IDENTIFYING THE SEX OF FIORDLAND CRESTED PENGUINS BY MORPHOMETRIC CHARACTERS

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ABSTRACT

We assessed the utility of morphometric characters for identifying the sex of adult Fiordland Crested Penguins (*Eudyptes pachyrhynchus*) on the Open Bay Islands. Penguins that gave ecstatic calls at nest sites during the courtship period were designated as males; their companions at nest sites were designated as females. Measurements of culmen length, foot length and weight showed overlap between sexes, but bill depth and a bill index (culmen length × bill depth) did not. The bill depth and bill index of penguins of unknown sex fell on either side of the zone of non-overlap between sexes. Although the specific criteria for determining sex vary between populations of Fiordland Crested Penguins, measures of bill size appear to be the best criteria in this and other species of penguin.

INTRODUCTION

Sexual dimorphism in size is common among penguins (Davis & Speirs 1990), males being larger than females. Because males and females are otherwise monomorphic, morphometric characteristics are prime candidates for identifying the sex of live birds captured in the field. Their value is limited, however, because measurements overlap between sexes, although discriminant function analyses provided reasonably accurate separation by sex for Magellanic Penguins (*Spheniscus magellanicus*) (Scolaro *et al.* 1983) and Blue Penguins (*Eudyptula minor*) (Gales 1988).

The sexual dimorphism of crested penguins (*Eudyptes* spp.) is well documented (Warham 1975, Cooper *et al.* 1990) and average differences in size between sexes, particularly for bill dimensions, are among the greatest recorded for penguins. Neverthless, attempts to distinguish the sexes of live crested penguins from measurements alone are rare. Stonehouse (1971) found for Snares Crested Penguins (*Eudyptes robustus*) that several measures of body and appendage size overlapped considerably between groups of individuals designated as male or female from their behaviour. The best separation was achieved with a culmen index (culmen length × culminicorn width) for which only 4.2% of 118 birds showed overlap. Similarly, Warham (1974) used a bill shape index to separate a sample of Fiordland Crested Penguins (*Eudyptes pachyrhynchus*) by sex, but he did not verify the lack of overlap between the sexes by using independent behavioural criteria.

Here we assess the efficacy of several measures of the bill and foot of Fiordland Crested Penguins for discriminating between sexes.

METHODS

We captured 62 Fiordland Crested Penguins on 16-27 July 1990 within a few days of their arrival on shore for breeding at Taumaka, the largest of

