BREEDING BIOLOGY OF MAGELLANIC PENGUINS *SPHENISCUS MAGELLANICUS* AT GOLFO SAN JORGE, PATAGONIA, ARGENTINA

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SUMMARY

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We studied the breeding biology of the Magellanic Penguin *Spheniscus magellanicus* at Golfo San Jorge, Argentina, during 1999. Egg-laying was relatively synchronous, with 88% of eggs being laid during the first two weeks of the laying period. Median laying date of the first egg was 14 October (range 6 October–1 November). Mean female mass at egg-laying was 3.54±0.35 kg. Mean clutch size was 1.91±0.29 eggs/nest and mean calculated egg volume was 227±21 cm^3. The volumes of both eggs were positively correlated with female body condition at laying. The length of the incubation period was 39.8±1.7 days. Of the 280 eggs laid, 101 (36%) were lost and hatching success was 1.23±0.85 eggs per nest. Female body condition during egg-laying at nests where two eggs hatched was significantly higher than that at nests where only one or no eggs hatched. Chicks started to hatch on 15 November. No significant differences were found between sibling mass or morphological measurements at hatching. Ninety-one (53%) of the 171 hatched chicks were lost and breeding success was 0.56±0.67 chicks per nest. The mass of first chicks at 60 days of age was 15% larger than for second chicks (2.67±0.49 vs 2.32±0.63 kg). Female body condition and egg volume of both eggs were significantly correlated with laying date. Nests with no, one or two hatched eggs differed significantly with respect to laying date. Both clutch size and breeding success were not significantly associated with laying date.

Keywords: Magellanic Penguin, *Spheniscus magellanicus,* Argentina, breeding biology

INTRODUCTION

The Magellanic Penguin *Spheniscus magellanicus* has a wide breeding distribution and is the most abundant seabird on the Argentine coast (Yorio *et al*. 1999). It is also one of the main tourist attractions on the coasts of the Provinces of Chubut, Santa Cruz and Tierra del Fuego. The breeding biology of this species has been intensively studied at some localities, such as Punta Tombo (Scolaro 1984, Boersma *et al*. 1990) and Cabo Vírgenes (Frere & Gandini 1996, Frere *et al*. 1998). Some aspects of its breeding cycle have also been analysed at Península Valdés (Perkins 1984). These studies showed that although Magellanic Penguins have similar breeding cycles at different geographical locations, some of their breeding parameters differ between sites.

More than 220 000 Magellanic Penguin pairs breed along the northern coastal sector of Golfo San Jorge, Province of Chubut (Yorio *et al*. 1998). This is one of the most important sectors of the Argentine coast in terms of coastal and marine biological diversity, and is currently subject to several economic activities which could directly or indirectly affect Magellanic Penguins (Fundación Patagonia Natural 1996, Gandini *et al*. 1999). However, Magellanic Penguin populations which breed along these coasts are poorly studied, and little is known even about the basic aspects of their breeding biology. This baseline information becomes relevant for developing management guidelines and may greatly contribute to the conservation of penguin populations. In this paper we present information on the breeding biology of the Magellanic Penguin at Golfo San Jorge and we discuss the results in comparison with those previously obtained at other localities in Patagonia.

METHODS

Study area

The study was conducted at a Magellanic Penguin colony consisting of 6200 pairs on Isla Vernacci Norte (45°11'S, 66°31'W), located near the mouth of Caleta Malaspina, Golfo San Jorge (Fig. 1). It is a low island covered with vegetation consisting

