CAN WE USE DISCRIMINANT FUNCTION ANALYSIS TO SEX PENGUINS PRIOR TO CALCULATING AN INDEX OF A MORPHOMETRIC CHARACTERISTIC?

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Abstract

In sexually dimorphic species, morphometric characteristics have separate distributions for males and females, and these often overlap. Whilst discriminant analysis can be used to determine the sex of individuals, it is only able to correctly sex a certain proportion of birds. Two overlapping normal distributions are used to show that there is a difference between the real mean characteristic for a sex, and the apparent mean derived by sexing the birds using discriminant analysis.

When discriminant functions are able to correctly determine the sex of birds with greater than 80% success, the difference between the true and apparent mean is likely to be undetectable when fewer than 600 birds are sampled.

Therefore, under most normal sampling regimes a discriminant function with greater than 80% success may be used to derive statistically robust estimates of male and female characteristics.

Combining all data for both sexes is considered as a procedure for avoiding the necessity of sex determination. However, uncertainty in sex ratios can lead to considerable Type I and Type II errors. Lack of knowledge about the sex ratio between years makes combining the data a very doubtful procedure and use of a discriminant function to determine sex is recommended as being most practically robust.

Résumé

Chez les espèces à dimorphisme sexuel, les caractéristiques morphométriques ont pour les mâles et les femelles des distributions distinctes qui se chevauchent souvent. Alors que l'analyse discriminante peut servir à déterminer le sexe des individus, elle n'y parvient que pour un certain pourcentage d'oiseaux. Deux distributions de Gauß se chevauchant mettent en évidence la différence entre la moyenne réelle d'une caractéristique d'un sexe et la moyenne apparente dérivée de la détermination du sexe des oiseaux par l'analyse discriminante.

Lorsque les fonctions discriminantes parviennent à déterminer correctement le sexe de plus de 80% des oiseaux, la différence entre la moyenne réelle et la moyenne apparente risque d'être impossible à déceler si l'échantillon porte sur moins de 600 oiseaux.

Par conséquent, sous la plupart des régimes d'échantillonnage normaux une fonction discriminante ayant un taux de succès de plus de 80% peut

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être utilisée pour obtenir des estimations statistiquement robustes des caractéristiques se rapportant aux mâles et aux femelles.

Il n'est plus nécessaire de déterminer les sexes si l'on utilise la procédure qui consiste à combiner les données des deux sexes. Toutefois, les incertitudes liées au sex ratio peuvent conduire à des erreurs considérables de Type I ou II. Le manque d'informations sur le sex ratio des différentes années rend douteuse la procédure qui combine les données, et il est recommandé d'utiliser la fonction discriminante qui est la procédure la plus robuste à l'usage.

Резюме

У видов, имеющих половой диморфизм, морфометрические параметры самцов и самок имеют различные распределения, которые часто в какой-то мере совпадают. Хотя дискриминантный анализ можно использовать для определения половой принадлежности отдельных птиц, он дает возможность правильно определить половую принадлежность лишь какой-либо части птиц. Используются два частично совпадающих нормальных распределения с тем, чтобы показать существование разницы между истинной средней величиной параметра какого-либо пола и наблюдаемой средней, полученной при определении половой принадлежности птиц с помощью дискриминантного анализа.

Если дискриминантная функция дает возможность определять половую принадлежность птиц со степенью точности более 80%, то имеется низкая вероятность того, что при выборке меньше 600 птиц разница между истинной и наблюдаемой средней останется незамеченной.

Поэтому, обычно при нормальных режимах сбора проб для получения статистически устойчивых оценок характеристик мужского и женского полов можно использовать дискриминантную функцию, уровень точности которой свыше 80%.

Рассматривается возможность объединения всех данных по обоему полу для избежания необходимости определения половой принадлежности. Однако неопределенности в численном соотношении полов могут привести к существенным ошибкам Типа I и Типа II. Пробелы в знаниях о численном соотношении полов в разные годы делают объединение данных весьма сомнительной процедурой. Рекомендуется использовать дискриминантную функцию для определения половой принадлежности, так как она дает наиболее устойчивые результаты.

