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REPRODUCTIVE BIOLOGY AND PAIR BEHAVIOR DURING INCUBATION OF THE BLACK-NECKED SWAN (*CYGNUS MELANOCORYPHUS*)

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Resumen. – Biología reproductiva y comportamiento del Cisne de Cuello Negro (*Cygnus melanocoryphus*). – El cisne de cuello negro (*Cygnus melanocoryphus*) es la única especie del género *Cygnus* que habita en Sudamérica. Si bien, el resto de las especies del género han sido extensamente estudiadas, para *C. melanocoryphus* aún no se ha descrito la mayor parte de su biología reproductiva. En este estudio evaluamos el comienzo y extensión de la temporada reproductiva, y el tamaño de nidada utilizando datos recolectados en el Santuario Carlos Anwandter (SCA), Valdivia, Chile; correspondientes a 18 temporadas reproductivas. Por otro lado, estudiamos el comportamiento de las parejas durante el periodo de incubación, durante una temporada reproductiva. Se estimó el presupuesto de tiempo y distancia con respecto al nido en seis parejas nidificantes. El periodo de nidificación se puede extender desde junio a enero y está influenciado por el tamaño de la población reproductiva y las condiciones climáticas. El tamaño de nidada se mantiene constante con una moda de tres huevos (promedio 3.13 ± 0.017; n = 5897). Ambos miembros de la pareja desarrollan actividades de vigilancia y mantención del nido, sin embargo, la incubación es una tarea exclusiva de la hembra, mientras que la defensa activa del nido es realizada por el macho. De esta forma, se propone que tanto la extensión del periodo reproductivo y el número de parejas nidificantes podrían estar regulados por procesos denso-dependientes, el tamaño de nidada parece ser altamente conservativo. Finalmente, se observó una clara división de tareas por parte de cada sexo durante del periodo de incubación.

Abstract. – The Black-necked Swan (*Cygnus melanocoryphus*) is the only species of the genus inhabiting South America. Although most of the members have been extensively studied, the reproductive biology of *C. melanocoryphus*, has not been described yet. In this study, we evaluate the starting and extension of the breeding season and clutch size number, using data collected at Carlos Anwandter Santuary (CAS), Valdivia, Chile, corresponding to 18 reproductive seasons. We also studied male and female behavior during incubation period. We monitored time budget and the distance relative to the nest of 6 breeding pairs, during one reproductive season. Nesting period can extend from June to January and is influenced by the population number and weather conditions. Clutch size is constant across seasons with a mode of three eggs (mean of 3.13 ± 0.017 eggs; n = 5897). Both pair members cooperate in duties, such as vigilance and nest maintenance; however, incubation is an exclusive activity of females while the active defense of the nest is performed by males. Therefore, we propose that both extension of breeding season and number of breeding pairs are associated with density-dependent processes while clutch size seems to be highly conservative. Finally, we observed a clear separation in parental tasks for each sex during incubation period. *Accepted 14 February 2013*.

Key words: Black-necked Swan, *Cygnus melanocoryphus,* breeding biology, breeding season, clutch size, nesting behavior, incubation, Chile.

INTRODUCTION

The seven living species of swans of the genus *Cygnus* are the biggest and most conspicuous among the waterfowl. Swans form life-long pairs, and both sexes remain with the young for extended periods of time (Kear 1972, Ming & Dai 2000). Males have an important role during the reproductive period, and in some species they take part in the incubation, as in the case of *C. olor*, *C. bewickii*, and *C. atratus* (Braithwaite 1981, Brugger & Taborsky 1994, Kondratiev 1991). Swans usually build large semi-floating nests, using vegetation material of the environment although sometimes they may nest on dry land, but always in the proximity of water (Braithwaite 1982, Owen & Black 1990, Weller 1999, Ming & Dai 2000). Incubation period and clutch size vary according to the species ranging from 1 to 12 eggs (Lack 1968, Scott 1972, Braithwaite 1977, Birkhead *et al.* 1983, Bart *et al.* 1991, Mineyev 1991, Wlodarczyc & Wojciechowski 2001). The incubation period varies between 31 to 48 days (Scott 1972, Braithwaite 1981, Birkhead & Perrins 1986, Hawkins 1986). The cygnets stay with their parents at least six months (Scott 1977). Swans are highly territorial during egg laying and incubation period, only for *C. atratus* there are reports of natural breeding colonies (Braithwaite 1982) although solitary nesting is also common (Miers & Murray 1969).

