NOTORNIS

is the journal of the Ornithological Society of New Zealand (Inc.)

Editor Gábor Lövei,
16 Margaret Street,
PALMERSTON NORTH

VOLUME 42 PART 1 MARCH 1995

SEXUAL DIMORPHISM OF VOICE AND MORPHOLOGY IN THE THIN-BILLED PRION (*Pachyptila belcheri*)

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ABSTRACT

There are major sexual differences in the calls of Thin-billed Prion *Pachyptila belcheri*. This allowed birds to be sexed initially by calls, and then by their measurements. Males were on average larger than females for six out of eight morphometric characters, with the greatest difference being in the bill. We then investigated the possibility of sexing birds on the basis of external measurements: a discriminant function analysis based on the eight measurements allowed correct classification of 84.4% of the 281 birds. In 89% of breeding pairs, males had greater bill depth than their partner. A stepwise discriminant analysis revealed that bill depth, head length and body weight were the three most discriminant variables. The combinations of two measurements (bill depth and body weight, or bill depth and total head length) allowed correct classification of 84.3 and 83% of the birds respectively, whilst a classification solely based on bill depth gave a 83.2% correct classification. The degree of sexual dimorphism in this species is similar to that found in other tubenoses.

KEYWORDS: Thin-billed Prion, *Pachyptila belcheri*, sexual dimorphism, voice, morphology.

INTRODUCTION

Because of a lack of gross sexual dimorphism, petrels (Procellariiformes) are not easy to sex in the field, which is unfortunate for field studies (e.g.

on breeding biology, behaviour or demography). The sex of adult petrels can be determined by cloacal inspection (serventy 1956, Copestake *et al.* 1988) during the laying period but this method is applicable only to females which have recently laid an egg, and to their known mates (Serventy 1956, Boersma & Davis 1987). More recently, laparotomy has been used successfully on petrels (Simons 1981, Jones *et al.* 1984), but takes too long to be useful for large samples of birds. Position during copulation can be useful for sexing diurnal petrels (e.g. *Macronectes spp.*) but is useless for the burrowing species, in which copulation occurs in a deep nest chamber (Warham 1990). In some gadfly petrels, males may have more filoplumes on their crowns than females (e.g. *Pterodroma macroptera* Imber 1971, but see James 1986). Lastly, all species of petrels investigated, except Bulwer's Petrel *Bulweria bulweri*, are sexually dimorphic in the voice (Brooke 1978b 1988, Bretagnolle 1989, 1990, Bretagnolle & Lequette 1990, Taoka *et al.* 1989, James 1984, James & Robertson 1984, 1985).

In albatrosses and petrels, males are generally larger than females (Marchant & Higgins 1990), but in storm petrels (Hydrobatidae), sexual dimorphism is reversed (e.g. Murphy & Irving 1951, Beck & Brown 1971, Copestake & Croxall 1985). However, sexual dimorphism in petrels is usually slight and does not always allow correct discrimination between sexes (e.g. parameters are not always adequate to reveal sexual dimorphism in measurements ; multivariate analysis being generally a more powerful tool Cruz & Cruz 1990).

The genus *Pachyptila* is not known to be sexually dimorphic (Warham 1990), and morphometric differences between the sexes are poorly documented. However, in the Fulmar Prion *Pachyptila crassirostris*, males have longer bills and wider maxillary nails than females, but in the case of Fairy Prions *Pachyptila turtur*, there is no difference between male and female specimens (mostly immatures) of unknown origin from beaches (harper 1980). In the Dove Prion *Pachyptila desolata*, sexual dimorphism is slight and there is no significant difference between the sexes except for body weight (Tickell 1962). In this study, we investigate sexual dimorphism in the Thin-billed Prion *Pachyptila belcheri*, and develop a method for sexing adults by discriminant analysis of external measurements.