Resumen

En especies que presentan dimorfismo sexual, las características morfométricas tienen distintas distribuciones para machos y hembras, y éstas a menudo se superponen. Aunque los análisis discriminantes

pueden ser utilizados para determinar el sexo de algunos individuos, sólo pueden acertar en el sexado de una proporción de las aves. Se utilizan dos distribuciones normales superpuestas para demostrar que existe una diferencia entre la media real de una característica para un sexo dado, y la media aparente deducida al sexar las aves mediante un análisis discriminante.

Cuando las funciones discriminantes pueden determinar correctamente el sexo de las aves con un éxito superior al 80%, la diferencia entre la media aparente y la real es casi imperceptible cuando se muestrean menos de 600 aves.

Por lo tanto, en casi todos los regímenes normales de muestreo se puede utilizar una función discriminante que tenga un éxito superior al 80%, para deducir valores de ciertas características masculinas y femeninas que sean válidos estadísticamente.

Se considera que se podría evitar esta determinación combinando la totalidad de la información de ambos sexos aunque la incertidumbre en cuanto a las proporciones de sexos puede producir errores significativos del Tipo I y II. La falta de información sobre la proporción de los sexos en distintos años hace que la combinación de los datos sea un procedimiento bastante dudoso, por lo que se recomienda - como un criterio más valedero - el uso de una función discriminante en la determinación del sexo.

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1. INTRODUCTION

In sexually dimorphic species, morphometric characteristics (such as the CEMP characteristic A1, "weight on arrival") have separate distributions for males and females, and these often overlap. Whilst discriminant analysis can be used to determine the sex of individuals, it is only able to correctly sex a certain proportion of birds. The WG-CEMP has recognised this problem, in 1991 noting that analyses by Scolaro *et al.* (1990) and Kerry *et al.* (1992) had determined discriminant functions for Adélie penguins that correctly identified the sex of 87 to 89% of birds. Concern was expressed that it may be necessary to know the sex of birds with absolute accuracy, and that discriminant analysis may not be sufficient for this purpose (SC-CAMLR, 1991 - paragraphs 4.8 to 4.12). A suggestion was made that one way to avoid the problem of sex determination would be to combine males and females for the calculation of an index.

This paper evaluates the suggestion that male and females should be combined when monitoring certain CEMP parameters, such as penguin weight at arrival, if sex is not easily determined. I approach this problem from two directions:

(i) A characteristic such as bill depth has equal variance in males and females but the means are sufficiently close that there is some overlap between the distributions. If a discriminant function is used to identify males and females with a certain error, is this likely to give us a false estimate of the characteristic?

(ii) We are required to monitor a characteristic so that we can detect changes in it. With distributions as (i), if we combine the data from males and females will we still be able to detect changes in the characteristic with the same sensitivity as if we considered males and females separately?

2. METHODS

For the purposes of this analysis, I consider distributions of the morphometric characteristics bill length, depth and body weight to behave similarly. Thus we may separate sexes on bill characteristicistics in order to monitor body weight. From now on, then, I make reference only to an undescribed "characteristic". This work is mostly theoretical but in the cases where real data are used illustratively these were supplied by Dr Knowles Kerry (Australian Antarctic Division) to whom I am grateful. These data were collected between 22 and 31 December 1990 at Bechervaise Island, Mawson Base (67'36°W 62'49°E) by Judith Clarke and Grant Else, and comprise measurements of bill, head, flipper and toe dimensions and body weight of 34 females and 37 males. Birds were sexed by cloacal examination. The measurements and full methodology are described in Kerry *et al.*, 1992.

In identifying a discriminant function for these data, Kerry *et al.* (1992) established that the following criteria for discriminant analysis were met (Klecka, 1980):

(i) no characteristics were linear combinations of each other;

(ii) correlation coefficients between characteristics used for the final discriminant function were less than 0.60; and

(iii) the variance - covariance matrices were not significantly different: Box's M statistic (Pearson and Hartley, 1976) = 55.49: $\chi^2_{(45)} = 43.14$, $F_{(45,5460)} = 0.9586$, $P > 0.5$;

and discriminant functions are derived using bill length and depth (correct prediction of sex of 87% of birds) and an additional factor, flipper width (89%).