Most of Black-necked Swan (*Cygnus melanocoryphus*) basic reproductive biology in the wild is, unlike in the other species of swans, unknown (Canevary & Narosky 1995). The Black-necked Swan is the only representative species of the genus in the Neotropics, its distribution comprises southern Brazil, Paraguay, coastal Uruguay, almost all Argentina, and Central and southern Chile (Schlatter *et al.* 1991a, Rodríguez *et al.* 2006). The Black-necked Swan (BNS) is an efficient grazer, consuming large amount of aquatic plants (Corti 1996), nesting only in areas where the emergent vegetation is abundant and the level of water is stable (Corti & Schlatter 2002).

In this work, we aimed to determine two basic breeding parameters, extent of the breeding period and clutch size, using field data collected during 18 breeding seasons. We also evaluated pair behavior and space utilization during incubation period, using data collected during one breeding season.

METHODS

Study area. Field work was conducted at Carlos Anwandter Sanctuary (CAS), located at Cruces River (39º49'S, 73º15'W), Los Ríos Region, Chile. CAS surface area covers about 4877 ha, 25 km long, and is 2 km wide on average (Salazar, 1988). This extensive wetland is part of an estuarine complex which includes marsh areas, calm waters, and a bottom substrate of lime and sand (Steubing *et al.* 1980, Ramírez *et al.* 1991). The weather type in this area is Csb3 according to Köppen classification system. The mean annual temperature is 12.1°C and the mean annual rainfall is 2415 mm (Huber 1970, 1975). There are no dry months, but the highest rainfall occurs during winter (Di Castri & Hajek 1976). The flora comprises 90 species, with more than 30% of alochtonuous elements. Amongst the submerged and flooded plant species *Egeria densa*, *Elodea canadensis*, *Myriophyllum aquaticum*, and *Ludwigia peploides* are dominant. Amongst the marshland plants *Scirpus californicus* and *Juncus procerus* are widely dominant (Ramírez *et al.* 1991, San Martín *et al.* 2000).

Breeding parameters. Two breeding parameters were evaluated, extent of the breeding period and clutch size. We analyzed data collected by CONAF (Corporación Nacional Forestal) park rangers at CAS, on a monthly basis surveys during 18 BNS breeding seasons (1986–2004), following the established protocol

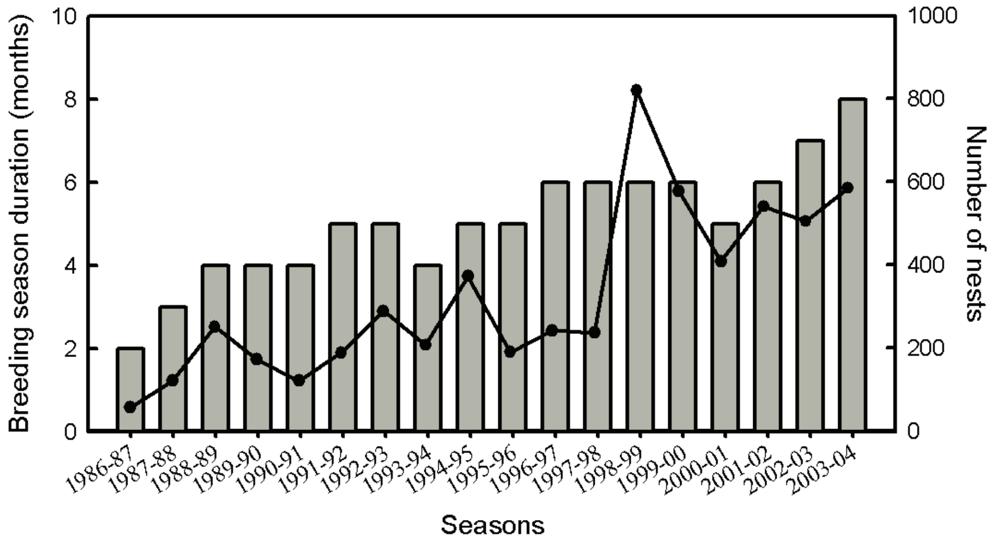

FIG. 1: Population estimators for 18 Black-necked Swan breeding seasons. Data collected from 1987–2004 at Carlos Anwandter Santuary by CONAF park rangers; shown are duration of breeding seasons (bars) and number of nests (line) found during each season.