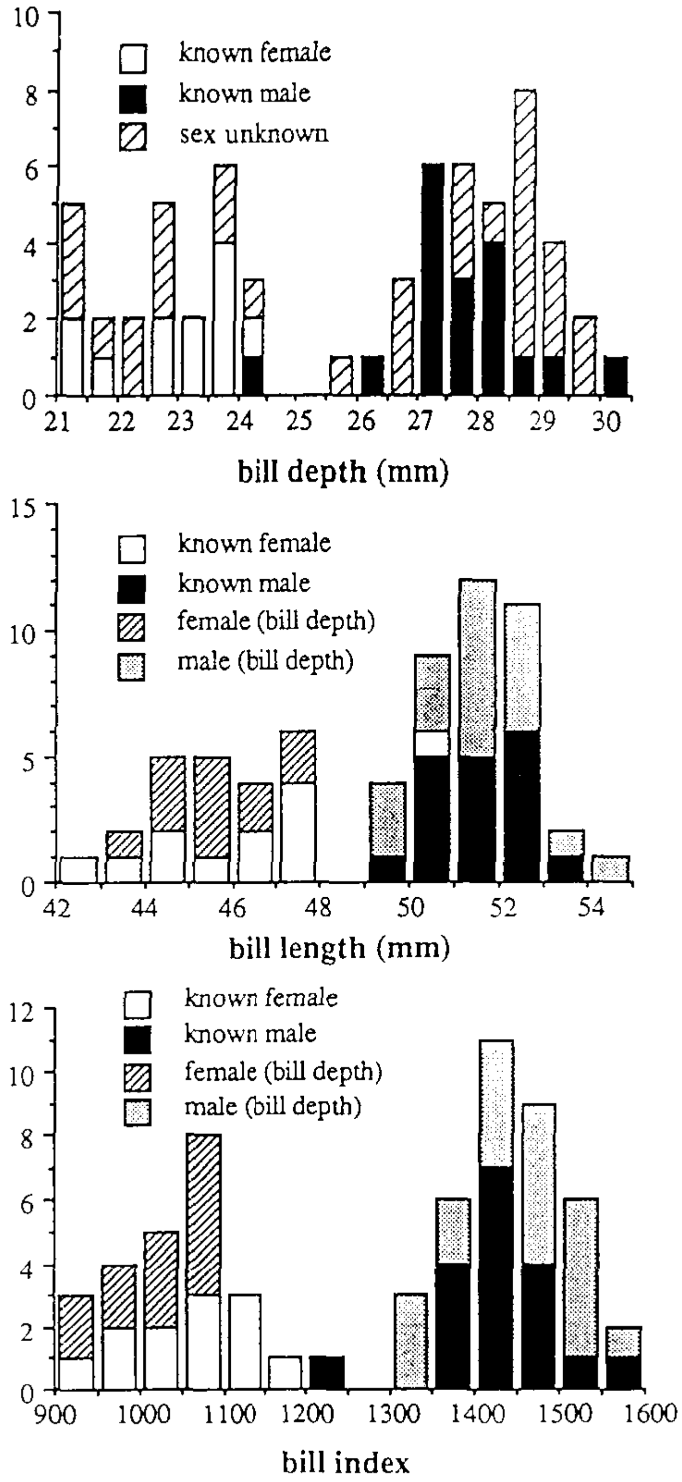

FIGURE 1. (a) Frequency histogram of bill depth for 30 adult Fiordland Crested Penguins whose sex was determined from their behaviour and 32 birds of unknown sex. Each bar represents a 0.5 mm interval. The values for the 3 birds in the 24.0-24.5 range are: 24.3, male; 24.1, female; 24.0, unknown sex.

(b) Frequency histogram of culmen (bill) length for 30 adult Fiordland Crested Penguins whose sex was determined from their behaviour and 32 adults whose sex was determined from bill depth. Each bar represents a 1 mm interval.

(c) Frequency histogram of a bill index (culmen length × bill depth) for 30 adult Fiordland Crested Penguins whose sex was determined from their behaviour and 32 adults whose sex was determined from bill depth. Each bar represents an interval of 50.

the Open Bay Islands, on the west coast of New Zealand. Birds were noosed on or near nest sites known from studies during the previous 2 years (St. Clair 1990, Phillipson unpubl. data) and weighed to the nearest 0.05 kg with a spring balance. The following measurements were made to the nearest 0.1 mm with metal calipers: culmen length and bill depth (as illustrated by Warham 1972, 1975); and foot length, from the back of the heel to the end of the middle toe pad (Darby & Seddon 1990). All measurements were taken by one person (LSD). Bill width was also taken, but is not considered further owing to the difficulty of measuring at a consistent point along the continuously tapering bill. We attached numbered metal wing bands to the 18 birds not previously banded.

We identified 18 penguins as males by observing them give ecstatic calls from nest sites during the courtship period. In other species of penguin only males routinely emit ecstatic calls from nest sites before egg-laying (Sladen 1958, Jouventin 1982). Three of these birds were also seen to mount a mate. By 27 July, 11 of the penguins designated as males were joined on a nest site by a second bird, including one male whose initial partner was replaced by another; these 12 mates comprise our sample of known females.

RESULTS

All measurements of males and females overlapped except bill depth (Table 1). Among the other measures, overlap was least for culmen length, intermediate for foot length, and greatest for weight. Average values for males were significantly greater than for females in all cases (Table 1).

Measures of bill depth for the remaining 32 birds lay on either side of the non-overlap zone (Figure 1a), indicating that bill depth was probably sufficient to distinguish males from females in this sample. For all other measures the number of birds falling into the zone of overlap between sexes increased with the addition of birds of unknown sex.

Although we found no overlap in bill depth between sexes, the zone of non-overlap is so narrow that bill depth may not be reliable for discriminating between sexes in a larger sample. To achieve greater separation, we derived a bill index by multiplying bill depth by culmen length. We used culmen length because, like bill depth, we could measure it consistently on all birds and we found a reasonable gap between the measures of males and females (Figure 1b), except for one female with an unusually long bill. The bill index provides a larger gap between birds of known sex (7% of the range of values recorded) than does bill depth alone (2% of the range of values recorded) (Table 1). The 32 birds of unknown sex fall well outside the zone of non-overlap (Figure 1c). The 11 calling males that acquired mates were all larger than their respective mates in both bill index and bill depth.

DISCUSSION

Our results indicate that bill depth, or the product of bill depth and length, can be used to distinguish male and female Fiordland Crested Penguins on the Open Bay Islands. The analysis confirms Warham's implication (1974, Fig. 7) that bill size can be used to identify sex in this species. We cannot

TABLE 1. — Measurements of live adult Fiordland Crested Penguins whose sex was determined from their behaviour. The sample size is 18 males (M) and 12 females (F). Student's *t* tests were used for comparisons between sexes.