3. IMPLICATIONS OF SEXING PENGUINS USING DISCRIMINANT ANALYSIS

Let us assume that we measure a characteristic, x, (such as bill length) which varies with the discriminant function and is normally distributed in both males and females ($\mu_{females} < \mu_{males}$), with equal variance, and that there is some overlap between the male and female distributions of the characteristic (Figure 1). We can consider this to be a representation of a single factor discriminant function with a mean discriminant score equal to v on Figure 1. We are interested in the mean and variance in males and females, where sex is determined using discriminant analysis with a proportion of correct identification of sex ($= p$). It is therefore important to us to know whether, with the sampling size chosen, the discriminant function will give us mean values for the characteristic that are significantly different from the true means of that characteristic in the population.

Consider the case of females in Figure 1, with true mean μ and standard deviation σ. Only those females with $x<v$ will be identified as females by the discriminant function, and therefore the success of the discriminant function (p) is equal to the proportion of area under the normal curve for females with $x<v$, where v can be expressed in units of standard deviation. The apparent population of females is that part of both female and male distributions to the left of v. The mean and standard deviation of the apparent populations μ_1, σ_1 can be found by integrating both distributions over $x = -\infty$ to v, finding the weighted mean of x, and can be expressed in terms of the true mean and standard deviation:

$$\mu_1 = \mu - c\sigma \quad \text{for females,} \quad \mu_3 = \mu' + c\sigma \quad \text{for males} \tag{1}$$
$$\sigma_1 = d\sigma$$

where c, d are constants. Table 1 shows the c and d calculated for different p.

Although the variance of the apparent population is obviously lower than that of the true population, we can make an approximate calculation of the sample size required to detect the difference between the true and apparent means. The equation given in Sokal and Rohlf (1981) for finding the sample size needed to detect a given true difference between means[1] requires $\left(\frac{\sigma}{\delta}\right)$, where σ is the estimated true standard deviation and δ is the difference in the mean that must be detected. Here, $\delta = \mu - \mu_1 = c\sigma$ [equation 1] and therefore

$$\frac{\sigma}{\delta} = \frac{1}{c} \tag{2}$$

and is independent of σ or μ.

The sample size required in order to be 80% certain of detecting the difference at the 5% level of significance is shown in Table 1. At sample sizes of less than 300 for each sex, using a discriminant function that successfully determines the sex of more than 80% of birds is unlikely to yield an apparent mean for one sex which is significantly different from the true mean for that sex. Thus if we are restricted to small sample sizes discriminant functions with success rates of 80% and over are probably acceptable for all practical purposes. This means that the insistence on completely accurate sexing is not necessary.

True and apparent means of selected Adélie penguin characteristics are shown in Table 2. Bill length and depth behave approximately in conformity with the theoretical values given in Table 1. For example, apparent mean bill length for females is 0.378 mm smaller than the mean of females sexed by cloacal examination. Body weight does not behave in a similar way, presumably because it is not directly related to the discriminant function whereas bill length and depth are. We are therefore even less likely to be able to detect a difference between mean weight of the true and apparent populations if we use a discriminant function based on bill dimensions for sex determination.

4. EFFECT OF COMBINING MALES AND FEMALES

I now turn to the case where we want to be able to detect a change in a parameter. Is it better to ignore the sex of birds when trying to detect this change, or to sex birds with an understood error due to the success rate p. Consider first the special case of Figure 1, where the number of males and females in the sample are the same and σ and σ' are equal. In this case the point v corresponds to the mean of the combined sample, μ_2, and μ and μ' and σ and σ' are the means and standard deviations of the females and males respectively.

We can calculate μ_2 and σ_2 in terms of units of σ:

$$\begin{aligned} \mu_2 &= v = \mu + a\sigma \\ \sigma_2 &= b\sigma \end{aligned} \tag{3}$$

using the same methodology as described in the foregoing section, integrating instead from $-\infty$ to $+\infty$. Values of a and b are given in Table 3.