described in Schlatter *et al.* (1991a) and Schlatter & Mansilla (1998).

Breeding behavior. The data corresponding to breeding behavior were collected during the breeding season from September 2003 to January 2004. Black-necked Swans inhabit this site during the whole year; however, the population size is fluctuating with a maximum in spring (September–December) and a minimum in winter (June–August). Six breeding pairs were selected considering the visibility of their nests from inland. One nest was in the laying phase and the other five nests were in the incubation stage when found. A kayak was used to visit the nests on a weekly basis after beginning the observations. Pairs were observed through binoculars (10x42 mm) and spotting scope (15–60x60mm) at distances of 100–300 m in order to keep disturbance levels at minimum. Instantaneous focal animal sampling (Altmann 1974) was used to record the behavior of the male and female of each pair. All registrations were made considering the pair members as separate individuals, but simultaneously. The sex was determined based on the corporal size, coloration, and size of the caruncle (Scott 1972, Nascimento *et al.* 2001, MSG unpubl.). The individuals were identified based on the pattern of the eye lines (Seijas 1996). The observations were made during the daylight hours, divided into three periods: 09:00–12:00 h; 13:00–16:00 h; and 17:00–19:00 h. Each period was divided in 30 intervals of 10 min, and recordings were made for each minute. The individual's positions was registered with regard to the nest distance: i) distance 0, individual positioned on the nest; ii) distance 1, individual positioned between 0.5 and 1 m in relation to the nest; iii) distance 2, individual positioned between 1.0 and 10 m in relation to the nest; and iv) distance 3, individual positioned between 10 m and beyond in relation to the nest. The activity or predominant state was also registered: i) incubation, individual staying on the nest, ii) resting, individual remaining with the neck folded and resting on the