		Mean ± SD	Range	*t* value	
Bill depth (mm)	M	27.6 ± 1.2	24.3-30.0	10.82	P<0.001
	F	22.9 ± 1.0	21.1-24.1		
Bill length (mm)	M	51.7 ± 1.2	49.6-53.8	8.79	P<0.001
	F	46.0 ± 2.2	42.8-50.6		
Foot length (mm)	M	116.9 ± 4.5	109.3-126.8	4.74	P<0.001
	F	109.7 ± 2.9	104.4-113.6		
Body weight (kg)	M	4.16 ± 0.36	3.50-5.10	3.31	P<0.01
	F	3.68 ± 0.40	2.80-4.20		
Bill index (depth x length)	M	1429 ± 76	1232-1569	2.42	P<0.05
	F	1055 ± 85	907-1184		

compare our bill index directly with the index used by Warham (1974), because he incorporated culminicorn width in the final product. However, the products of mean depth and mean length for males and females, based on data from Table 5 in Warham (1974), lie well below the mean values for our entire sample (males, 1333 v. 1441; females, 981 v. 1041). The differences result primarily from significant differences in bill depth between samples from Warham's study at Jackson Bay and this study (Table 2). Bill lengths did not differ significantly (Table 2). Somewhat surprisingly, the weights of both males and females in Warham's population (Warham 1974: Table 5, line 1) were significantly greater than the weights we recorded (Table 2. Although weights of penguins decrease through the reproductive period, both samples were obtained soon after birds arrived at breeding areas in July. Yearly variation might account for the differences in weight between studies.

This comparison between areas indicates that sex criteria based on size may not apply to all populations of Fiordland Crested Penguins, even if they are nearby (Jackson Bay is on the mainland about 30 km from Open Bay Islands). Similarly, Gales (1988) found that her discriminant function formula derived from bill measurements of Blue Penguins in Australia was much less effective in distinguishing the sex of birds in a different subspecies of Blue Penguin in New Zealand.

TABLE 2. — Bill measures and body weights of live adult Fiordland Crested Penguins at Jackson Bay (Warham 1974) and the Open Bay Islands (this study). Student's *t* tests were used for comparisons between areas.

	Jackson Bay		Open Bay Island			
	n	Mean ± SD	n	Mean ± SD	*t*	
Bill depth (mm)						
Males	94	26.1 ± 1.7	38	28.0 ± 1.1	6.33	P<0.001
Females	61	21.8 ± 1.3	24	22.7 ± 1.0	3.02	P<0.01
Bill length (mm)						
Males	94	51.1 ± 2.0	38	51.5 ± 1.2	1.14	P>0.10
Females	61	45.0 ± 1.7	24	45.8 ± 1.8	1.90	P>0.50
Weight (kg)						
Males	20	4.53 ± 0.37	38	4.11 ± 0.39	3.93	P<0.001
Females	17	4.03 ± 0.40	24	3.71 ± 0.40	2.46	P<0.05

Our finding that bill measurements provided the least overlap between sexes, and hence the greatest discriminatory power for identifying sex, reflects the general situation in penguins. The bill is the most dimorphic character in Blue Penguins (Gales 1988), and bill depth and width of Magellanic Penguins had the greatest discriminating power of the 10 variables used by Scolaro *et al.* (1983) for determining sex. A sex dimorphism index (male value/female value) is greater for one or more bill measures than for foot or flipper length in Adélie Penguins (*Pygoscelis adeliae*) (Ainley & Emison 1972) and all of the crested penguins (Stonehouse 1971, Warham 1974, 1975, Cooper *et al.* 1990). Although dimorphism indices for body weight can be as large as for bill measures, changes in body weight over time and considerable overlap between sexes make weight a poor indicator of sex. Thus, bill morphometrics are likely to be of greatest use in deriving sex criteria for other species of penguin and in refining sex criteria for Fiordland Crested Penguins.

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SHORT NOTES

Bellbirds feeding on sap of black beech

The Bellbird (*Anthornis melanura*), like other meliphagids, specialises in nectar feeding (e.g. Turbott 1947, Falla *et al.* Moon 1982, Soper 1984). The structure of its tongue seems particularly adapted for this purpose (McCann 1964), and the list of flowering plants on which it feeds is impressive (see esp. Merton 1966, Gravatt 1970, Falla *et al.* 1978:203, Baker 1986). Bellbirds are also known to eat fruits and berries (Turbott 1947, McCann 1964, St. Paul 1975, Falla *et al.* 1978, Norton 1980, Moon 1982, Soper 1984), insects (Turbott 1947, McCann 1964, Merton 1966, Gravatt 1970, St. Paul 1975, Falla *et al.* 1978, Gaze & Fitzgerald 1982, Moon 1982, Soper 1984), spiders (Turbott 1947), pollen (Gaze & Fitzgerald 1982, Soper 1984), and artificial foods such as sugar water and honey (Falla *et al.* 1978, Moon 1982). Bellbirds