y los niveles 1 y 2) durante todo el año y esta preferencia podría estar relacionada con los fuertes vientos en el área. Los biguaes migrantes llegaron al estuario en invierno y primavera, aumentaron sus números durante el verano y mostraron una gran disminución en el otoño, cuando probablemente se muevan hacia áreas reproductivas en el interior.

PALABRAS CLAVE: *abundancia, Biguá,* Phalacrocorax brasilianus*, sitio de descanso, variación estacional.*

Received 16 April 2007, accepted 26 May 2008

The Neotropic Cormorant (*Phalacrocorax brasilianus brasilianus*) is widespread on both the Atlantic and Pacific coasts of America and inland waters, from Panama to Tierra del Fuego in southern Argentina (Pinto 1964, 1978, Harrison 1985). Despite their wide distribution and high abundance in several freshwater, estuarine, and coastal areas, several aspects of their biology remain in need of study (Telfair and Morrison 1995, Kalmbach et al. 2001, Frere et al. 2005). According to Browning (1989), despite being frequently referred as *Phalacrocorax olivaceus*, the early description of *brasilianus* (*Procellaria brasiliana* Gmelin), based on paintings from northeastern Brazil, clearly refers to this species and has priority over *olivaceus*, so should be restated as the correct name for the species. Thus *Phalacrocorax brasilianus* is the name we have used throughout this study.

Nonbreeding cormorants and shags (Phalacrocoracidae) usually feed at least once a day (del Hoyo et al. 1992), and frequently at particular times. Feeding often occurs in the early

morning and evening, as in the case of the Great Cormorant (*Phalacrocorax carbo*) in the Arctic Circle (Johansen et al. 2001), or during the morning in Scotland (Richner 1995), with roosting in the intervals between meals (Richner 1995, Johansen et al. 2001). The Double-crested Cormorant (*Phalacrocorax auritus*) in the Delta region of Mississippi spent most of the day roosting and loafing instead of actively foraging (King et al. 1995). The Neotropic Cormorant disperses in flocks during daytime to foraging grounds and, during the night, roosts in large flocks at known sites (Escalante 1970), such as sheltered marshes, trees, trunks, rocks or on the coast (Belton 1994, Sick 1997). After swimming, they usually roost with open wings to dry their plumage or to aid thermoregulatory processes (Sick 1997).

The Neotropic Cormorant is an important piscivorous bird in terms of biomass at the Lagoa dos Patos estuary. They feed mainly on white croacker (*Micropogonias furnieri*) and catfish (Ariidae) (Barquete et al. 2008) which are important species for the artisanal fishery (Reis et al. 1994). Amongst the large flocks seen in the Lagoa dos Patos estuary in August were some birds banded as chicks in Santiago del Estero, Argentina, 1400 km away (Olrog 1968, Sick 1997). The aquatic bird community in the estuary is poorly known, with studies restricted to the Black Skimmer (*Rynchops niger*) (Naves and Vooren 2006) and terns (Bugoni and Vooren 2004, 2005). Lagoa dos Patos estuary is considered an important wintering ground for the Neotropic Cormorant, which does not have a well established colony within the estuary and have only two small colonies in nearby wetlands which are not used every year (Belton 1994, AS Peter, pers. com.).

In 2000, large numbers of cormorants were observed roosting at dusk on a power tower at the southern portion of the Lagoa dos Patos estuary (Vooren, unpublished data). By performing censuses on the margins of the lagoon and at the power tower we determined the abundance of the Neotropic Cormorant, monthly variations in abundance and how these birds use this site for nocturnal roosting in the Lagoa dos Patos estuary.

METHODS

Lagoa dos Patos is a coastal lagoon stretching in NE–SW directions, between 30°30'S and 32°12'S, and connected to the Atlantic Ocean in the southern portion, near Rio Grande city (Fig. 1). The estuarine area is 971 km^2, approximately 10% of the lagoon, and connects to the ocean by a channel 20 km long, 0.5–3 km wide (Asmus 1998) and up to 18 m of depth (Calliari 1998). The estuary is an important feeding and nursery ground for several fishes and crustaceans (Castello 1986) and sustains an important fishery targeting several species (Reis et al. 1994).