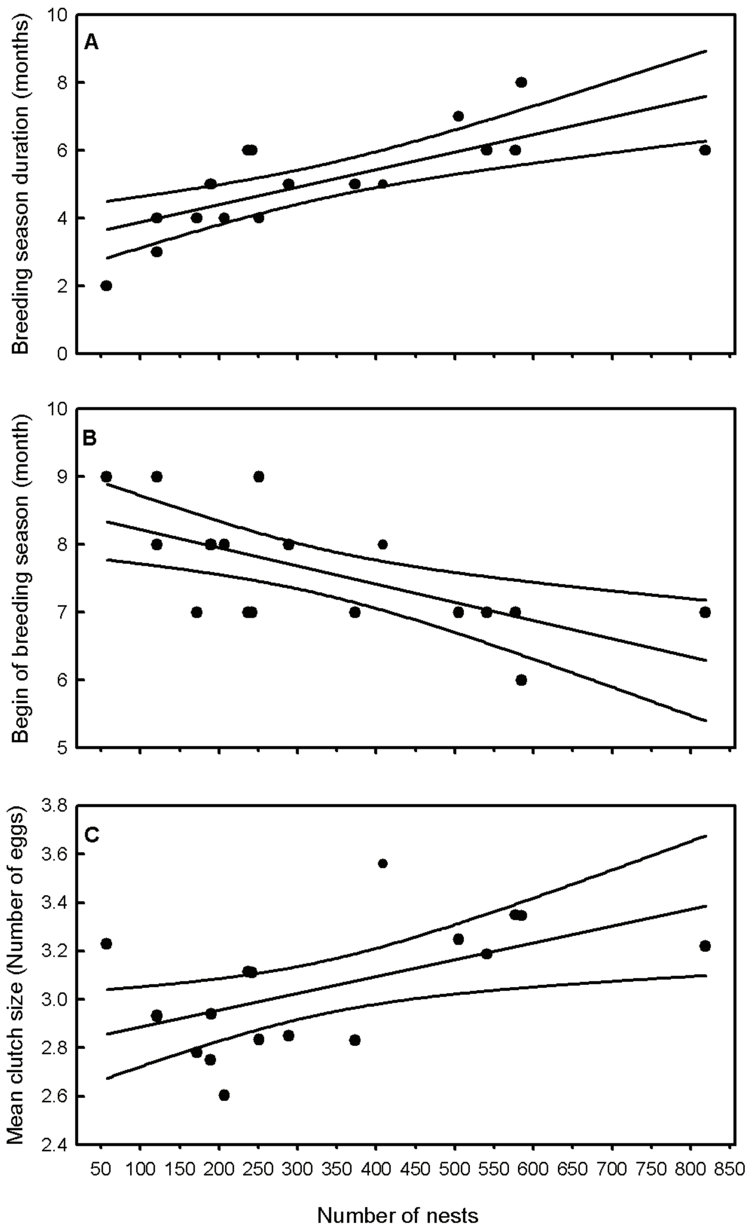

FIG. 2. A) Relation between number of Black-necked Swan nests and breeding season duration at Carlos Anwandter Sanctuary. Linear regression shows a significant relation with r^2 = 0.55. B) Relation between number of nest and the beginning of breeding season. Linear regression shows a significant relation with r^2= 0.42. Number 5 represents May and no. 10 represents October. C) Relation between number of nest and mean of clutch size. Linear regression shows a significant relation with r^2 = 0.31. Outer lines represent the 95 % of confidence of data.

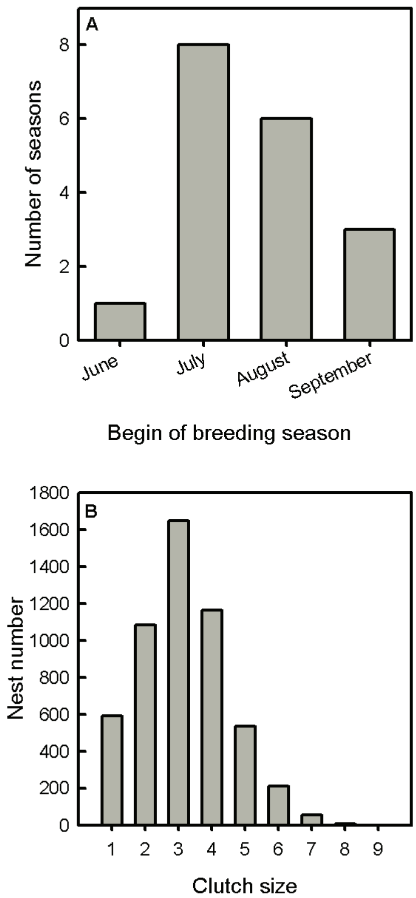

FIG. 3. Population estimators for the Black-Necked Swan based on data collected from 1987–2004 at CAS by CONAF park rangers. A) Breeding season start month in relation to the total number of seasons; B) clutch size number in relation of the number of total nests found during the 18 breeding seasons.

back, or with head placed under a wing; iii) alert, individual vigilantly attentive with neck in a straight position; iv) preening, individual smoothing or cleaning their feathers with the bill; iv) nest maintenance, individuals adding or rearranging material or cleaning the nest; and vi) others, include foraging and aggressions received and aggressions towards others. This protocol produced 92 hours of systematic observations during 23 days. The results are presented in relation to the three periods of observation described above.

Statistical analyses. Parametric and non-parametric statistics were used. To analyze the relation between the number of nests across seasons and breeding season's begin and duration and clutch size mean, we used a lineal regression analysis. To evaluate the relation among periods of the day and the distance relative to the nest, and periods of the day and activities during incubation period, we used a Kruskal-Wallis test, using mean individual's behavior as unit sample. A non-parametric Multiple Comparison of Mean test (*post hoc*)

TABLE 1. Clutch size variation across 18 Black-Necked Swan breeding seasons (1986–2004). We include the number of nest (N), clutch size mean ± standard error, median, mode, and range (Min–Max).

