

## MAXIMUM DIVING DEPTHS OF THE MAGELLANIC PENGUIN

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**Abstract.**—Timing and duration of foraging trips, and maximum diving depths were recorded in Magellanic Penguins (*Spheniscus magellanicus*) during the chick-rearing stage at two breeding colonies in Argentina. Measures were taken with capillary depth gauges made from plastic tubing containing an inner layer of soluble indicator powder. Most penguins returned to their nests at dusk and during the night. At the San Lorenzo colony, penguins dove to a maximum depth of 90 m, with a modal maximum depth of 68 m. Penguins at Punta Lobería dove to a maximum depth of 80 m, with a modal maximum depth of 42 m. Whereas at San Lorenzo all the dives were deeper than 20 m, 35.5% of the dives from Punta Lobería did not reach 20 m. Diving patterns of the Magellanic Penguin followed the behavior of its main prey, Anchovy (*Engraulis anchoita*), and were also correlated with the topography of the sea shelf surrounding each breeding colony.

### PROFUNDIDAD DE BUCEO DEL PINGÜINO DE MAGALLANES

**Sinopsis.**—Se registró para los Pingüinos de Magallanes (*Spheniscus magellanicus*) el tiempo y duración de los viajes de alimentación y la máxima profundidad de buceo alcanzada, durante el período de crianza de los pichones, en dos colonias de aves en Argentina. Las medidas fueron tomadas con indicadores capilares de profundidad construidos con tubos plásticos que contenían una capa interna de polvo indicador soluble. La mayoría de los pingüinos regresaron a sus nidos al atardecer y durante la noche. En la colonia de San Lorenzo la máxima profundidad de buceo fue de 90 m, con una modal máxima de 68 m. Los pingüinos de Punta Lobería bucearon a una profundidad máxima de 80 m, con una modal máxima de 42 m. Mientras en San Lorenzo todos los buceos fueron más profundos que 20 m, el 35,5% de los buceos en Punta Lobería no alcanzaron los 20 m. El patrón de buceo de los pingüinos siguió el comportamiento de su principal presa, la Anchoita (*Engraulis anchoita*), y estuvo también correlacionado con la topografía del fondo marino alrededor de cada colonia.

Study of behavioral ecology in seabird species requires precise information about diving patterns, including maximum and modal diving depths (Adams and Brown 1983). Indirect inferences about diving depths of penguin species have been based on captures in fishing nets and the analysis of penguin prey (Croxall and Furse 1980, Croxall and Prince 1980). Direct measurements have been made with electronic gauges (Kooyman et al. 1982, Trivelpiece et al. 1986) and with autoradiographic depth gauges (Adams et al. 1988, Brown 1987, Wilson and Bain 1984). However, the use of these devices is limited by size restrictions, operability and exposure time. Thus, many measurements have been made with capillary dive recorders which are based on the Boyle's Gas Law, can be built quite easily, and are inexpensive. The accuracy and limitations of

capillary depth gauges for the study of free-swimming birds have been exhaustively described (Burger and Wilson 1988). Direct studies of diving depths have only been made in 10 of the 17 known penguin species (R. P. Wilson and M-P. Wilson, pers. comm.). Here, we report on diving depths of the Magellanic Penguin, measured with capillary dive recorders.

#### METHODS

This study was carried out during two consecutive breeding seasons (1987 and 1988) at two breeding colonies of the Magellanic Penguin, *Spheniscus magellanicus*: Estancia San Lorenzo (42°04'S, 63°21'W) and Punta Lobería (44°35'S, 65°22'W). All recordings were made in December, because during that period both parents guard the nest and follow a chick-feeding routine that has been previously described (Scolaro 1984).

During the first 22 d after hatching (guard stage), one of the parents takes care of the brood while the other goes to sea, returning with food about 2 d later (Scolaro 1984). Thus, only nests with chicks smaller than 22 d old were chosen for this study, and dive gauges were fixed to birds awaiting their relief. Nests were monitored every 2 h during daylight hours and gauges were easily recovered when birds returned from the sea.