Turning once more to the Adélie penguin data (Table 2), μ_2 is taken to be the midpoint v between male and female distributions (very close to the calculated combined means), the mean of the standard deviations of males and females is taken as an estimate of σ, and μ is known.

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[1] $n \geq 2(\sigma / \delta)^2 \{t_{\alpha[v]} + t_{2(1-P)[v]}\}^2$: see Sokal and Rohlf (1981) for explanation

We can now estimate a and b:

bill length	$a = 0.913$	$b = 1.206$
bill depth	$a = 0.756$	$b = 0.931$
weight	$a = 0.949$	$b = 1.118$

Referring to Table 3 these estimates of a and b correspond to p of about 80%. This p derived for a single characteristic is lower than the success of the discriminant function for two characteristics described by Kerry *et al.* (1991) of 87%, as would be expected.

Now, the sample size required to detect a change k in the means μ and μ_2 can be calculated using the equation of Sokal and Rohlf (1981), which as previously stated requires $\left(\frac{\sigma}{\delta}\right)$. Firstly, for the mean of females, μ, set $\lambda = \frac{\sigma}{\delta}$ then

$$\lambda = \frac{\sigma}{\delta} = \frac{\sigma}{k\mu} \tag{4}$$

For the combined mean μ_2, $\frac{\sigma_2}{\delta_2}$ is required:

$$\frac{\sigma_2}{\delta_2} = \frac{\sigma_2}{k\mu_2} \quad \text{since we are looking for a combined change } k \text{ in males and females}$$

$$= \frac{b\sigma}{k(\mu + a\sigma)} \quad \text{substituting equation (3)}$$

$$= \frac{b\lambda}{1 + ka\lambda} \quad \text{substituting equation (4)} \tag{5}$$

We can now calculate the effective sample sizes, required to detect a change k in the means μ and μ_2 for different coefficients of variation of the female population, (r), since $\sigma = r\mu$ and $\frac{\sigma}{\delta}$ simplifies to $\frac{r}{k}$.

Table 3 shows values of a and b for different $\Delta\mu = \mu_1 - \mu$ in units of standard deviation, and the corresponding percentage success of a discriminant function acting through v. Sample size required to detect a change k is also given, for $k = 0.1$ and coefficient of variation $r = 0.05$, 0.1, 0.2, 0.4.

If a sample size n is required for a single sex, then $2n$ would be required to achieve adequate sampling of both males and females. Therefore only those cases where the combined sample size is greater than twice the single sex sample size imply that a greater sampling effort would be required should the data be combined for males and females.

It is clear that when there is a large overlap between male and female distributions ($\Delta\mu$ and p are low) and the coefficient of variation is high then the sample size required to reliably detect a 10% change in the mean is greater if single sexes are considered than if the sexes are combined. In terms of the sample number required, there is an advantage in combining the sexes unless μ and μ' are widely separated or r is very small.

5. THE EFFECT OF SEX RATIO ON COMBINED MALE AND FEMALE SAMPLING

The conclusion of the previous paragraph is dependent on the assumptions of equal variance and equal numbers of males and females in the sample. The first condition was met in our sample (variance covariance matrices were similar; see Methods) as was the second (the number of females was 34, males was 37). However, it is obvious that if the numbers of males 'and females in a sample vary, then it is likely that false changes in the characteristic may be identified, or that real changes may be masked. For instance, if all females are sampled one year, and all males the next, then the characteristic will appear to have increased in size.

Consider the situation of pooled sexes as described in the previous section. If the sex ratio changes then a in equation (3) will change. Figure 2 shows the effect of a changing sex ratio on q, where

$$q = \frac{a^*}{a_2} \qquad (6)$$

and a^* is the value of a for the a certain sex ratio, a_2 is the value of a for equal numbers of males and females (sex ratio = 0.5 = number of males/total numbers). If we expect to get variation in the means of the combined male and female population purely as a result of variation in the sex ratio, then what is the magnitude of this error?