Season	N	Clutch size Mean	Clutch size Median	Clutch size Mode	Clutch size Range
86–87	57	3.23 ± 0.19	3	3	1–7
87–88	121	2.93 ± 0.13	3	3	1–8
88–89	254	2.83 ± 0.08	3	3	1–6
89–90	174	2.78 ± 0.09	3	3	1–6
90–91	123	2.93 ± 0.11	3	3	1–7
91–92	189	2.75 ± 0.08	3	3	1–6
92–93	289	2.85 ± 0.08	3	3	1–8
93–94	207	2.60 ± 0.09	3	3	1–6
94–95	377	2.83 ± 0.06	3	3	1–6
95–96	190	2.94 ± 0.08	3	3	1–7
96–97	243	3.11 ± 0.08	3	3	1–6
97–98	237	3.11 ± 0.09	3	3	1–6
98–99	819	3.22 ± 0.05	3	3	1–7
99–00	577	3.35 ± 0.06	3	3	1–9
00–01	409	3.56 ± 0.07	3	3	1–9
01–02	541	3.19 ± 0.05	3	3	1–7
02–03	505	3.25 ± 0.06	3	3	1–8
03–04	585	3.35 ± 0.06	3	3	1–9
TOTAL	5897	3.13 ± 0.02	3	3	1–9

was used to evaluate differences between groups. All statistical analyses were performed using Statistica 7 software (StatSoft 2004).

RESULTS

Breeding season extension ranges between 2 and 8 months among years, with a mean of 5.05 months (Fig. 1). The number of nest varies between seasons, but presents a significant increase along time ($r^2 = 0.620$, $p < 0.0001$, Fig. 1). The number of nests and the breeding season extension are linearly and positively related ($r^2 = 0.55$, $p = 0.0004$, Fig. 2A), and inversely related with breeding season beginning ($r^2 = 0.42$, $p = 0.004$, Fig. 2B). Number of nest and clutch size mean presented a significant and positive lineal relationship ($r^2 = 0.31$, $p = 0.02$, Fig. 2C). The breeding period can start as early as in June and as late as in September, but most nests started between July and August (Fig. 3A). The clutch size mean (considering all seasons) is 3.13 ± 0.017 eggs (n = 5897, Fig. 3B). Analyzing clutch size by season the mean varied in a range of 2.60 ± 0.09 to 3.56 ± 0.07 eggs (Table 1). The median and mode for all seasons was 3, but the maximum clutch size varied from 6 to 9 eggs (Table 1). For females, we found statistically significant differences for the four categories of distance considered in relation to the nest. For period 1, females stayed over 75% of the time in distance 0 (on the nest), while the 25% was uniform distributed in the three other categories (K-W, $H_{[3, 24]} = 15.42$, $p = 0.015$, Fig. 4A). The same pattern was observed for the second period (K-W, $H_{[3, 24]} = 17.1$, $p < 0.001$, Fig. 4B), and period 3 (K-W, $H_{[3, 24]} = 14.99$,