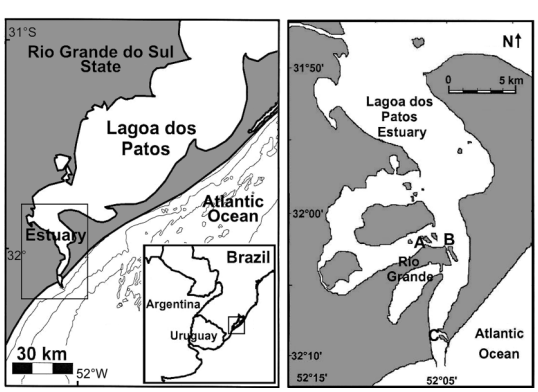

Figure 1. Study site in southern Brazil with the location of the Lagoa dos Patos estuary where censuses of Neotropic Cormorant (*Phalacrocorax brasilianus*) were performed. A: Ilha da Pólvora, B: Clube Regatas, C: power tower near Pontal Sul.

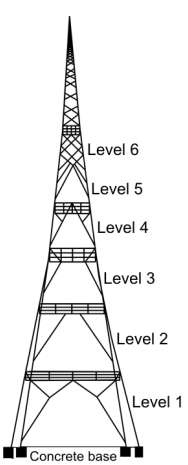

Figure 2. Power tower placed at the mouth of Lagoa dos Patos estuary, southern Brazil. The tower, a major nightly roosting site for the Neotropic Cormorant (*Phalacrocorax brasilianus*), is 135 m in height and was divided into seven levels (concrete base and levels one to six).

To determine where the Neotropic Cormorant was coming from in the morning, and where it was going in the evening, censuses of roosting birds and records of dispersal of flying birds were taken at Clube Regatas and Ilha da Pólvora (Fig. 1). These data were gathered weekly from 29 August to 5 October 2001, from 6:20 h to 10:30 h and from 15:00 h to 18:00 h.

Searches for dense flocks of cormorants and other important places that could be used as nocturnal roosting sites were performed on 6, 8 and 9 November 2001, from 8:00 h to 17:00 h on the southern margin of Lagoa dos Patos estuary. During the day there were some groups foraging and roosting, mainly around Clube Regatas and Ilha da Pólvora. At dusk no flock was found along the borders, and birds were located roosting only on a power tower. This tower was built in 1993 near Pontal Sul at the mouth of Lagoa dos Patos (32°08'S, 52°05'W; Fig. 1). At a height of 134.85 m, the top of the tower supports cables for electric energy transmission across the estuarine channel. The tower has a concrete base surrounded by water, with four platforms 2×6 m connected by traverses elevated 4 m over the water surface. Horizontal, vertical and oblique beams of iron constitute the body of the tower, with horizontal beams from 15–25 m between each other (Fig. 2). Horizontal beams were used to define different height levels for censuses (see below). To determine the number of cormorants at the power tower, weekly censuses of roosting birds were performed from November 2001 to October 2002. Censuses were carried out by direct counts following Bibby et al. (1993), using 10×50 binoculars and a 12–36×50 scope. The observer was located on the southern margin of the channel, about 800 m from the tower, and counted birds every 30 min at least 2 h before dusk (i.e., census started around 15:30 h in spring, autumn and winter or around 16:00 h in summer). Dusk is defined as the moment when there was not enough luminosity for counts. In order to identify patterns of occupancy by birds, the area of the tower up to 90 m in height was divided into seven levels separated by horizontal beams: the concrete base and levels 1 to 6 (Fig. 2). During each count the number of roosting birds was recorded for each level. A total of 309 counts were carried out over 47 days of census. In order to determine whether cormorants stayed on the tower overnight, censuses were performed at the tower on 10 and 30 September 2002, from dawn to 4 h later, using the same census method described above.