Let γ = proportional difference in the mean μ_2 that is due to sex ratio variation. If we sample at the extreme of the sex ratio variation, with $\mu*$ and a^*, then

$$\gamma = \frac{\mu_2 - \mu^*}{\mu_2}$$

$$\gamma = \frac{ra_2(1-q)}{1+ra_2} \qquad \text{substituting equations 3 and 6} \qquad (7)$$

where r = coefficient of variation for females γ will have its own distribution dependent on the distribution of sex ratios. However, if we assume that within a time period we know the maximum and minimum sex ratio, we can make a 'worst case' estimate of the amount of difference between two means that could be due to sex ratio 'sampling' alone.

For example, take the case of body weight in Table 2. Taking the expected combined mean to be halfway between the male and female mean weights, and the estimated σ to be the mean of the sample standard deviations, we get

combined population mean = 4.386
combined population SD = 0.385
a_2 from equation 3 = 0.949
coefficient of variation r = 0.344/4.021 = 0.09

Now let us suppose that we sample over a time when we can expect sex ratio to vary from 0.3 to 0.5 (ratio of males/total). Then q from Figure 2 is 0.74 and thus γ = 0.021 from equation 6. Therefore, if we observe a change in the mean of 10%, 2.1% of this may be due to changes in sex ratio, and only 7.7% can be said not to be attributable to possible changes in sex ratio.

An additional example: if the sex ratio is expected to vary from 0.1 to 0.9 then $q = 0.33$ and $2\gamma = 0.105$ (we require 2γ because Figure 2 only deals with sex ratios from 0.1 to 0.5). In this latter case, the usual criterion for changes in an index within CEMP (10% change) could not be used to indicate that there was a change in the combined mean of the characteristic, as it may have been due to a change in sex ratio (Type I error). Conversely, it is possible that a change in characteristic has been masked by an opposite change in sex ratio (e.g., males and females got smaller, but the proportion of males in the second sample was greater); thus a change of 10% could in fact be a masked change of up to 20%, a very serious situation (Type II error).

6. DISCUSSION

It is apparent that it would be dangerous to establish a monitoring program using data from two sexes combined without knowing the sex ratios at the time of sampling. This could be done for a small sample by cloacal examination, or for example by discriminant analysis. However, Brennan *et al.* (1991) have shown that estimating sex ratios by discriminant analysis requires considerable sample sizes. They estimated that for dunlins (*Calidris alpina*), using a discriminant analysis with $p = 89\%$ on a population of size 2 000, 300 birds would have to be sampled to be 95% confident of obtaining a proportion of females within 0.05 of the real ratio.

Sex can also be determined by behavioural means, and Kerry *et al.* (1991) have shown that for Adélies, sex ratio of birds on shore is highly sensitive to breeding behaviour and changes almost daily. Any sampling regime that utilises sex ratio information must be highly specific in relation to the breeding cycle of these birds, and without sub-sampling for sex it would appear that combining data from both sexes into one index would be unsuitable for Adélies.

It is shown in the first part of this paper that using a discriminant function that correctly identifies the sex of >80% of birds, the estimated mean of a characteristic for males and females is not likely to be significantly different from the actual mean unless the sample size is very large. Moreover, the error will be consistent and independent of the sex ratio of the birds so long as the discriminant function does not change Kerry *et al.* (1992) note that the discriminant function may change between populations, but will probably not change significantly between years within the same population.

The implications of this paper can be summarised as:

If the discriminant function is greater than about 80% successful:

- sexes should be separated; and
- sex determination by discriminant analysis will usually give acceptable indices.

If the discriminant function is less than 80% successful:

- sexes should probably not be separated;
- pooling sexes will require a smaller sample size; and
- sex ratio should be known and have low variance.

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Table 1: Apparent mean and standard deviation of a single sex (e.g., females) sexed by discriminant analyses of varying success. Values of c and d in equation (1) together with the sample size required to be 80% certain of detecting the difference between true and apparent means at 5% significance level (replicates = 2).