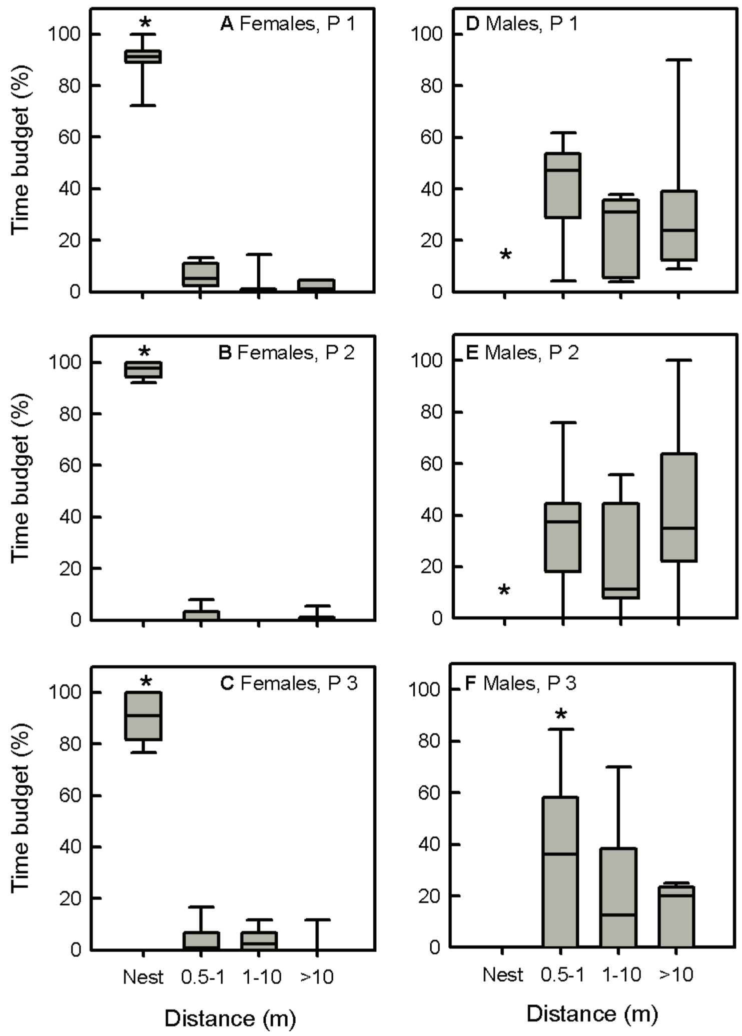

FIG. 4. Distance in relation to nest for females and males of the Black-necked Swan. Budget is expressed as percentage of time spent at each distance category for the 3 period categories. Females period 1 (A), period 2 (B), period 3 (C). Males period 1(D), period 2 (E) and period 3 (F). An asterisk (*) indicates *post-hoc* significant differences at $P < 0.05$.

p = 0.002, Fig. 4C). For males, the time invested in relation to the nest distance varied during the first period (K-W, H [3, 24] = 14.39, p = 0.002). A *post hoc* Multiple Comparison of Mean test showed that distance 0 (on the nest) is significantly different from the other three categories. Males were never observed on the nest (Fig. 4D). The same pattern was observed for the second period (K-W, H [3, 24] = 10.42, p = 0.02, Fig. 4E). For the third period, the differences persist among categories (K-W, H [3, 24] = 7.99, $p < 0.045$); a *post hoc* Multiple Comparison of Mean test showed that males spent significantly more time at 0.5–1.0 m (Fig. 4F).

For females, distance 0 corresponds to incubation. During incubation, females were able to perform in parallel the activities of resting, preening nest care, and others. We found significant differences in the time invested among activities during period 1 (K-W, H [4, 30] = 22.83, p = 0.0001). Using a *post hoc* Multiple Comparison of Mean test we found resting time is not different from alert and nest care, but there are significant differences between them and preening and other, meaning females spent more time in alert and nest care activities (Fig. 5A). For period 2, significant differences were also found among the time invested on the activities (K-W, H [4, 30] = 19.16, p = 0.0007) where more time is allocated to alert than preening and others, and nest care is not different from others (Fig. 5B). We found significant differences for period 3 (K-W, H [4, 30] = 12.12, p = 0.016), only on resting behavior, that showed differences with other (Fig. 5C). Differences were detected among activities for the period 1 and 2 (K-W, H [4, 30] = 13.32, p = 0.01 and K-W, H [4, 30] = 14.49, p = 0.006, respectively; Figs 5A–B), where the activity "other" is significant different from the other activities. For period 3, no significant differences were observed (K-W, H [4, 30] = 13.77, p = 0.44, Fig. 5C). Incubation bouts ranged from 1 to 36 min (n = 40). There is no significant differences between activities during incubation bouts, in none of the three periods of the day considered (Figs 5A–C). Males' activities for period 1 presented significant differences (K-W, H [4, 30] = 17.20, p = 0.002), where the activity other was different and less time was spent in this activity, from resting and preening (Fig. 6A). Period 2 also showed significant difference among activities (K-W, H [4, 30] = 15.91, p = 0.003), where other was different from preening (Fig. 6B). Period 3 showed no significant differences among activities (Fig. 6C).