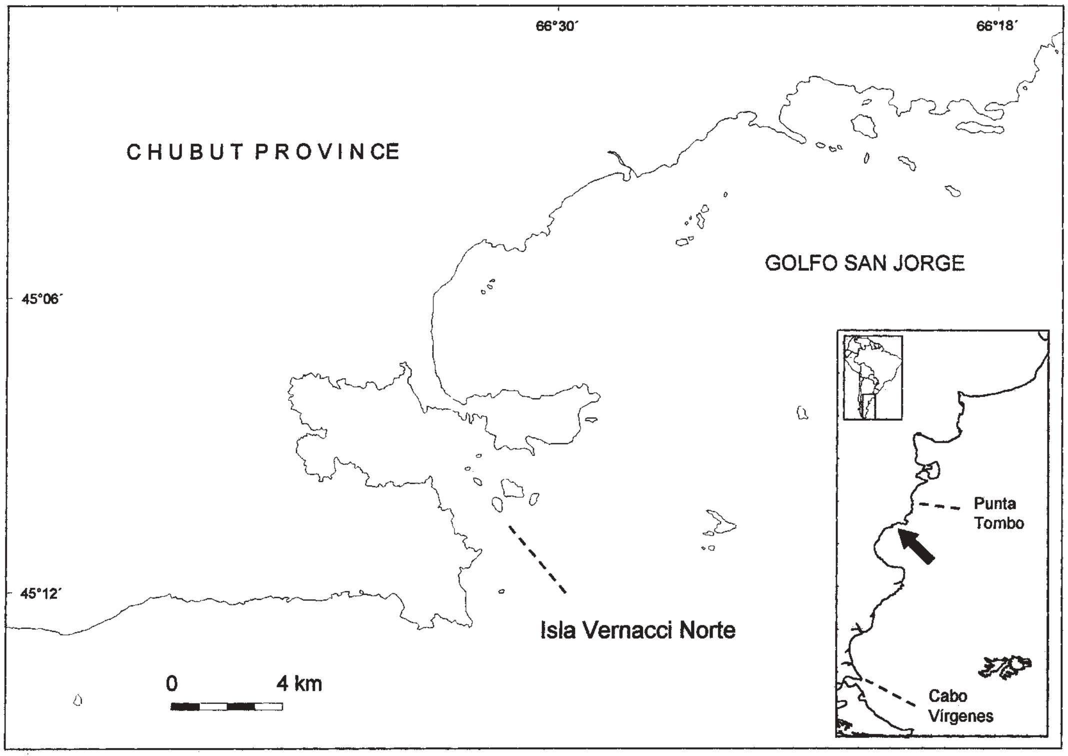

Fig. 1. *Location of the Magellanic Penguin colony of Isla Vernacci Norte, Golfo San Jorge, Chubut.*

mainly of bushes of *Atriplex* spp., *Suaeda divaricata* and *Lycium chilensis* and in some sectors herbaceous vegetation such as *Salicornia ambigua* and *Stipa tenuis* is present. On this island more than 90% of the Magellanic Penguin pairs nest under bushes (unpubl. data).

Breeding parameters

The study was conducted during the austral spring and summer of 1999/2000. A sample of 156 nests was randomly selected, marked and studied. At every nest, adults were banded with numbered stainless steel flipper bands during egg laying. At this time, they were weighed with a 6-kg (50-g increments) spring scale to the nearest 10 g. Bill length (culmen) and bill depth were measured with digital calipers to the nearest 0.1 mm, and flipper (from the joint between humerus and radius-ulna to the tip) and foot length (from the bend in the tarsus to the end of the middle toe nail) with a ruler to the nearest 1 mm. Within pairs, birds were sexed based on bill size and the behavioural pattern of nest relief. Males have longer and thicker bills (Scolaro *et al*. 1983, Boersma *et al*. 1990) and females take the first incubation spell (Yorio & Boersma 1994b).

Regular checks of nests began during early October, before egg-laying started. Nests were checked every 1–3 days during egg-laying and incubation. Egg maximum length and maximum width were measured to the nearest 0.1 mm using digital calipers and eggs were marked with their nest number and egg-laying order using an indelible felt pen. A volume index (V) was calculated as: $V = \text{length} \times \text{maximum width}^2$ (Boersma *et al*. 1990). The length of the incubation period was defined as the time elapsed between the laying of an egg and the hatching of the respective chick. Daily checks of each nest were started at most 38 days after laying of the first egg, so that all chicks were sampled within 24 hours of hatching. At hatching, each chick was weighed, measured (bill length, bill depth, flipper and foot length) and marked with a fibre-tape band around one flipper giving its nest number and hatching order. Thereafter, nests were checked during weekly visits and chicks were re-weighed and measured at 60 days of age. A chick was considered to have starved when it was found dead at the nest after having lost mass during previous nest checks. A chick was considered to have died because of exposure when it was found dead at the nest after a storm and no mass loss was recorded during previous nest checks.

Hatching success was defined as the number of chicks hatched per nest where at least one egg was laid and breeding success as the number of chicks alive on 25 January per nest where at least one egg was laid. At Punta Tombo, few chicks die after mid-January (Boersma & Stokes 1995), so the number of chicks surviving after this date was considered to be a good indicator of fledging success. Sample sizes of different variables analysed may differ due to the loss of nests or to other nest checking problems.