METHODS

Thin-billed Prions were studied on Mayes Island, Kerguelen Archipelago (48°38′ S, 68°38′ E), between 1987 and 1992. Individuals first return to land in early October for prenuptial visits to the breeding grounds. Egg-laying occurs in mid-November, hatching from the end of December to early January and fledging from the end of February to early March (Weimerskirch *et al.* 1989).

Calls from burrows were recorded in December 1987 with a Nagra IV tape recorder and a MD 421 Sennheiser microphone placed at the entrance. Sonograms of five different males and females sexed by cloacal inspection (Serventy 1956) are shown in Figure 1. As in the closely related Blue Petrel *Halobaena caerulea*, male and female calls are strikingly different in timing and syntax (ordering of short and long syllables) (Bretagnolle 1990). Sexual

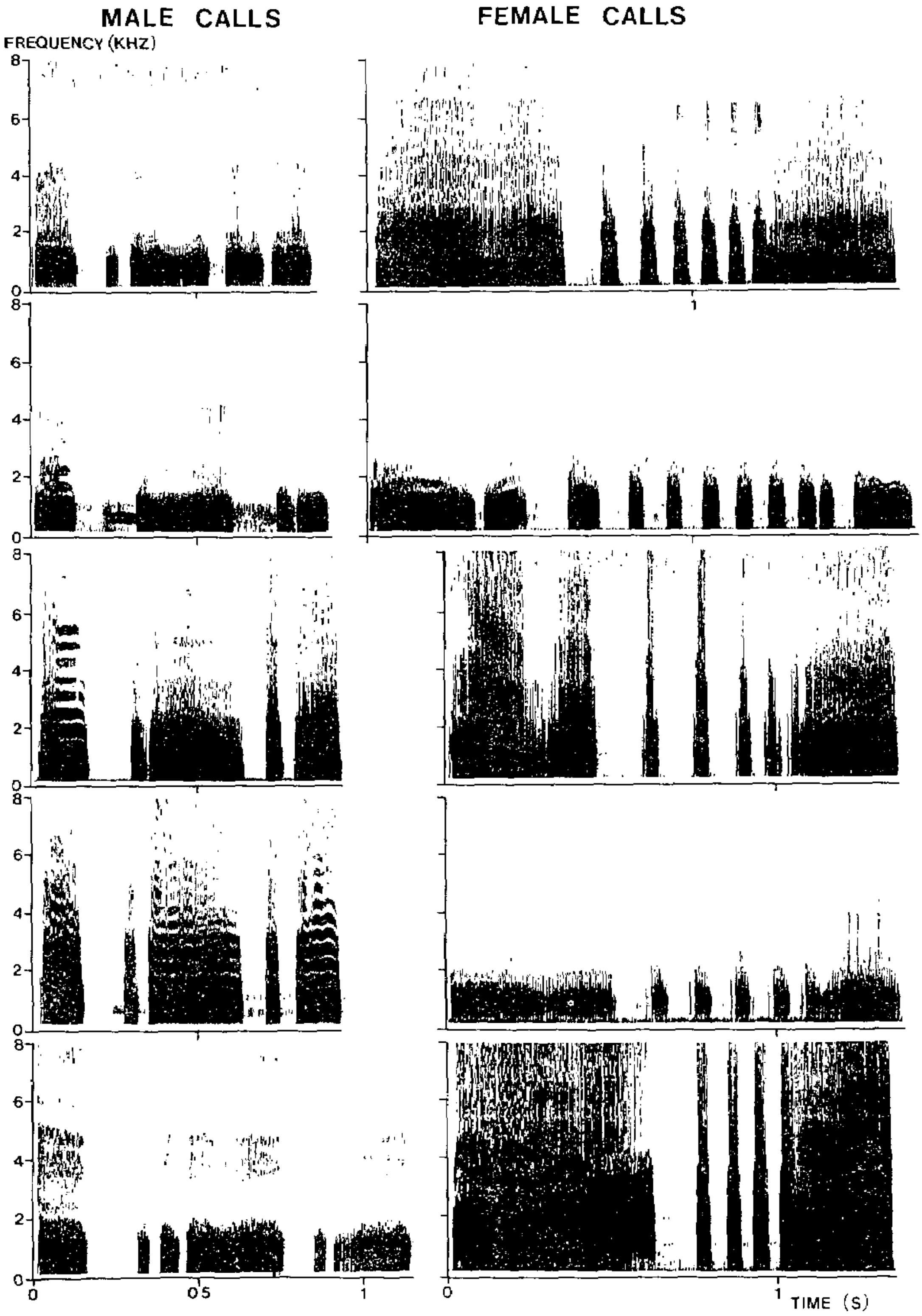

FIGURE 1 – Sonograms of five male and female Thin-billed Prions from Mayes Island, Kerguelen. The major differences concern syntaxic parameters: females begin with a long syllable followed by short ones, while males always begin with a short syllable.

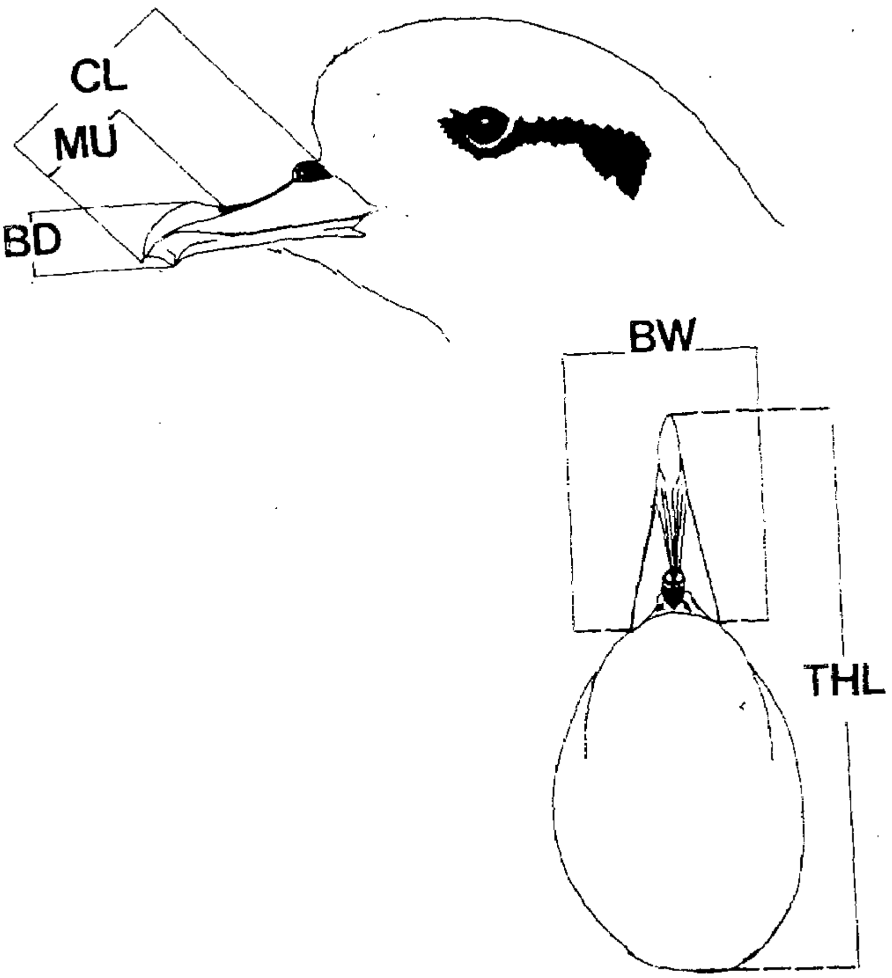

FIGURE 2 – Head and bill measurements (CL = culmen length, MU = maxillary unguis, BD = bill depth, BW = bill width, THL = total head length).

dimorphism in voice has already been documented for fairy and Broad-billed *P. salvini* POrions (*in* Marchatna and Higgins 1990, Bretagnolle 1990, Bretagnolle *et al.* 1990), and is always based on the same parameters. The Thin-billed Prion is thus no exception.