Dive recorders were made as described by Montague (1985), using a 10-cm section of plastic capillary tubing, either 2.0 or 0.8 mm internal diameter. The inner walls were covered with a water-soluble mixture of methylene blue and talc (1:3, respectively), and one end was sealed. Thus, the height of the air column at the maximum diving depth corresponds to the length of blue-colored tubing. This length was read to the nearest 0.1 mm using calipers. Standardization of the gauges (column height versus meters below sea level) was made from a boat by releasing to 90 m depth six devices attached every 2 m. Simulation of penguin underwater activity was made with 24 recorders released three times to 44 m depth, as suggested by Burger and Wilson (1988).

The 2.0 mm tubes were discarded after this test because their air-water columns were disrupted more often than those of 0.8 mm tubes, showing a higher tendency to accumulate water droplets in their lumens. Each dive recorder was attached with epoxy resin to a colored plastic, numbered flipper band, and attached around the wing at the shoulder. The flipper bands were similar in size and shape to those previously used in Magellanic Penguins (Scolaro 1983).

#### RESULTS

About 60% of penguins returned to their nests between 0800 and 2000 h while 40% returned between 2000 and 0800 h (Fig. 1). The duration of foraging trips showed two modes of ca. 24 h ( $n = 26$ ) and 48 h ( $n = 35$ ), with very few individuals (3%,  $n = 2$ ) returning between 60 and 72 h. Birds arriving between 1000 and 1800 h ( $n = 25$ ) made shorter trips than those ( $n = 38$ ) returning before 1000 or after 1800 h ( $\chi^2 = 16.2$ ,  $df = 1$ ,  $P < 0.001$ ). Maximum diving depths were not significantly

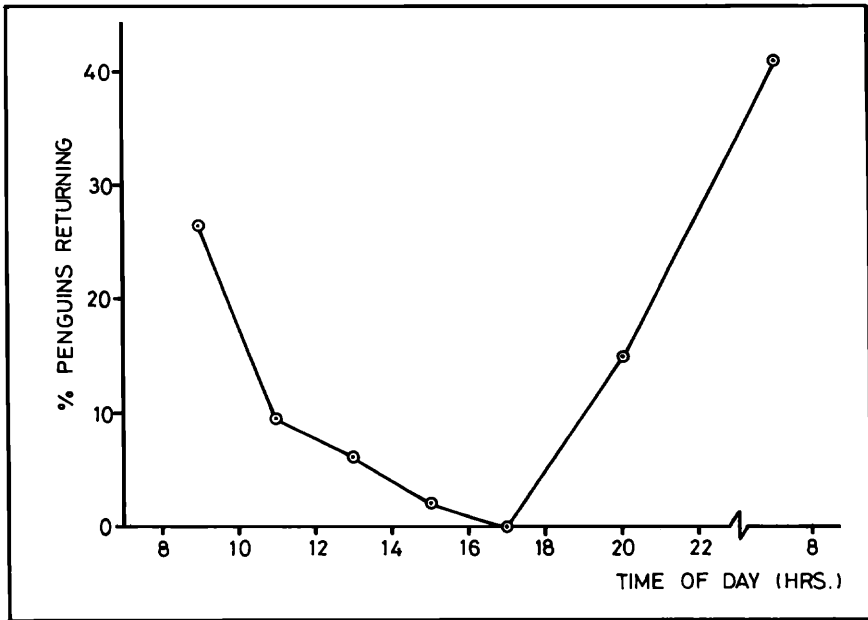


FIGURE 1. Proportions of penguins returning to their nests at different times of day.

correlated with the time interval between tagging and recapture, nor with the recapture time ( $\chi^2 = 2.8$ ,  $df = 3$ , and  $\chi^2 = 6.3$ ,  $df = 3$ ,  $P > 0.05$ , respectively).