DISCUSSION

The number of BNS nests through all the breeding seasons analyzed (1986–87/2003–04) at CAS presents an increasing trend which could be related to the increase in the extension of the breeding season. During the same period, the BNS population at CAS fluctuated, also exhibiting an increasing trend (Schlatter *et al.* 2002). Therefore the most probable cause for the nest number increase and breeding season extension is population growth, a density-dependent phenomenon (Schlatter *et al.* 2002, Vilina *et al.* 2002). Our data also suggest that breeding season extension is due to an early start of the breeding season and not to a late end of it, and early beginning is positively correlated with an increase on nest numbers. A factor that could be influencing the number of nests and breading season extension is weather conditions (Schlatter *et al.* 1991a, 1991b, 2002; Vilina *et al.* 2002). The occurrence of heavy rain and wind events could cause a delay of nest building and egg laying (Schlatter *et al.* 1996), but also the loss of nests. Renesting attempts could explain the prolonged breeding seasons detected (Kear 1972). Although the observed clutch size median and mode across all breeding seasons considered in this study was three eggs (similar to that described in Schlatter *et al.* 1991b), pointing to a conservative clutch size, we observed an increase of egg number associated to the number of nests. We suggest two possible explanations for this phenomenon: first, an arrival of older and more experienced individuals from other wetlands, nomadic movements related to climatic events (see Schlatter *et al.* 2002) and second, a possible increase in food availability (Böhning-Gaese *et al.* 2000).

The behavior of pairs during breeding season has been not sufficiently studied. Jones (1947) and Haedo (1953) described BNS males always guarding the nest while the

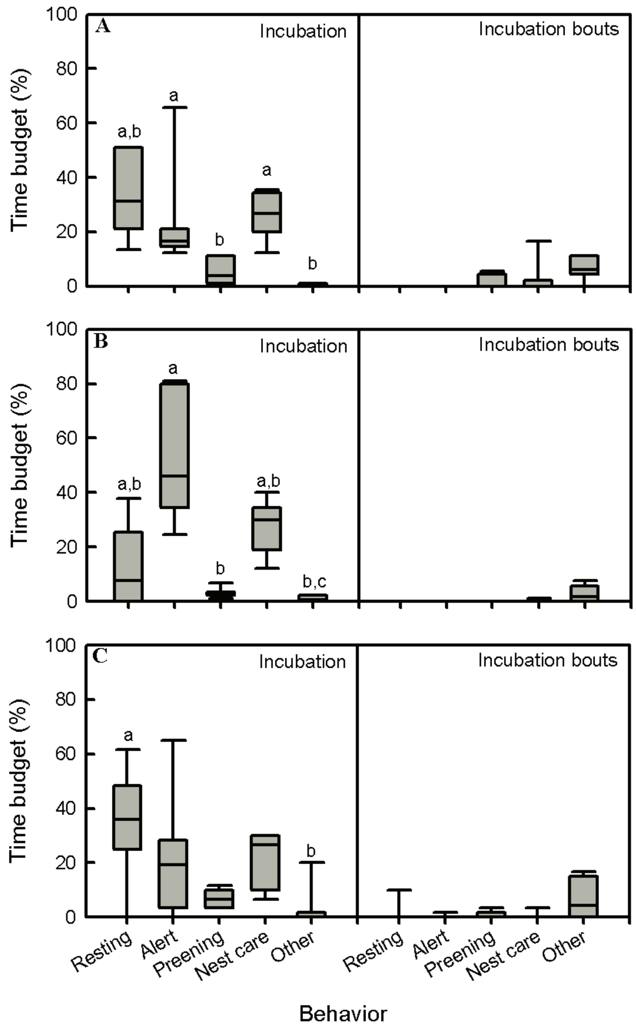

FIG. 5: Female Black-necked Swans' time budget for activities during nesting period for incubation and incubation bouts for the three period categories (A: 09:00–12:00 h; B: 13:00–16:00 h; C: 17:00–19:00 h). Budget is expressed as percentage of time spent for each activity. Letters indicates post-hoc significant differences at $P < 0.05$.

