and the director of the Brasilia National Park for permits and support and Dr. Paulo Emílio Vanzolini, Director of the Museu de Zoologia da Universidade de São Paulo, for the permission to examine specimens. We thank Philip S. Humphrey for his corrections on our first English text.

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Received 2 February 1982, accepted 18 May 1982.

The Magellanic Penguin (*Spheniscus magellanicus*): Sexing Adults by Discriminant Analysis of Morphometric Characters

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The identification of sexes in the Magellanic Penguin (*Spheniscus magellanicus*) is a subject of interest for researchers of this species, but several attempts to discriminate sexes based on external characters (Conway 1965, Boswall and MacIver 1974, Daciuk 1976) have met with only modest success. Probably differences in age or size between members of a pair contribute to this problem. Morphometric indices have been used for other species of penguins with varying success. Stonehouse (1971) measured seven characters in two populations of *Eudyptes robustus,* obtaining an acceptable degree of sex separation with length and depth of the bill. He found overlap, however, in the ranges of the variables and also differences between populations. Ainley and Emison (1972) and Warham (1972) found significant differences in bill dimensions in *Pygoscelis adeliae* and *Eudyptes sclateri,* respectively. Warham (1975) summarizes data on bill and flipper dimensions for several species of crested penguins that show a considerable dimorphism, especially in the bill. Other authors, such as Ainley (1978) and Sladen (1978), sexed penguins by examination of the cloaca. Our superficial examination of the cloaca of *Spheniscus* gave inconsistent results. Probably an in-depth examination, together with the use of adequate instruments and a good deal of practice, could change this.

Our objective in this study was to find a method of sexing penguins based on ethological considerations that was harmless to the animal and easy to use in the field, even for the unskilled researcher or technician. Specimens for this study were collected at the colony of Punta Tombo (Chubut, Argentina), described in previous contributions (Scolaro et al. 1979, 1980), during the breeding season 1976–1977. Samples of pairs were taken at random from the nesting population. For each individual, 10 measurements were taken, and its sex was determined by dissection. A total of 49 pairs were used for the analysis (n = 98).

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TABLE 1. Morphometric data for Magellanic Penguins (means and standard deviations).[a]

	Males		Females		Pooled	
Variable	Mean	SD	Mean	SD	Mean	SD
BW	4.47	0.49	3.77	0.40	4.11	0.56
L	64.5	2.2	61.4	2.2	63.0	2.7
FL	19.5	0.5	18.6	0.5	19.0	0.7
FB	6.3	0.2	6.0	0.2	6.1	0.3
LT	4.94	0.22	4.64	0.19	4.79	0.26
LMT	8.2	0.3	7.6	0.4	7.9	0.4
AE	5.5	1.0	5.2	0.8	5.3	0.9
FA	6.8	0.4	6.1	0.4	6.5	0.5
BL	5.88	0.26	5.45	0.20	5.66	0.32
BD	2.50	0.11	2.16	0.13	2.33	0.21
R	0.82	0.14	0.84	0.13	0.83	0.13

[a] BW in kg; other measurements in cm; n = 49 for males and females; n = 98 for pooled set.