A total sample of 281 birds, sexed by their calls from their burrow, were then measured. Of these, 63 were breeding pairs with an egg, 50 breeders alone with an egg (cases where only one partner has been caught), and 105 non-breeders. Five head and bill measurements (see Figure 2) and tarsus length were taken from each bird by the same person with vernier calipers to the nearest 0.1 mm; wing length to the nearest 1mm with a steel tape and weight to the nearest 2 g with a long-scale 300 g Pesola spring balance. For each measurement, an index of sexual dimorphism was calculated (female/male × 100, Croxall 1982). Morphological measurements were treated either with univariate statistics (one-way analysis of variance, ANOVA) or with a multivariate procedure (discriminant function analysis, DFA, and canonical discriminant analysis). All variables were normally distributed except body weight, which was then log-transformed. Probability levels of <0.05 were considered to be significant. All these analyses were performed with SAS version 6 (SAS 1988).

RESULTS

Measurements of 154 males and 127 females from Mayes Island are given in Table 1. For all but two parameters (wing length and weight), males averaged larger than females, although there was much overlap. In a one-way ANOVA, highest F-values were found for bill measurements, especially bill depth which appeared to be the best discriminator. Using a multivariate approach, a DFA performed on the eight morphometric variables was highly significant (Wilks' Lambda = 0.52, F = 31.0, $P<0.0001$), and assigned up to 84.4% of the birds to their correct sex category (Figure 3.). A stepwise discriminant analysis revealed that bill depth, head length and body weight were the three most discriminant variables. A discriminant analysis using bill depth and body weight correctly classified 84.3% of birds (Figure 4), whilst a classification solely based on bill depth gave a 83.2% correct classification. Thus, combining two variables instead of eight resulted in a loss of only 0.1% of the discrimination. The sex of a Thin-billed Prion can therefore be predicted from the following classification formula:

$$\mathbf{D = -26.898 + (10.275\ BD) - 19.522\ (Log\ (W))}$$

where positive value for D indicated a male.

This formula correctly classified 130 out of the 154 males (84.4%) and 107 out of the 127 females (84.3%), the rate of correct classification showing no significant difference between the sexes ($\chi^2 = 0.016$, df = 1, P = 0.89). A DFA excluding weight based on two measurements (bill depth and total head length) correctly assigned 83% of the birds to their correct sex category, and provided the following classification formula:

$$\mathbf{D = -51.2044 + (8.887\ BD) - (0.154\ THL)}$$

TABLE 1 – Measurements of Thin-billed Prions from Mayes Island, Kerguelen. Measurements are in mm.

	Mean ± standart deviation (Range)		One-Way ANOVA	
Measurement	Male (N = 154)	Female (N = 127)	F	P-values
Culmen length	25.2 ± 0.9 22.4 - 27.3	24.7 ± 0.9 22.5 - 26.8	F = 17.61	P<0.0001
Bill depth	7.0 ± 0.3 6.1 - 7.9	6.6 ± 0.3 6.0 - 7.4	F = 198.23	P<0.0001
Bill width	11.6 ± 0.4 10.3 - 12.6	11.3 ± 0.4 10.1 - 12.0	F = 50.04	P<0.0001
Max unguis	12.4 ± 0.6 10.7 - 13.9	11.8 ± 0.6 10.3 - 13.3	F = 64.14	P<0.0001
Head length	61.7 ± 1.2 53.3 - 64.8	60.5 ± 1.3 57.0 - 64.1	F = 62.21	P<0.0001
Tarsus length	37.7 ± 0.8 31.4 - 35.8	33.3 ± 1.0 30.6 - 35.6	F = 18.27	P = 0.0001
Wing length	183.7 ± 3.9 174 - 194	183.0 ± 3.9 173 - 196	F = 2.26	P = 0.13
Weight, g	144.7 ± 15.2 112 - 192	145.0 ± 15.5 114 - 181	F = 0.02	P = 0.88