For the analysis of censuses of roosting birds and records of dispersal of flying birds at Clube Regatas and Ilha da Pólvora each count was presented as the proportion of birds in relation to the first count in the morning and evening, as $P_{f,t} = N_f / N_t$, where $P_{f,t}$ is the presence factor of birds at time t, N_f is the absolute number of birds at the first count, and N_t is the absolute number of birds at time t. For the analysis of each census day at the tower, the number of birds in each count was presented as the proportion of birds in relation to the last count. The occupancy pattern of different tower levels by cormorants was determined as $F_{n,i} = 100\,(N_{n,i} / N_{t,i})$, where $F_{n,i}$ is the occupancy factor of level n at time i, $N_{n,i}$ is the mean annual number of birds on level n, and $N_{t,i}$ is the mean annual number of birds on the tower. Differences in monthly numbers of cormorants roosting at the tower were tested using the Kruskal-Wallis Test (Zar 1999) and the BioEstat software (Ayres and Ayres 1998).

RESULTS

At Ilha da Pólvora and Clube Regatas, birds were recorded arriving just after dawn and then departing at dusk (Fig. 3). At these places there are structures used as perches during daytime (stakes used by fishermen to fix nets, piers, buoys for nautical navigation and rocks). Cormorants were observed feeding in nearby waters and using these perches for preening and daytime roosting. Other nightly roosting sites were not found in the estuary area during our trips along the margins. The number of cormorants counted at the tower increased from mid-evening to dusk (Fig. 4). The lowest number of birds was 2, recorded at the first count (15:30 h), performed in May. The highest number was 1501 birds, recorded at dusk in January.

On the two morning censuses performed at the tower in September, 783 and 252 birds were recorded, respectively. A few cormorants were flying and swimming around the tower and flocks were departing to estuarine locations away from the ocean. Numbers decreased over the morning and at the last count (10:00 h) there were only 12 and 68 cormorants

Table 1. Mean number (mean percentage in parenthesis) of individuals of Neotropic Cormorant (*Phalacrocorax brasilianus*) at the last count (dusk) of censuses from November 2001 to October 2002 at each power tower level (concrete base and levels 1 to 6) in the Lagoa dos Patos estuary, southern Brazil. Values indicated in parenthesis for each month are number of sampling days.

Month	Base	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
November (4)	114.0 (9.9)	370.8 (32.3)	314.3 (27.3)	180.3 (15.7)	117.8 (10.2)	52.0 (4.5)	0.3 (0.1)
December (3)	112.3 (9.0)	399.7 (31.9)	347.7 (27.7)	211.3 (16.9)	131.7 (10.5)	50.0 (3.9)	0.3 (0.1)
January (4)	116.8 (8.4)	455.0 (32.7)	372.3 (26.8)	209.5 (15.1)	143.3 (10.3)	88.3 (6.4)	4.8 (0.3)
February (4)	110.0 (8.1)	464.8 (34.1)	392.0 (28.8)	211.3 (15.5)	123.8 (9.1)	53.0 (3.9)	6.5 (0.5)
March (4)	27.0 (3.2)	371.3 (44.5)	282.5 (33.9)	98.3 (11.8)	47.8 (5.7)	6.3 (0.8)	0.3 (0.1)
April (4)	0.5 (0.2)	164.8 (69.9)	70.3 (29.8)	0.3 (0.1)	0	0	0
May (3)	1.3 (1.1)	105.3 (90.3)	10.0 (8.6)	0	0	0	0
June (4)	46.8 (14.7)	237.0 (74.7)	33.5 (10.6)	0	0	0	0
July (5)	46.4 (8.3)	309.4 (55.6)	189.6 (34.1)	11.2 (2.0)	0	0	0
August (4)	76.0 (8.7)	362.8 (41.7)	275.8 (31.7)	132.3 (15.2)	23.5 (2.7)	0	0
September (4)	141.3 (13.0)	399.3 (36.8)	299.0 (27.6)	154.8 (14.3)	62.8 (5.8)	26.8 (2.5)	0
October (4)	150.0 (13.2)	417.8 (36.8)	295.5 (26.0)	156.5 (13.8)	90.0 (7.9)	26.8 (2.3)	0

roosting, confirming the use of the tower as a nightly roosting site. These results show that cormorants roost on the tower at night and spread out in estuarine waters during the day, making the abundance at this place, estimated through the last count at dusk, a good minimum population estimate for the southern portion of the estuary.