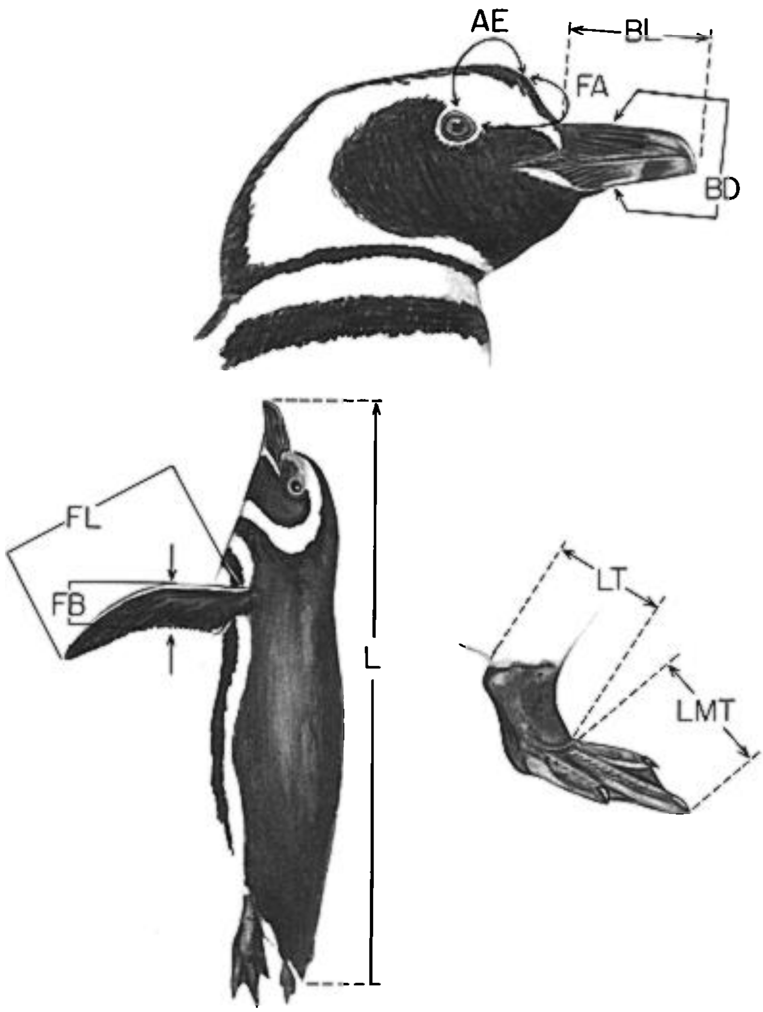

Fig. 1. Schematic illustration of variables measured to differentiate sex in Magellanic Penguins.

The variables considered are listed below and depicted in Fig. 1; unless otherwise stated, they are standard measurements (Baldwin et al. 1931).

Body Weight (BW), taken within an hour of collection; *Total Length* (L); *Flipper Length* (FL), equivalent to length of open wing; *Flipper Breadth* (FB), maximum breadth, close to humero-cubital joint; *Length of Tarsus* (LT); *Length of Middle Toe and Nail* (LMT); *Arc between Eyes* (AE), between upper edges, going over the head (crown); *Forehead Arc* (FA), between front edges of both eyes, over the forehead; *Bill Length* (BL), equivalent to length of exposed culmen; and *Bill Depth* (BD), equivalent to height of bill, similar to Warham (1975).

The selection of these variables was based, in most cases, upon ethological considerations. In other cases, they were chosen to verify the validity of some proposed criteria (e.g. AE and FA), or to account for size-dependent differences (e.g. L and W). As some authors (Boswall and MacIver 1974, Daciuk 1976) have suggested that males have a bulkier, more protruding forehead and, in general, a larger head, an attempt was made to quantify this observation by generating an additional variable from the ratio of AE to FA, *Ratio AE/FA* (R), even though the measurements of AE and FA are not very precise.

The statistical treatment used was discriminant analysis (SPSS; Nie et al. 1975). The method of Wilks was selected, and we report values of λ, in our case the complement of Pearson's r^2 between the predictor and sex.

A summary of the measurements of the variables

TABLE 2. Pooled within-groups correlation matrix.[a]

	BW	L	FL	FB	LT	LMT	AE	FA	BL	BD	R
BW	1.00										
L	0.24*	1.00									
FL	0.03	0.31**	1.00								
FB	0.37**	0.25*	0.32**	1.00							
LT	−0.10	0.28**	0.23*	0.11	1.00						
LMT	0.04	0.33**	0.39**	0.13	0.36**	1.00					
AE	0.16	0.23**	0.10	0.18	0.06	−0.04	1.00				
FA	0.24*	0.22*	0.27**	0.20	0.27**	0.19	0.29**	1.00			
BL	−0.03	0.12	0.06	0.11	0.12	0.24*	0.14	0.12	1.00		
BD	0.15	0.14	0.16	0.11	0.24*	0.13	−0.04	0.27**	0.02	1.00	
R	0.06	0.15	−0.01	0.10	−0.05	−0.13	0.92**	−0.09	0.09	−0.16	1.00