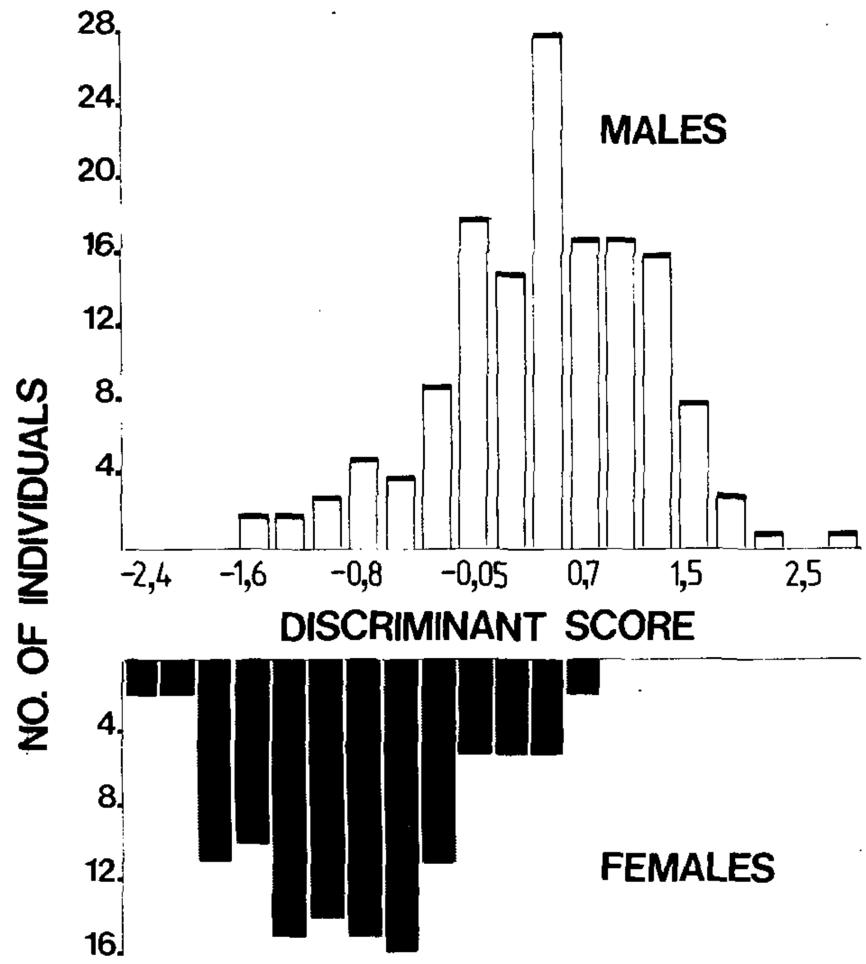

FIGURE 3 – Discriminant scores of known sex Thin-billed Prions, calculated from the *eight measurements.*

Use of this equation resulted in 82.5% of males and 83.5% of females being assigned to their correct sex. When only breeding pairs were considered, bill depth could be used to distinguish 81.3% of males and females (Table 2). The index of sexual dimorphism (Croxall 1982) for each measurement were 93.4 (bill depth), 95.4 (maxillary unguis), 96.9 (bill width), 98.0 (total head length), 99.2 (culmen length), 98.7 (tarsus length), 99.6 (wing length) and 100.2 (weight).