The distribution of cormorants on different levels of the tower at the last count is shown in Table 1. During months with high numbers of individuals roosting at the tower (over 1000 birds, from September to February), percentage values for each level had low variation, from 8.1–13.2% at the concrete base and 26.0–28.8% at level 2. Large numbers of cormorants rested in levels 1 and 2, accounting for 60% of birds from November to March and from August to October. From April to July (months with low abundance), 90% of all birds were on levels 1 and 2, and no bird rested on levels 4–6. The highest number of roosting birds was recorded on levels 1 and 2 in February, with mean values of 464.8 and 392.0 birds, respectively. Level 6 was occupied only when

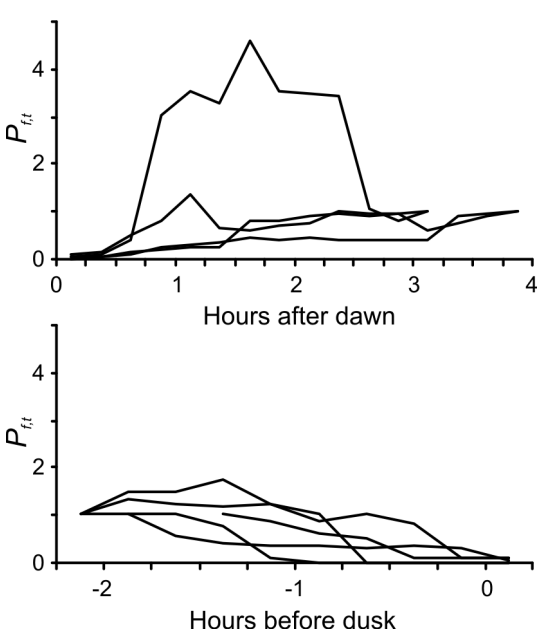

Figure 3. Temporal variation in the abundance of Neotropic Cormorant (*Phalacrocorax brasilianus*) roosting in Clube Regatas and Ilha da Pólvora, Lagoa dos Patos estuary, southern Brazil, in September and October 2001. Each line corresponds to a one-day census.

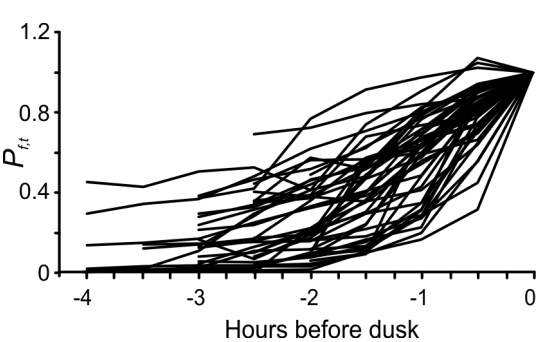

Figure 4. Temporal variation in the abundance of Neotropic Cormorant (*Phalacrocorax brasilianus*) roosting on the power tower placed at the mouth of Lagoa dos Patos estuary, southern Brazil, from November 2001 to October 2002. Each line corresponds to a one-day census.

abundance was high, from November to March, and the number at this level was low even during February, when 6.5 birds on average were recorded. January was the month with the highest number of roosting cormorants on the tower, with an average of 1390 birds (Table 1).

Occupancy patterns of each tower level are shown in Fig. 5. Cormorants rested on both horizontal and oblique beams, arriving around 15:30 h (i.e., in the middle of the afternoon) and roosting in the lowest levels (concrete base, levels 1 and 2), and using higher levels (levels 4–6) once low levels were unavailable (Fig. 5). In general, cormorants started to roost at level 4 from 17:30 h onwards, at level 5 around 18:30 h onwards, and at level 6 only around 19:30 h, near dusk, and when lower levels were crowded (Fig. 5).

During the study, significant monthly variation in cormorant abundance was found ($H = 34.1$, $P = 0.0004$). Two distinct periods could be identified when analyzing abundance: months with high abundance (1099–1390 birds) from September to February, and months with low abundance (117–557 birds) from April to July (Fig. 6). March and August were months with intermediate abundance. The increase in birds from the minimum in May to the maximum in January occurred gradually.