Total data showed a maximum diving depth ranging from 6 to 90 m, with a median maximum depth of 50 m and a modal maximum depth of 68 m. Diving depths recorded from San Lorenzo colony were deeper than those from Punta Lobería ( $\chi^2 = 37.7$ ,  $df = 8$ ,  $P < 0.001$ ) and they were non-randomly distributed ( $\chi^2 = 25.8$ ,  $df = 8$ ,  $P < 0.001$ ) with 11 dives reaching less than 20 m and 52 dives exceeding 20 m (82.5%).

At San Lorenzo colony, all the dives exceeded 20 m, with a range of 24–90 m. The median maximum depth was 66.5 m and the modal maximum depth was 68 m. In contrast, 64.5% of Punta Lobería records exceeded 20 m, and only two of these surpassed 60 m (Fig. 2).

The diving depths of males were not different from those of females ( $\chi^2 = 4.3$ ,  $df = 3$ ,  $P > 0.05$ ).

#### DISCUSSION

Penguins dive to feed, but also dive for other purposes (Croxall and Lishman 1987, Trivelpiece et al. 1986). Thus, records of maximum diving depths could be related to many different factors, such as prey habits, predator evasion, topography of the oceanic floor or exploratory activity.

The disruption of the air-water column in capillary diving gauges

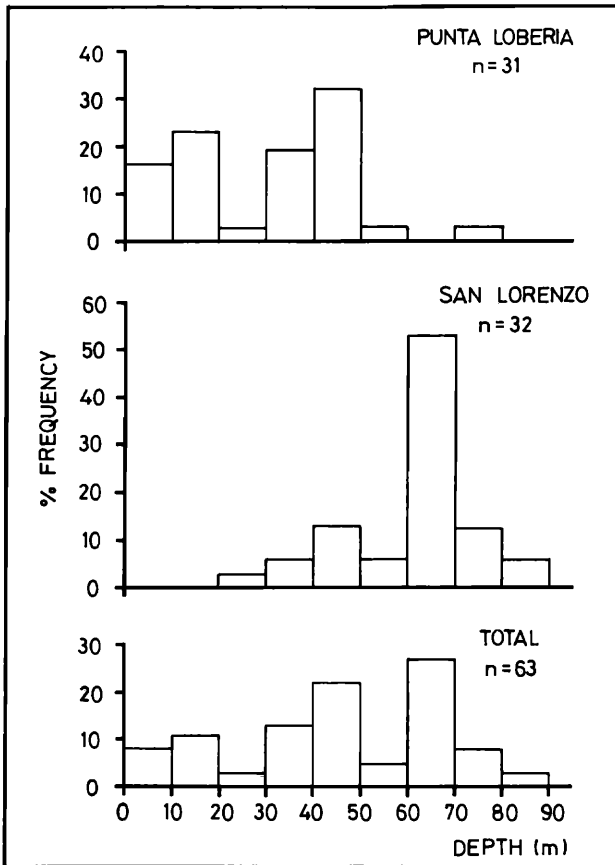


FIGURE 2. Diving-depth profiles for Magellanic Penguins at two latitudinally separated colonies.

probably reflects underwater activity of the birds, such as violent pulling and jarring. Five percent of the 0.8 mm gauges recovered from returning birds showed water droplets in their lumens (and were discarded), suggesting that Magellanic Penguins have active underwater locomotion. The use of narrow tubes minimizes the water column breaks; on the other hand, by using devices on the flipper where movements and changes in acceleration are greater, the breakage is higher. Thus, as Burger and Wilson (1988) have pointed out, attachment of the devices to the body by means of waterproof adhesive tape or special glue would greatly reduce the likelihood of errors associated with maximum depth gauges.