DISCUSSION

In the Thin-billed Prion, as in many other procellariiforms, males are larger than females (e.g. giant petrels *Macronectes* sp. Conroy 1972, Hunter 1984; Snow Petrel *Pagodroma nivea* Croxall 1982; Cory's Shearwater *Calonectris diomedea* Mougin *et al.* 1986; Grey-faced Petrel *Pterodroma macroptera* Johnstone & Niven 1989; Antarctic petrel *Thalassoica antarctica* Lorentsen & Rov 1994). However, sexes could not be separated with 100% of confidence on morphometrics alone: this seems to be a general rule in procellariiforms. A similar degree of sexual dimorphism (ca. 80-90%) has been reported for Northern Fulmars *Fulmarus glacialoides* (Dunnet & Anderson 1961), Cape

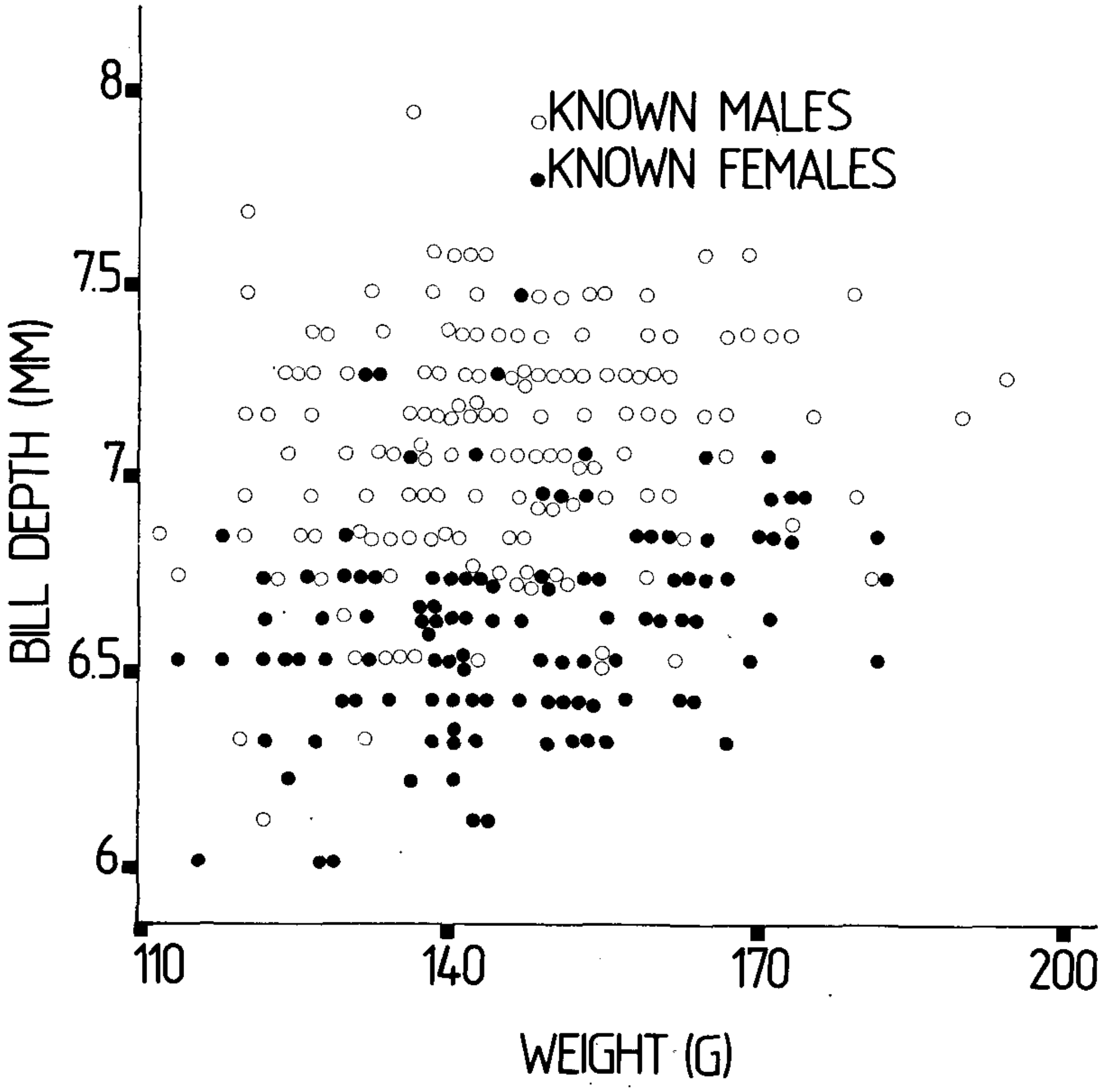

FIGURE 4 – Measurements for bill depth against weight of known sex Thin-billed Prions from Mayes Island, Kerguelen.