DISCUSSION

The foraging behaviour of the Neotropic Cormorant regulates daily movement patterns at Lagoa dos Patos estuary near dawn and dusk. Cormorants, like other seabirds, are visual predators, dependent upon light for foraging activities (Wanless et al. 1999), which explains dispersal to feeding grounds at dawn and return to roosting sites at dusk. Similar dispersal patterns were recorded for non-breeding individuals of the Neotropic Cormorant in Uruguay and Argentina, where Escalante (1970) and Daciuk et al. (1985) found regular movements for feeding and night roosting in similar periods. Jordán (1959) and King et al. (1995) reported similar patterns for the Guanay Shag (*Phalacrocorax bougainvilli*) and the Double-crested Cormorant, in Peru and United States of America, respectively. Intensive feeding during the morning was suggested as a standard behaviour of non-breeding or post-breeding cormorants by Coleman and Richmond (2007), a pattern also recorded for the Common Tern (*Sterna hirundo*) in the study area (Bugoni and Vooren 2005, Bugoni et al. 2005), which suggests that this is a common pattern for non-breeding seabirds.

No nightly roosting site other than the power tower was found along the estuary, except for

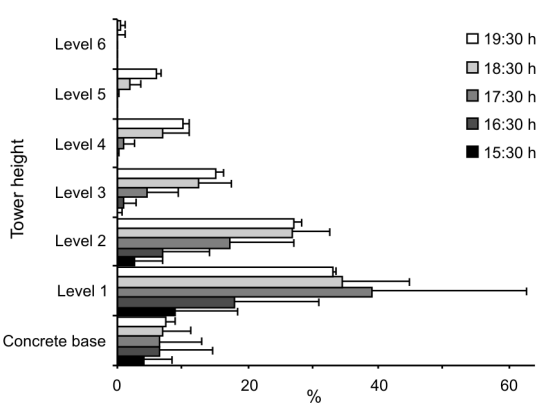

Figure 5. Mean (+ SD) percentage of individuals of Neotropic Cormorant (*Phalacrocorax brasilianus*) roosting at each power tower height (concrete base and levels 1 to 6) at different hours between November 2001 and October 2002 in the mouth of Lagoa dos Patos estuary, southern Brazil. To make the figure clearer, results are presented per hour and not every 30 min as collected.

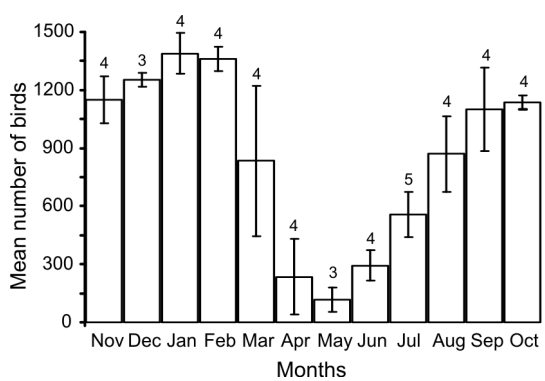

Figure 6. Mean (± SD) monthly abundance of individuals of Neotropic Cormorant (*Phalacrocorax brasilianus*) roosting on the power tower placed at the mouth of Lagoa dos Patos estuary, southern Brazil, from November 2001 to October 2002. Numbers above bars are number of sampling days.

a small lake at the university campus, about 2 km from the estuary. From August to December 2002, around 250 cormorants shared two small islands covered by trees 10 m in height with similar numbers of Snowy Egret (*Egretta thula*), Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis*) and White-faced Ibis (*Plegadis chihi*) (Barquete and Aguiar, unpublished data). In contrast, at the tower where the Neotropic Cormorant was censused for the present study it was the only species recorded. Johansen et al. (2001) found in a similar study in Norway that the Great Cormorant used a lighthouse 800 m from the shore as a nightly roosting site, also indicating the use of anthropogenic structures for nightly roosting by cormorants.