[a] * = $P < 0.05$; ** = $P < 0.01$.

is presented in Table 1. The within-groups correlation matrix is presented in Table 2. The latter shows a relatively low degree of colinearity for this type of system. Bill measurements, for instance, are not significantly correlated with size when it is expressed as length or weight. This relationship is valid only within the range studied, but it still provides a measure that is reasonably independent of size for some of the variables. By including all variables simultaneously, we obtained the following ranking, with the corresponding λ values: BD (0.34), BL (0.53), LMT (0.59), BW (0.63), FA (0.64), LT (0.65), L (0.66), FB (0.70), AE (0.96), and R (0.99).

Bill dimensions have the highest discriminating power, whereas size or "forehead" measurements rate quite poorly. Bill depth is by far the most significant of all, followed by bill length. Interestingly, these two variables are uncorrelated. In general, the first four variables selected are related to behavioral differences between the sexes during the breeding season (Scolaro 1978). Three of the four are related to fighting behavior; the remaining one is related to digging and maintenance of the burrows. They all show higher values for the males.

In order to define the smallest subset of significant variables discriminating between the sexes, a stepwise analysis was performed. There are minor changes with respect to the simultaneous inclusion; among them, BW now enters third. Only the first four variables make a significant contribution to the discrimination process (Table 3). The remaining variables are not significant, either when considered individually or when pooled together (pooling the seven variables not included in the previous group gives an F of 0.69, df = 7, 86). Chi-square tests comparing predicted with observed sex were highly significant for all subsets considered ($P < 0.001$).

After eliminating BW for reasons of convenience in fieldwork, we obtain the following discriminating functions for the subsets with 1, 2, or 3 variables: (1) *Bill Depth*: $W = 22.47^*\text{BD}$, $C = 52.3$; (2) *Bill Depth* and *Bill Length*: $W = (22.17^*\text{BD}) + (7.73^*\text{BL})$, $C = 95.4$; and (3) *Bill Depth, Bill Length,* and *Flipper Length*: $W = (20.72^*\text{BD}) + (7.46^*\text{BL}) + (2.1^*\text{FL})$, $C = 130.4$. [In every case compare W with C; if $W > C$, the bird is a male, if $W < C$, the bird is a female, and if $W = C$, the sex cannot be determined.]

In the near future, we hope to be able to determine the sex of birds that are not yet sexually mature, which will aid an understanding of the dynamics and ecology of these populations. Preliminary results are very encouraging, and even for chicks the error is less than 10%, indicating that the dimorphism appears at a very early age. We believe that this method provides a simple and objective way of sex discrimination and hope that it will reduce the need for sacrifices in future studies.

We thank R. Taylor, A. Monochio, Z. Kovacs, O. Kovacs, C. Lasta, R. Barrena, and J. Colos for assistance in the field, C. Kovacs for the illustration, and M. Picallo for the typing. We also acknowledge the contribution made by our reviewers through their comments and criticisms. This investigation was sponsored partly by SECYT (Secretaria de Estado de Ciencia y Tecnologia) and partly by CONICET (Consejo Nacional de Investigaciones Cientificas y Tec-

TABLE 3. Variables in a step-wise regression analysis of sexual differences in morphology of Magellanic Penguins.

Variable	r^2	F[a]	df	Percentage of cases correctly classified
Bill depth	0.66	185.47	1, 96	92.8
Bill length	0.08	27.64	2, 95	94.8
Body weight	0.02	8.69	3, 94	not included
Flipper length	0.02	7.02	4, 93	95.9

[a] All F values are highly significant ($P < 0.01$).

nicas); the assistance of M. J. Pizarro, J. Velasco Suarez, H. B. de Williams, and other members of the staff of the Centro Nacional Patagonico is deeply appreciated.

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Received 20 May 1981, accepted 11 April 1982.