Capillary diving recorders only provide evidence of the deepest dive during a relatively long foraging excursion. Therefore, they might only reflect occasional exploratory dives from birds that otherwise show an

epipelagic behavior (Burger and Wilson 1988). If this were true, the frequency of the deeper immersions should increase in those birds remaining out of their nests for a longer time. As such a correlation was not observed, the maximum depths found in our sampling of 63 dives cannot be considered to result from exploratory deep dives. On the contrary, they could represent the normal pattern for this species and reflect probable foraging and prey-catching behaviors of this species.

The different diving patterns for each breeding colony were probably related to the topography of the sea shelf at each site. The 80 m isobath is only 2.2 km offshore at San Lorenzo, but 7.5 km from the Punta Lobería coastline (Argentine Navy, Nautical Charts No. 3, 58 and H-216). Thus, the modal maximum diving depth for San Lorenzo can be reached 1.0–1.5 km from shore (the 68 m isobath), whereas the modal maximum diving depth for Punta Lobería (the 42 m isobath) is 1.8–2.0 km from the coastline. Thus, Magellanic Penguins could forage at the shortest distance where prey are available, as has been shown for other *Spheniscus* penguins (Wilson et al. 1989, R. P. Wilson and M-P. Wilson, pers. comm.).

Maximum diving depths of Magellanic Penguins could be related to the behavior of Anchovy (*Engraulis anchoita*), which form about 97.2% (by number) of the stomach contents in both colonies during December (Scolaro, unpubl. data). During daytime, Anchovy form compact shoals at depths greater than 35 m and down to 75–100 m, while at night they form thin and dispersed layers near the surface (3–20 m) (Brandhorst et al. 1971). In addition, it is known that Anchovy behavior makes catching them at night very difficult (Brandhorst and Castello 1971). Therefore, modal diving depths suggest that Magellanic Penguins have a diurnal foraging pattern; maximum depth values are variable according to location and time of year and probably reflect changes in prey ecology (R. P. Wilson and M-P. Wilson, pers. comm.).

However, all depths recorded cannot be related to feeding activity; penguins arriving at the nest after 48 h did not always bring food to their chicks. These birds probably explored areas farther than 2 km offshore, suggesting that Anchovy is not always an available source of food near the colonies. Besides, the time some penguins rest on shore before the trip and also during foraging still remains unknown (Scolaro 1983).

Most penguin species are diurnal foragers, leaving their breeding sites at dawn and returning at dusk (Richdale 1957, Warham 1963, Wilson 1985, Wilson et al. 1989). However, nocturnal feeding has recently been observed in Macaroni Penguins (Croxall et al. 1988). Our findings show that many Magellanic Penguins return at night, as has also been mentioned for another colony of this species (Capurro et al. 1988). A large percentage of the penguins (40%) arrive between 2100 and 0800 h of the following day. As overnight monitoring was restricted to minimize human perturbation of penguins (Hockey and Hallinan 1981) we could not determine exact arrival times at the colony. However, depth records of penguins returning during the night were not different from birds arriving during daylight hours.

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### MEETINGS OF INTEREST

**Animal Behavior Society**, 27th annual meeting, University of North Carolina, Wilmington, North Carolina, 1-6 June 1991.

Address inquiries to: Janet Driscoll, ABS Secretary, 2550 W. 43rd Avenue, Denver, CO 80211-1732.

**American Ornithologists' Union**, 109th Stated Meeting, Montreal, Quebec, Canada, 13-17 August 1991.

For information contact: AOU Local Committee, Department of Renewable Resources, McGill University, 21,111 Lakeshore Road, Box 197, Ste. Anne de Bellevue, Quebec, H9X 1C0, Canada.

**4th International Behavioral Ecology Congress**, Princeton University, Princeton, New Jersey, 17-22 August 1992.

Details available from: ISBE Committee, Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544-1003.

**22nd International Ethological Conference**, Kyoto, Japan, 22-29 August 1991.

Contact: 22nd IEC Conference Secretary, % Simul International, Inc., International Conference Department, Kowa Building No. 9, 1-8-10 Akasaka, Minato-ku, Tokyo, 107 Japan.