In spite of the shelter from terrestrial predators and human disturbance offered by the tower, the exposure to wind could probably be an unfavourable aspect of this roosting site for the Neotropic Cormorant, due to its location at the mouth of the estuary. Hebshi (1998) found that long-term exposure to strong wind, among other factors, determines where the Brandt's Cormorant (*Phalacrocorax penicillatus*) forages. At Lagoa dos Patos estuary, strong winds 18–38 km/h from NE are common around the year (Braga and Krusche 2000). During summer, when NE winds predominate, large numbers of cormorants used the tower. In winter, strong S and SW winds and influxes of cold fronts are common (Braga and Krusche 2000), although the number of cormorants roosting at the tower increased. Evidently, the degree of exposure at the tower does not limit its use by birds; however it could explain the preference of birds for low levels of the tower. High levels are more exposed than lower levels and we presume they are exposed to stronger winds (although wind speeds at different levels of the tower were not measured). The fact that during months with low abundance of birds (April to July), only the three lower levels were used, and in months with high abundance the occupancy started in the three lower levels, provides additional evidence about the preference of the birds for low levels of the tower.

The Neotropic Cormorant migrates to Lagoa dos Patos during the austral winter and spring (end of June to December), staying at the estuary during summer (January to March) and departing to other sites at the end of March, April and May. The influx to the estuary takes place gradually, over 3 to 8 months, while departure from the area in March is abrupt. The abundance of cormorants in the estuary decreased during autumn (April to May), similar to results reported by Vooren and Chiaradia (1990) on Cassino Beach, adjacent to the estuary. A similar pattern was recorded by Daciuk et al. (1985) who observed minimum numbers in Chascomús Lagoon, Argentina, in June and July, and suggested that birds migrate to breeding areas at Entre Ríos and Santa Fe provinces, Argentina. Low numbers of the Neotropic Cormorant at Lagoa dos Patos estuary during autumn and winter could also be explained by their migration to breeding sites, despite breeding records at Rio Grande do Sul State during spring (Belton 1994). The gradual arrival of birds in winter and spring is related to the influx of juveniles and adults from breeding sites. The low number of cormorants in southern Brazil in autumn (Branco 2002, this study) does not correspond with the breeding period in several nearby places, such as Rio Grande do Sul State (Belton 1994), Santa Catarina State (Azevedo 1995), and Lower Paraná River, Argentina (Bó 1956), where cormorants breed in spring. However, the absence of cormorants in autumn coincides with the breeding period in Santa Fe, Argentina, where de la Peña (1980) found a colony with 4000–5000 nests in April, and in the Paraná River Basin, where Olrog (1975) banded chicks in late May and early June. An alternative hypothesis is that birds migrate from southern Brazil to the Pantanal region, where the Neotropic Cormorant starts to breed in May (da Silva et al. 2000). In addition, a colony of the Neotropic Cormorant with 80 nests was recently discovered near the Lagoa dos Patos in autumn 2005 (AS Peter, pers. com.). Since this is a comparatively low number of birds in relation to those wintering in Lagoa dos Patos estuary, it suggests that most birds in the southern portion of the estuary breed elsewhere. To clarify migration patterns of the Neotropic Cormorant in the Lagoa dos Patos estuary, further tracking studies and investigation of potential areas for local colony establishment are required.

The study of the Neotropic Cormorant population in the Lagoa dos Patos estuary identifies the species as an important piscivorous predator, where they prey mostly on

species of commercial value (Barquete et al. 2008). According to Duffy and Siegfried (1987), colonies of Guanay Shag and Cape Cormorant (*Phalacrocorax capensis*) do not compete with fisheries. However, Birt et al. (1987) established that fish densities are significantly lower in areas close to Double-crested Cormorant colonies in comparison to areas without foraging birds. Lagoa dos Patos estuary is an important spawning, nursery and feeding ground for coastal and estuarine fish species (Sinque and Muelbert 1998). Due to its high abundance in the estuary and its piscivorous diet, the Neotropic Cormorant should be included in fish stock management (Barquete et al. 2008). Although this species is abundant in coastal and inland environments throughout America, its life history is still poorly known, and in need of more study.

ACKNOWLEDGEMENTS

Authors would like to thank Universidade Federal do Rio Grande (FURG) and Instituto de Oceanografia for logistic support during the study and to P. C. Vieira and N. M. Gianuca for comments on an earlier version of the manuscript. We appreciate the improvements in English usage made by Stacy Small through the Association of Field Ornithologists' program of editorial assistance.