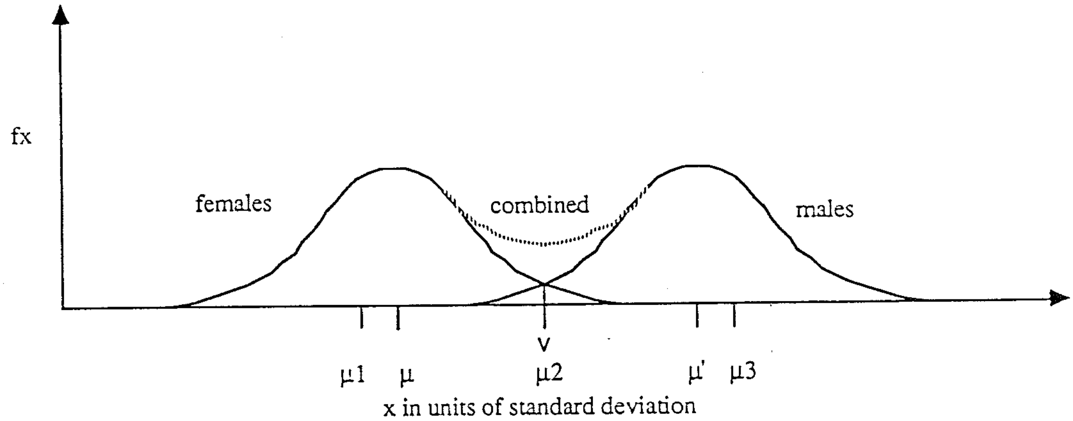
% Success of Discriminant Function	Apparent Mean in Units of Standard Deviation σ (constant c in $\mu_1=\mu\pm c\sigma$)	Apparent Standard Deviation in Units of σ (constant d in $\sigma_1=d\sigma$)	Sample Size (for single sex)
70.000	0.381	0.675	109
75.000	0.299	0.713	177
80.000	0.224	0.758	314
85.000	0.156	0.808	646
90.000	0.095	0.865	1740
91.000	0.084	0.877	>2000
95.000	0.042	0.928	.
99.000	0.007	0.984	.

Table 2: True and apparent mean and standard deviation of male and female Adélie penguins at Béchervaise Island. True was derived from cloacally sexed birds: 34 females, 37 males. Apparent was derived from birds sexed with the discriminant function D = 0.601 (bill length) + 1.154 (bill depth), mean discriminant score = 44.96 (Kerry *et al.*, 1992): 32 'females', 39 'males'.

	True Mean	True SD	Apparent Mean	Apparent SD
Females:				
Bill length (mm)	36.953	1.557	36.575	1.227
Bill depth (mm)	18.244	0.984	18.066	0.830
Weight (g)	4.021	0.344	4.025	0.299
Males:				
Bill length (mm)	40.381	2.197	40.515	1.936
Bill depth (mm)	19.630	0.849	19.705	0.785
Weight (g)	4.751	0.425	4.710	0.483

Table 3: The effect of the amount of overlap between two distributions on the mean and standard deviation of the combined populations. *a* and *b* are taken from equation (3). σ/δ and σ_2/δ_2 are calculated from equations (4) and (5), and the corresponding sample size necessary to detect a 10% change in the mean with 80% certainty and at a significance level of 1% is shown.

				coefficient of variation = 0.40		coefficient of variation = 0.10		coefficient of variation = 0.05	
v in units of standard deviation	% success of discriminant function	a, in $\mu_2=\mu+a\sigma$	b, in $\sigma_2=b\sigma$	σ/δ or σ_2/δ_2	sample size	σ/δ or σ_2/δ_2	sample size	σ/δ or σ_2/δ_2	sample size
calculation of σ_2/δ_2				$\sigma_2/\delta_2=$		$\sigma_2/\delta_2=$		$\sigma_2/\delta_2=$	
0.52	70.00	0.52	1.13	3.73	326	1.07	28	0.55	9
0.67	75.00	0.67	1.21	3.80	338	1.13	31	0.58	10
0.84	80.00	0.84	1.31	3.91	359	1.21	35	0.63	11
1.04	85.00	1.04	1.44	4.07	388	1.30	41	0.68	13
1.28	90.00	1.28	1.63	4.30	433	1.44	50	0.76	15
1.65	95.00	1.65	1.93	4.64	505	1.65	66	0.89	20
2.33	99.00	2.33	2.53	5.25	645	2.05	100	1.13	31
calculation of σ/δ				$\sigma/\delta=4$	375	$\sigma/\delta=1$	24	$\sigma/\delta=0.5$	7



μ true mean of females
μ' true mean of males
μ1 apparent mean of females after sexing using discriminant analysis
μ2 mean of combined distribution = v when sample size is equal
μ3 ....males..