TABLE 2 – Comparison of morphometric characters between partners of 63 breeding pairs with an egg from Mayes Island, Kerguelen. Only cases where both partners of the same pair were measured are included in the analysis.

	Characters							
	Culmen length	Bill depth	Bill width	Max. unguis	Head length	Tarsus length	Wing length	Weight
Number of								
males > females	41	56	45	46	44	34	24	26
females > males	20	4	14	13	17	29	38	36
equal values	2	3	4	4	2	0	1	1

Pigeons *Daption capense australe* (Sagar 1986), and Snow petrels (Croxall 1982). Moreover, morphometric differences seem to depend on locality (Jouventin & Viot 1985, Sagar 1986). In the Grey-faced Petrel, 92% of birds can be sexed correctly using bill depth and weight (Johnstone & Niven 1989); however, this applied only to weights taken immediately after laying, or at the start of incubation. This is why we looked for a discriminant function using only bill variables, which can be used at any time and on dead birds. In the case of the Grey-faced Petrel, a classification formula based only on bill measurements was unsatisfactory because it had a 37% error (Johnstone & Niven 1989). More recently, van Franeker & ter Braak (1993) have shown how to cope with this specific problem using data on five different species of petrels.

Heterogeneity in the samples (e.g., effect of age) means that only a proportion (usually between 80 and 90%) of petrels are correctly sexed. Classification can be improved, for example, when only breeding pairs are used. Lower body weights of non-breeders are found in many procellariiform species (Fisher 1967, Harper 1976, Baker & Coleman 1977, Brooke 1978a, Furness & Baillie 1981) and in other seabirds (Warham 1972, Harris 1979), and an increase in weight with age has also been noted in Wandering albatrosses *Diomedea exulans* (Weimerskirch 1992) and Manx Shearwaters *Puffinus puffinus* (Brooke 1978a). Similarly, younger Manx Shearwaters *Puffinus puffinus* have significantly shorter wings than older ones, although there is apparently no change in bill measurements with age (Brooke 1978a). In the Common Diving Petrel *Pelecanoides urinatrix* and British Storm Petrel *Hydrobates pelagicus*, non-breeding birds have shorter wings than breeders (Scott 1970, Payne & Prince 1979, Furness & Baillie 1981), and pre-breeding Westland Petrels *Procellaria westlandica* are also relatively smaller than adults in some dimensions (Baker & Coleman 1977).

Several explanations for sexual dimorphism in procellariiforms have been proposed. In Snow Petrels it could increase the range of vocal frequencies and thus intraspecific repertoire (Croxall 1982). In giant petrels, sexual dimorphism was explained as being a result of differences in feeding, resulting from intraspecific competition for food (Hunter 1984). However, we suggest that in Thin-billed Prions, sexual dimorphism may have arisen by selection operating through burrow defence rather than differences in the feeding ecology. Intrasexual competition and fights between males for burrows are common during the breeding period (Strange 1980, pers.obs.), but struggles between females seem to be rare (pers. obs.). The sexual dimorphism that occurs, with males having larger bills, may thus result from intrasexual selection.

ACKNOWLEDGEMENTS

This work is part of the Birds and Mammals Antarctic Research Team directed by P. Jouventin. We are indebted to the "Terres Australes et Antarctiques Francaises" for financial and logistical support in the field. L. Ackermann helped with the field-work, L. Ruchon drew the sonogram figures and O. Chastel drew the head illustration. Lastly, O. Chastel, P. Duncan and two anonymous referees improved a previous draft and J. F. Ward corrected the English.

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