Antarctic Science 4 (4): 433–434 (1992)

Short note
Maximum dive depths attained by South Georgia diving petrel *Pelecanoides georgicus* at Bird Island, South Georgia

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Accepted 25 September 1992

Introduction

Maximum dive depths have been recorded for a number of sea-bird species using simple lightweight capillary gauges (Burger & Wilson 1988). So far these studies have been confined to penguins (Montague 1985, Seddon & van Heezik 1990, Whitehead 1989, Wilson & Wilson 1990, Scolaro & Suburo 1991), alcids (Burger & Simpson 1986, Burger & Powell 1988, Harris *et al.* 1990, Burger 1991) and cormorants (Burger 1991, Wanless *et al.* 1991).

The most proficient divers of the order Procellariformes are likely to be the diving petrels in the family Pelecanoididae. Although the diet of some species has been studied (Payne & Prince 1979), their diving performance and foraging ecology are unknown. This paper reports the first data on maximum depths attained by South Georgia diving petrels *P. georgicus* (weighing less than 100g) while engaged in rearing chicks. This is the smallest sea-bird whose diving performance has been investigated.

Methods

Fieldwork was carried out on Bird Island, South Georgia (54°00S, 36°08W) between 10–12 March 1989. Ten capillary-tube gauges were attached to birds that had returned to feed their chicks. Four gauges were recovered the following night and two the night after. Recorders were essentially the same as described by Montague (1985). A length of 1 mm diameter PVC tubing was cut into 10 pieces (mean length 114.9 sd 15.2 mm). Each tube weighed *c.* 1.5 g (<1.6% of adult body mass). The tubes were heat sealed at one end and a soluble indicator powder was blown down the inside of each tube (Burger & Wilson 1988). Using small cable ties the gauge was attached to feathers on the bird's back. During chick rearing, birds usually visit their burrow each night. Four birds were recaptured 24 h after deployment and two 48 h after deployment; four gauges were not recovered, either due to the birds not returning or to the gauges being lost. Recapture of the birds was aided by placing a hoop with long strands of white cotton draped over their burrow entrances. When the birds returned they displaced the cotton, signalling their presence in the burrow. The burrow entrance was then temporarily covered and birds extracted from nest chambers through a previously constructed access passage. On recovery of the recorders the length of tube still covered with indicator powder was measured to the nearest 0.5 mm. Maximum depth attained was calculated by the equation:

$$d_{max} = 10.08\ (\frac{L_s}{L_d} - 1)$$

where d_{max} is maximum depth (m) L_s is the initial length (mm) of undissolved indicator and L_d the length (mm) on recovery (Burger & Wilson 1988).

Results

The results are shown in Table I. For all six gauges the mean maximum depth dived was 25.7 m sd 11.4 (range=17.1–48.6). If only the four gauges recovered within 24 h are considered then the mean maximum dive depth is reduced to 21.3 m sd 3.0. If the deepest dive of 48.6m is not included then the next maximum depth reached by any of the remaining five birds is reduced to 24.4m.

Discussion

Effect of device

It is difficult to know what effect the tube would have on the birds diving performance, except that any adverse effect is likely to increase under water (Wilson *et al.* 1986). In addition, Wanless *et al.* (1991) found that similar recorders placed on common shags *P. aristotelis* and not recovered within 24 h tended to give less plausible results. This was consistent with Burger & Wilson (1988) finding that repeated

Table I. Maximum dive depth of South Georgia diving petrels *P. georgicus* at Bird Island, South Georgia.

Maximum duration (hrs)	Initial tube length (mm) L_s	Distance (mm) compressed L_d	Maximum depth (m)
24	138.5	40.5	24.4
24	98.0	31.0	21.8
24	114.5	42.5	17.1
24	123.0	38.5	22.1
48	99.0	17.0	48.6
48	116.5	38.5	20.4

submersions to the same depth could lead to an over estimate of maximum depth. From the six results obtained (four collected within 24 h and the remaining two within 48 h), five were notably similar, with a range of 17.1–24.4 m. The exception was one bird that was out at sea for 48 h and recorded a maximum dive depth of 48.6m, double the maximum depth for the other five birds. It is worth noting that, in most other studies carried out on diving birds, occasional dives much deeper than the mean maximum depth are found (Burger & Wilson 1988). Explanations offered are that these dives may either represent exploratory dives searching for prey or dives associated with larger prey (Burger 1990).

Comparison with auks and penguins

The diving abilities of auks and penguins are generally related to body mass (Piatt & Nettleship 1985, Prince & Harris 1988, Burger 1991). The South Georgia diving petrel is half the mass of the smallest species so far investigated (189 g Cassin's auklet *Ptychoramphus aleuticus*; Burger & Powell 1990) so it is of particular interest to see how our data compare to the allometric equations, relating maximum dive depth to body mass, derived by Burger (1991) for penguins and alcids.

Using the allometric equation (Burger 1991) where M = mass in kg, for both groups combined (d_{max}=75.905 $M^{0.316}$) with the mean weight of *P. georgicus* 93g in March (sd 3.64, *n*=6) (Payne & Prince 1979), a dive depth of 35.8 m is predicted for *P. georgicus*. However, if comparison is made with alcids and penguins separately then predicted maximum dives would be 17.4 m (d_{max}=132.222 $M^{0.855}$) and 14.2 m (d_{max}=48.990 $M^{0.521}$) respectively. The observed average maximum dive depths of 24.4 or 25.7 m are thus closest to, but deeper than the prediction for alcids, which are widely recognized to include the closest ecological and morphological analogues of diving petrels (Thoresen 1969).

The only quantitative dietary information available is from Payne and Prince's (1979) study. *P. georgicus* fed mainly on euphausiids (76% by volume) and copepods (20%), amphipods made up the remaining 4%. Future studies, using these depth gauges, should investigate the relationship between diving depths and prey availability.

Acknowledgements

We are grateful to Mike Harris for assistance in the field and to John Croxall, Alan Burger and Peter Rothery for helpful criticism of the manuscript.

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