A body size index was calculated as the first factor extracted from a principal component analysis on measurements of bill length, bill width and foot length. Residuals of the mass × size regression were used as indices of body condition. Only adult masses recorded during egg-laying were used to assess body condition. Laying date was not normally distributed (Shapiro-Wilk's Test, $W = 0.93$, $P < 0.001$), hence non-parametric statistics were used. Means are presented together with standard deviations.

RESULTS

Adult measurements

As has been reported in previous studies (Boersma *et al*. 1990, Gandini *et al*. 1992), all morphological measurements differed significantly between males and females (Table 1).

Egg-laying and incubation

Egg-laying commenced on 6 October, and continued for 25 days until 1 November. Egg-laying was relatively synchronous (SD = 4.55; CV = 30.25), with 88% of eggs being laid during the first two weeks (Fig. 2). The median laying date of the first egg was 14 October.

Two-egg clutches were laid in 90.4% of nests. The remaining females had one egg. Mean female mass at egg-laying was 3.54±0.35 kg (n = 143). Mean clutch size was 1.91±0.29 eggs/nest, whereas median clutch size was two eggs. Mean calculated egg volume was 227±21 cm^3 (n = 297). Calculated volume of first eggs was 2.24% larger than of second eggs in the same clutch (Table 2). The calculated volumes of first and second eggs were positively correlated with female body condition at laying (first: $r_{142} = 0.27$, $P = 0.001$; second: $r_{134} = 0.32$, $P = 0.0002$). The length of the incubation period was 40.9±1.3 days (n = 50) for first eggs and 38.6±1.1 days (n = 48) for second eggs, with a general mean of 39.8±1.7 days (n = 98).

Of the 280 eggs laid, 101 (36.6%) were lost: 20.7% disappeared from the nest so the cause of mortality could not be established, 3.2% were preyed upon, 7.5% were found broken at the nest, 4.8% were addled, and 0.4% were accidentally broken during nest checks. The percentages of first and second eggs that were lost were 37.7 and 34.3%, respectively. Hatching success was 1.2±0.85 eggs per nest (n = 146), with one-egg clutches having a significantly lower hatching probability ($\chi^2 = 13.00$, $P = 0.0003$). Female body condition during egg-laying from nests where two eggs hatched (0.063±0.28, n = 69) was significantly higher than that of nests where only one (–0.08±0.39, n = 31) or no eggs hatched (–0.10±0.35, n = 35) (ANOVA: $F = 3.84$, $P = 0.023$), with the last two groups showing similar body condition (Newman-Keuls Test, $P > 0.05$).

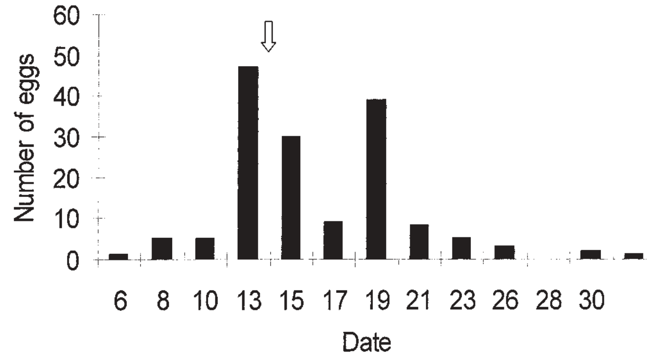

Fig. 2. *Timing of laying of Magellanic Penguin first eggs at Isla Vernacci Norte, Golfo San Jorge, Chubut, during October–November 1999. The arrow indicates the median laying date.*

Chick stage

Chicks started to hatch on 15 November. Hatching interval between first and second chicks was 1.2±0.71 days (n = 44). No significant differences were found between sibling mass or morphological measurements at hatching (Table 3).

Ninety-one (53%) of the 171 chicks that hatched in nests which were followed during this stage were lost (n = 142 nests). Of these, 25.3% disappeared from the nest so the cause of mortality could not be established, 34.1% were found dead at the nest but the cause of mortality could not be identified, 17.5% starved and 23.1% died of exposure. The percentages of first and second chicks that were lost were 26.9 and 26.3%, respectively. Breeding success at nests which were regularly followed during the chick stage was 0.56±0.67 chicks per nest (n = 142). The mass of first chicks at 60 days of age (2.67±0.49 kg; n = 30) was 15% larger than for second chicks (2.32±0.63 kg; n = 26) (*t*-test, $t = 2.3$, $P = 0.026$).