Figure 1: Explanation of symbols used in the text. The distribution of a parameter of x for males and females, and the combined distribution is shown. The point v is the midpoint between the distributions.

Note: This figure shows overlapping normal distributions with the following symbols:

females	distribution f	mean μ	standard deviation (SD) σ	coef. var. (CV) r
males	distribution f'	mean μ'	standard deviation σ'	

point of contact between distributions = midpoint v
a discriminant function is presumed to separate these two distributions at the midpoint v
females identified with discriminant analysis have mean μ_1 SD σ_1
the combined distribution (equal males and females) has mean μ_2, SD, σ_2, CV, r_2.

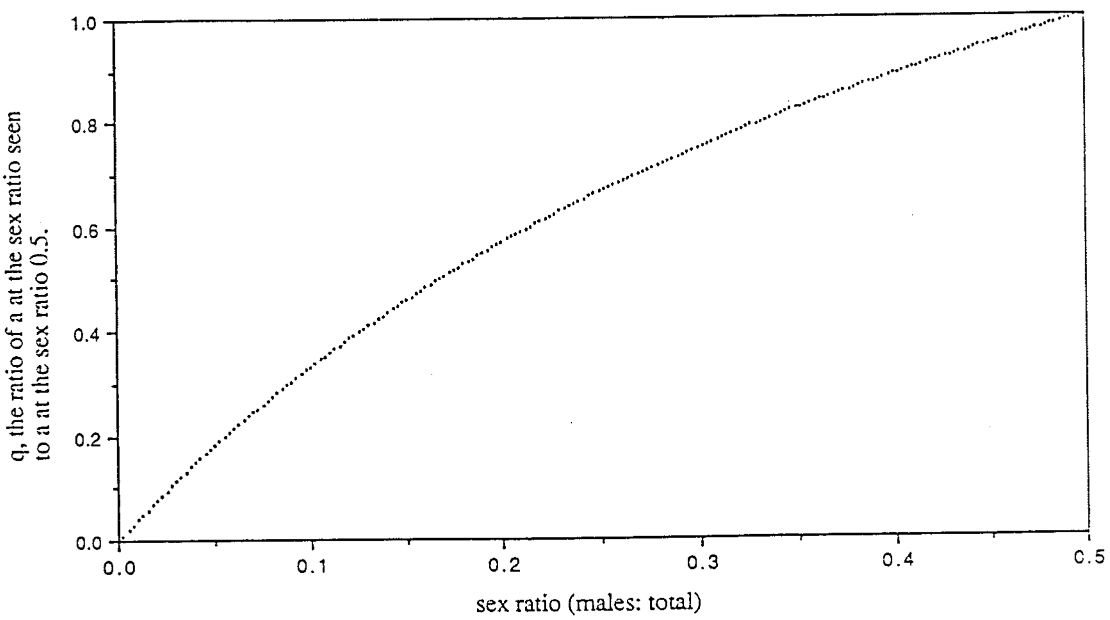


Figure 2: The effect of sex ratio on the mean of a combined population of males and females. See text for explanation of q and a.

Légende des tableaux

Tableau 1: Moyenne et écart-type apparents d'un seul sexe (par ex., femelles) qui a été déterminé avec plus ou moins de succès par des analyses discriminantes. Les valeurs de c et d de l'équation 1) considérées conjointement avec la taille de l'échantillon requise pour garantir à 80% que la différence entre les moyennes réelle et apparente sera décelée à un seuil de signification de 5% (répliques = 2).