female was away, but our observations showed unattended nest episodes. However, periods where the nests were left without vigilance were always short (1–15 min). It is possible that this behavior is due to the low predation pressure at CAS (Schlatter *et al.* 1996). We also suggest that the mild weather conditions favored the incubation, in contrast to the harsh conditions that arctic-breeding species, such as *C. olor* and *C. bewickii*, experience, where the males stay on the nest during females' incubation breaks in order to keep an adequate temperature (Hawkins 1986, Owen & Black 1990, Ming & Dai 2000). Males spent

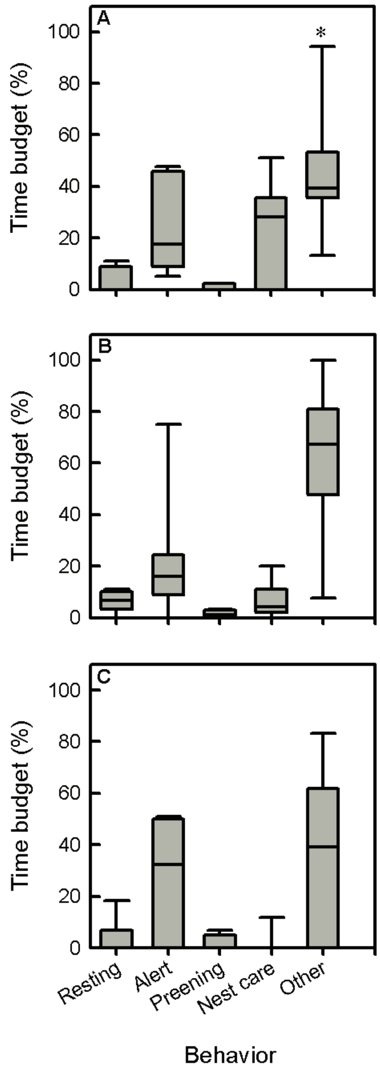

FIG. 6: Male Black-necked Swans' time budget for activities during incubation for the three period categories (A: 09:00–12:00 h; B: 13:00–16:00 h; C: 17:00–19:00 h). Budget is expressed as percentage of time spent for each activity. An asterisk (*) indicates *post-hoc* significant differences at $P < 0.05$.

a considerable amount of time away from the nest, but low visibility due to vegetation makes the record of male's activities more difficult while being away from the nest.

Resting and alert were the highest occurrence activities for females while incubating. Our data suggest that incubation in BNS is performed exclusively by females. Incubation does not follow a regular pattern, but breaks from nest are short and only occur during the warmest hours of the day preventing eggs' heat loss. Every time females left the nest, eggs were covered with nest material, down, and vegetation. The high incubation constancy helps to maintain an optimal incubation temperature, to shorten the incubation period, and to prevent egg loss (Owen & Black 1990, Afton & Paulus 1992). This high incubation constancy could entail an important loss in body mass of females as described for ducks and geese (Haedo 1953, Scott 1972, Hawkins 1986, Owen & Black 1990).

For males, the "other" behaviors represented the main activity including foraging, agonistic encounters, and time out of the observer's sight. As mentioned before, we did not get accurate data of the activities of males while being away from the nest; however, our observations suggest that the male is responsible for the active defense of the nest, so it is possible that males are investing this time in territorial patrolling. Hence, a study design which includes the monitoring of males outside the nest would be necessary in order to collect accurate information. Both female and male have an active participation in nest maintenance which is carried through all the incubation period. This is very important in order to keep the nest shape and to prevent the egg loss due to the high daily water level fluctuations and the frequent wind and rain events.

The Black-necked Swan is considered a good bio-indicator of wetland conditions (Corti 1996), and thus the adequate knowledge of its basic biology and ecology is necessary for the management and conservation of these habitats. Our study was conducted at Carlos Anwandter Sanctuary, a Ramsar site and one of the most important breeding colonies for this species in its distribution range (Schlatter *et al.* 1991a, 1996, 2002).

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