Female body condition and egg volume of both eggs were significantly correlated with laying date (Female body condition: $r_s = -0.34$, $P = 0.02$; first egg: $r_s = -0.25$, $P < 0.001$; second egg: $r_s = -0.20$, $P = 0.002$). Nests with no, one or two hatched eggs

TABLE 1

Body measurements of male and female Magellanic Penguins at Isla Vernacci Norte, Golfo San Jorge, during the 1999 breeding season (mean ± standard deviation)

Variable	Males (n = 61)	Females (n = 143)	*t* *
Bill length (mm)	57.7±2.00	53.3±2.00	–14.47
Bill width (mm)	23.9±0.80	20.7±2.7	–9.17
Flipper (mm)	156±5.6	148±4.7	–10.76
Foot (mm)	122±4.5	115±3.6	–11.38
Weight (kg)	4.01±0.34	3.54±0.35	–9.06

* *t*-test, $P < 0.0001$

TABLE 2

Measurements of first and second eggs of Magellanic Penguins breeding at Isla Vernacci Norte, Golfo San Jorge, during the 1999 breeding season (mean ± standard deviation)

Variable	First egg (n = 141)	Second egg (n = 141)
Length (mm)	74.7±3.1	73.1±3.6
Width (mm)	55.4±1.9	55.4±2.0
Calculated volume (cm^3)*	230.15±20.96	225.10±21.53

* Paired *t*-test, $t = 4.53$, D.F. =140, $P < 0.0001$.

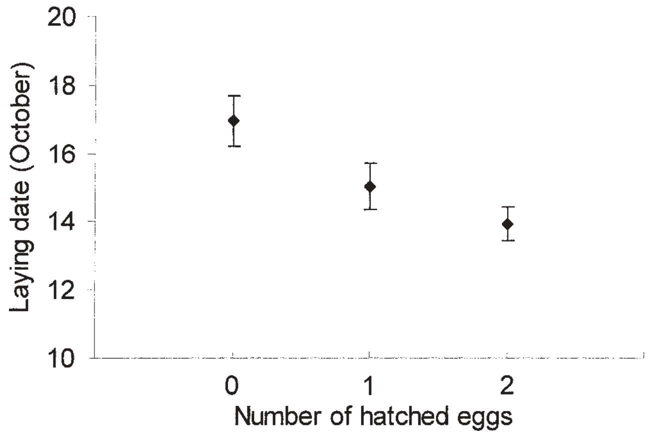

***Fig. 3.** Mean laying date (± S.E.) of nests where none, one or two eggs hatched for Magellanic Penguins breeding at Isla Vernacci Norte, Golfo San Jorge, Chubut, during 1999.*

differed significantly with respect to laying date (Kruskal-Wallis ANOVA, $H = 8.84$, D.F. = 2, $P = 0.01$) (Fig. 3). Neither clutch size nor breeding success were significantly associated with laying date (Kruskal-Wallis ANOVAs, $P > 0.05$).

DISCUSSION

At Caleta Malaspina, Golfo San Jorge, Magellanic Penguins started laying in early October, showing a similar timing of breeding to that observed at other colonies along the Patagonian coast. At the Punta Tombo and Cabo Vírgenes colonies, females start laying mostly in early October, although in the former colony laying may start in late September in some years (Scolaro 1984, Boersma *et al*. 1990, Frere & Gandini 1996). Despite this similar temporal pattern of nesting, differences are observed in the median laying date between colonies, with the onset of laying being later at Cabo Vírgenes (16 October in both 1990 and 1991; Frere & Gandini 1996) than at Punta Tombo (10, 14, 7, 9, and 13 October, for the years 1983 to 1987, respectively, Boersma *et al*. 1990). Frere & Gandini (1996) suggested that the observed differences in timing between the two colonies may be due to the higher latitude of Cabo Vírgenes, and Boersma *et al*. (1990) argue that the variability observed in the timing of egg laying at Punta Tombo is the result of variation among years in food availability. The median laying date observed at Golfo San Jorge (14 October) lies within the range of dates observed at the other two colonies. Although the timing of egg-laying observed could be related to the latitudinal variation mentioned earlier, it can not be ruled out that this study was made during a year with food limitations during the early stages of the breeding cycle, resulting in a relatively late year. Consistent with this hypothesis, female mass at laying in this study was lower than that recorded for females in poor body condition at Punta Tombo (Yorio & Boersma 1994b). No significant differences in body size were found between adults breeding at Caleta Malaspina and Punta Tombo (unpubl. data).