LITERATURE CITED

ASMUS ML (1998) A planície costeira e a Lagoa dos Patos. Pp. 9–12 in: SEELIGER U, ODEBRECHT C AND CASTELLO JP (eds) *Os ecossistemas costeiro e marinho do extremo sul do Brasil*. Ecoscientia, Rio Grande

AYRES M AND AYRES M JR (1998) *BioEstat, aplicações estatísticas nas áreas das ciências biológicas e médicas*. Sociedade Civil Mamirauá, Manaus

AZEVEDO TR (1995) Estudo da avifauna do campus da Universidade Federal de Santa Catarina (Florianópolis). *Biotemas* 8:7–35

BARQUETE V, BUGONI L AND VOOREN CM (2008) Diet of Neotropic Cormorant (*Phalacrocorax brasilianus*) in an estuarine environment. *Marine Biology* 153:431–443

BELTON W (1994) *Aves do Rio Grande do Sul, distribuição e biologia*. Unisinos, São Leopoldo

BIBBY CJ, BURGESS ND AND HILL DA (1993) *Bird census techniques*. Academic Press, London

BIRT VL, BIRT TP, GOULET D, CAIRNS DK AND MONTEVECCHI WA (1987) Ashmole's halo: direct evidence for prey depletion by a seabird. *Marine Ecology Progress Series* 40:205–208

BÓ NA (1956) Observaciones morfológicas y etológicas sobre el Biguá. *Hornero* 10:147–157

BRAGA MFS AND KRUSCHE N (2000) Padrão de ventos em Rio Grande, RS, no período de 1992 a 1995. *Atlântica* 22:27–40

BRANCO JO (2002) Flutuações sazonais na abundância de *Phalacrocorax brasilianus* (Gmelin) no estuário do Saco da Fazenda, Itajaí, Santa Catarina, Brasil. *Revista Brasileira de Zoologia* 19:1057–1062

BROWNING MR (1989) The correct name for the Olivaceous Cormorant, "Maiague" of Piso (1658). *Wilson Bulletin* 101:101–106

BUGONI L, CORMONS TD, BOYNE AW AND HAYS H (2005) Feeding grounds, daily foraging activities, and movements of Common Terns in southern Brazil, determined by radio-telemetry. *Waterbirds* 28:468–477

BUGONI L AND VOOREN CM (2004) Feeding ecology of the Common Tern *Sterna hirundo* in a wintering area in southern Brazil. *Ibis* 146:438–453

BUGONI L AND VOOREN CM (2005) Distribution and abundance of six tern species in southern Brazil. *Waterbirds* 28:110–119

CALLIARI LJ (1998) Características geológicas. Pp. 13–18 in: SEELIGER U, ODEBRECHT C AND CASTELLO JP (eds) *Os ecossistemas costeiro e marinho do extremo sul do Brasil*. Ecoscientia, Rio Grande

CASTELLO JP (1986) Distribución, crecimiento y maduración sexual de la corvina juvenil (*Micropogonias furnieri*) en el estuario de la "Lagoa dos Patos", Brasil. *Physis, A* 44:21–36

COLEMAN JTH AND RICHMOND ME (2007) Daily foraging patterns of adult Double-crested Cormorants during the breeding season. *Waterbirds* 30:189–198

DACIUK J, PADIN OH AND PROTOGINO LC (1985) Censos de la avifauna de la laguna Chascomús (Prov. de Buenos Aires, Argentina). *Physis, B* 43:93–102

DUFFY DC AND SIEGFRIED WR (1987) Historical variations in food consumption by breeding seabirds of the Humboldt and Benguela upwelling regions. Pp. 327–346 in: CROXALL JP (ed) *Seabirds: feeding biology and role in marine ecosystems*. Cambridge University Press, Cambridge

ESCALANTE R (1970) *Aves marinas del Río de la Plata y aguas vecinas del Océano Atlántico*. Barreiro y Ramos, Montevideo

FRERE E, QUINTANA F AND GANDINI P (2005) Cormoranes de la costa patagónica: estado poblacional, ecología y conservación. *Hornero* 20:35–52

HARRISON P (1985) *Seabirds, an identification guide*. Houghton Mifflin, Boston

HEBSHI A (1998) Foraging site preferences of Brandt's Cormorants off the Santa Cruz, California, coast. *Colonial Waterbirds* 21:245–250