Tableau 2: Moyennes réelle et apparente et écart-type des manchots Adélie mâles et femelles de l'île Béchervaise. La moyenne réelle a été dérivée d'oiseaux dont le sexe a été déterminé par examen du cloaque : 34 femelles et 37 mâles. La moyenne apparente a été dérivée d'oiseaux dont le sexe a été déterminé par la fonction discriminante D = 0,601 (longueur du bec) + 1,154 (hauteur du bec), moyenne discriminante = 44,96 (Kerry *et al.*, 1992): 32 "femelles" et 39 "mâles".

Tableau 3: Effet de l'ampleur du chevauchement de deux distributions sur la moyenne et l'écart-type des populations combinées. a et b proviennent de l'équation (3). σ/δ et σ_2/δ_2 sont calculés à partir des équations (4) et (5) et la taille correspondante de l'échantillon nécessaire pour déceler un changement de 10% dans la moyenne avec 80% de certitude et à un seuil de signification de 1% est indiquée.

Légende des figures

Figure 1: Explication des symboles utilisés dans le texte. La distribution d'un paramètre de x pour les mâles et les femelles et la distribution combinée sont indiquées. Le point v est le point central entre les distributions.

Figure 2: Effet du sex ratio sur la moyenne d'une population combinée de mâles et de femelles. Voir explications sur q et a dans le texte.

Список таблиц

Таблица 1: Видимое среднее и стандартное отклонение популяции одного пола (напр. самки), половая принадлежность которого определялась дискриминантными анализами с переменным успехом. Величины c и d в уравнении (1), а также размер проб, необходимый для того, чтобы иметь 80-процентный уровень достоверности выявления разницы между истинной и наблюдаемой средней величиной при уровне значимости 5% (повторения = 2).

Таблица 2: Истинная и наблюдаемая средние величины и стандартные отклонения для самцов и самок на о-ве Бешервез. Истинная средняя была получена путем клоакального осмотра птиц: 34 самки, 37 самцов. Наблюдаемая средняя была получена путем определения половой принадлежности с использованием дискриминантной функции D = 0,601 (длина клюва) + 1,154 (высота клюва), средний показатель дискриминанта = 44,96 (Kerry *et al.*, 1993): 32 "самки", 39 "самцов".

Таблица 3: Влияние степени частичного совпадения между двумя распределениями на среднее и стандартное отклонение объединенных популяций. a и b взяты из уравнения (3). σ/δ и σ_2/δ_2 вычислены по уравнениям (4) и (5), а также показан соответствующий размер проб, необходимый для того, чтобы выявить 10-процентное изменение средней при уровне удостоверности 80% и уровне значимости 1%.

Список рисунков

Рисунок 1: Объяснение условных обозначений дается в тексте. Показаны распределение параметра x для самцов и самок, а также объединенное распределение. Точка v - середина между распределениями.

Рисунок 2: Влияние численного соотношения полов на средние величины объединенной популяции самцов и самок. Переменные q и a объяснены в тексте.

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Tabla 2: Media real y aparente, y desviación típica del macho y la hembra de los pingüinos adelia de la isla Béchervaise. La media real se obtuvo de aves sexadas mediante examen cloacal: 34 hembras, 37 machos. La media aparente se derivó de las aves sexadas mediante la función discriminante D = 0.601 (largo del pico) + 1.154 (grosor del pico), resultado discriminante medio = 44.96 (Kerry *et al.*, 1992): 32 'hembras', 39 'machos'.

Tabla 3: El efecto del grado de superposición entre dos distribuciones sobre la media y la desviación típica de las poblaciones combinadas. a y b se obtienen de la ecuación (3). σ/δ y σ_2/δ_2 se deducen de las ecuaciones (4) y (5), y se presenta el tamaño de la muestra necesario para detectar un cambio del 10% en la media con un nivel de confianza del 80% y un nivel de importancia del 1%.

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Figura 1: Explicación de los símbolos utilizados en el texto. Se presenta la distribución de los parámetros de x para los machos y las hembras, y la distribución combinada; v es el punto medio entre las distribuciones.

Figura 2: Efecto de la proporción de cada sexo en la media de una población de machos y hembras. Véase el texto para una explicación de q y a.