As at other colonies, a relatively high laying synchrony was observed, with most eggs being laid in less than three weeks. At Punta Tombo, Boersma *et al*. (1990) reported that laying occurred within a period of two to three weeks during a five-year study, whereas at Cabo Vírgenes, Frere & Gandini (1996) reported that laying occurred within a period of approximately three weeks based on a three-year study.

Both the percentage of nests with two egg-clutches and the mean clutch size observed at Caleta Malaspina were similar to those recorded at Punta Tombo and Cabo Vírgenes (Boersma *et al*. 1990, Frere *et al*. 1998). Similarly, egg size was within the range reported for those colonies (Boersma *et al*. 1990, Frere *et al*. 1998), although closer to that observed in years which were considered relatively good years (Boersma *et al*. 1990). Hatching success (1.23 eggs per nest) was lower, except for one year, to that observed in a five-year study at the Punta Tombo colony (1.05–1.5 eggs per nest) (Boersma *et al*. 1990). Most of the eggs which were lost in this study disappeared from the nest, so the cause of mortality could not be established. However, it is very likely that those eggs were preyed upon or were taken after being abandoned. Kelp Gulls *Larus dominicanus* were regularly present in the study area and egg remains with signs of having been preyed upon by this predator species were found among penguin nests. In addition, female mass at laying was lower than that recorded for females which deserted their nests at the Punta Tombo colony (Yorio & Boersma 1994b), suggesting that some of the eggs that disappeared could have been previously abandoned. Predation and desertion are the main causes of egg loss at the Punta Tombo colony (Yorio & Boersma 1994a).

Chick mortality was mostly due to starvation and exposure. A storm which occurred during early December resulted in chick mortality probably due to the heavy rains and low ambient temperatures. At the same time, a substantial chick mortality due to similar causes was recorded at Punta Tombo (P.D. Boersma pers. comm.). Although in that colony the main cause of chick mortality is lack of food, a smaller proportion of chicks is preyed upon or dies due to heavy rains (Boersma *et al*. 1990, Frere *et al*. 1992). Heavy rains are also an important cause of chick mortality at the Cabo Vírgenes colony (Frere *et al*. 1998).

Many seabird studies have shown a seasonal decline in fecundity or breeding success (Moreno 1998). This study documents a lower female body condition, smaller size of both eggs and lower hatching success in late than early nests. A seasonal decline in egg size has also been reported in the Macaroni Penguin *Eudyptes chrysolophus* (Williams & Croxall 1991), but not observed in

TABLE 3

Body measurements at hatching of Magellanic Penguin siblings (n = 40) at Isla Vernacci Norte, Golfo San Jorge, during the 1999 breeding season (mean ± standard deviation)

Variable	First chick	Second chick	T	P
Bill length (mm)	15.4±0.55	15.5±0.74	–0.48	$P = 0.63$
Bill width (mm)	8.0±0.44	8.1±0.35	–0.36	n.s.
Flipper (mm)	29.5±1.77	29.8±1.74	–0.65	n.s.
Foot (mm)	34.2±1.99	33.7±1.71	1.42	n.s.
Mass (g)	90.0±11.83	88.3±10.60	0.92	n.s.

Gentoo *Pygoscelis papua* or Chinstrap *P. antarctica* Penguins (Williams 1990, Moreno *et al*. 1994). A lower hatching success in late breeders has also been recorded in the Chinstrap Penguin (Moreno 1998). Several hypotheses have been put forward to explain this seasonal decline in breeding parameters, the most plausible being the 'parental quality' hypothesis and the 'restraint' hypothesis (Coulson & White 1956, Curio 1983, Moreno 1998). Unfortunately, the lack of long-term studies at Caleta Malaspina and the absence of experimental treatments make it hard to identify the causes of the observed decline in breeding parameters of the Magellanic Penguin at Golfo San Jorge.

Breeding success at Caleta Malaspina was similar to that recorded at Punta Tombo and Cabo Vírgenes during seasons considered to be relatively good. At Punta Tombo, breeding success varied among years, ranging between 0.02 and 0.67 chicks per nest (mean of 0.40) between 1983 and 1992 (Williams 1995). At Cabo Vírgenes, Frere *et al*. (1998) reported a breeding success of between 0.19 and 0.83 chicks per nest between 1989 and 1991. The information obtained at Caleta Malaspina suggests that, at least during the study season, food availability played an important role in determining breeding success and that the stages before hatching were the most critical. Future efforts should analyse the inter-annual variability in breeding parameters of Magellanic Penguins nesting at Golfo San Jorge.

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