DEL HOYO J, ELLIOTT A AND SARGATAL J (1992) *Handbook of the birds of the world. Volume 1. Ostrich to ducks*. Lynx Edicions, Barcelona

JOHANSEN R, BARRETT RT AND PEDERSEN T (2001) Foraging strategies of Great Cormorants *Phalacrocorax carbo carbo* wintering north of the Artic Circle. *Bird Study* 48:59–67

JORDÁN R (1959) El fenómeno de las regurgitaciones en el Guanay (*Phalacrocorax bougainvillii* L) y un método para estimar la ingestión diaria. *Boletín de la Compañía Administradora del Guano* 34:23–40

KALMBACH E, RAMSAY SC, WENDELN H AND BECKER PH (2001) A study of Neotropic Cormorants in Central Chile: possible effects of El Niño. *Waterbirds* 24:345–351

KING DT, GLAHN JF AND ANDREWS KJ (1995) Daily activity budgets and movements of winter roosting Double-crested Cormorants determined by biotelemetry in the Delta Region of Mississippi. *Colonial Waterbirds* 18:152–157

NAVES LC AND VOOREN CM (2006) Diet of Black Skimmers in Southern Brazil. *Waterbirds* 29:335–344

OLROG CC (1968) El anillado de aves en la Argentina. 1964–1966. Quinto informe. *Neotropica* 14:17–22

OLROG CC (1975) Vagrancy in Neotropical Cormorant, egrets, and White-faced Ibis. *Bird Banding* 46:207–212

DE LA PEÑA MR (1980) Notas nidológicas sobre biguaes y cormoranes (aves: Anhingidae y Phalacrocoracidae). *Historia Natural* 1:109–112

PINTO OMO (1964) *Ornitologia brasiliense*. Secretaria de Agricultura do Estado de São Paulo, São Paulo

PINTO OMO (1978) *Novo catálogo das aves do Brasil. Part I*. Emp. Gráfica da Revista dos Tribunais, São Paulo

REIS EG, VIEIRA PC AND DUARTE VS (1994) Pesca artesanal de teleósteos no estuário da Lagoa dos Patos e costa do Rio Grande do Sul. *Atlântica* 16:69–86

RICHNER H (1995) Wintering cormorants *Phalacrocorax carbo carbo* in the Ythan estuary, Scotland: numerical and behavioural responses to fluctuating prey availability. *Ardea* 83:193–197

SICK H (1997) *Ornitologia brasileira*. Nova Fronteira, Rio de Janeiro

DA SILVA CJ, ABDO MSA, OLIVEIRA DMM AND GIARD P (2000) Caracterização ambiental do ninhal Corutuba, Pantanal de Barão de Melgaço, MT. Pp. 1–11 in: DANTAS M, KAWAKAMI ER AND COMASTRI FILHO JA (eds) *Anais do III Simpósio sobre recursos naturais e sócio-econômicos do Pantanal. Os desafios do novo milênio*. Embrapa Pantanal, Corumbá

SINQUE C AND MUELBERT JH (1998) Ictioplâncton. Pp. 56–60 in: SEELIGER U, ODEBRECHT C AND CASTELLO JP (eds) *Os ecossistemas costeiro e marinho do extremo sul do Brasil*. Ecoscientia, Rio Grande

TELFAIR RC II AND MORRISON ML (1995) Neotropic Cormorant (*Phalacrocorax brasilianus*). Pp. 1–22 in: POOLE A AND GILL F (eds) *The Birds of North America*. Academy of Natural Sciences and American Ornithologists' Union, Philadelphia and Washington DC

VOOREN CM AND CHIARADIA A (1990) Seasonal abundance and behaviour of coastal birds on Cassino Beach, Brazil. *Ornitología Neotropical* 1:9–24

WANLESS S, FINNEY SK, HARRIS MP AND MCCAFFERTY DJ (1999) Effect of the diel light cycle on the diving behaviour of two bottom feeding marine birds: the Blue-eyed Shag *Phalacrocorax atriceps* and the European Shag *P. aristotelis*. *Marine Ecology Progress Series* 188:219–224

ZAR JH (1999) *Biostatistical analysis*. Fourth edition. Prentice-Hall, Upper Saddle River