Body weight in relation to variation in body size of Oystercatchers Haematopus ostralegus

Zwarts, L.; Hulscher, J.B.; Koopman, K.; Zegers, P.M.

Published in:
Ardea

Publication date:
1996

DISCRIMINATING THE SEX OF OYSTERCATCHERS
HAEMATOPUS OSTRALEGUS

LEO ZWARTS[1], JAN B. HULSCHER[2], KLAAS KOOPMAN[3] & PIET M. ZEGERS[4]
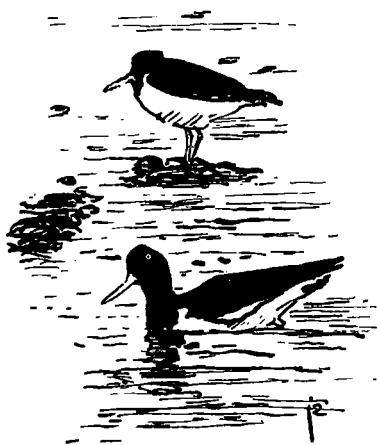
This paper presents methods to determine the sex of Oystercatchers of different age, using measurements of bill length, bill depth, shape of the bill tip, wing length and body weight. The bill length is the most important variable to differentiate between ♂ ♂ and ♀ ♀. The shape of the bill tip, the bill depth, the wing length and the body weight consistently vary with sex, but since the overlap is large, it is less reliable to determine sex from these variables. The best segregation between the sexes is obtained by measuring bill length, bill depth, and determining the shape of the bill tip. The paper gives formulae to distinguish the sexes when different sets of variables have been measured.

Key words: Oystercatcher - *Haematopus ostralegus* - sexing - discriminant analysis

[1]Rijkswaterstaat IJsselmeergebied, P.O. Box 600, 8200 AP Lelystad, The Netherlands; [2]Zoological Laboratory, University of Groningen, P.O. Box 14, 9750 AA Haren, The Netherlands; [3]Diligencelaan 11, 9351 PR Leek, The Netherlands; [4]St. Isidoorstraat 22a, 6089 NG Heibloem, The Netherlands.

INTRODUCTION

Male and female Oystercatcher *Haematopus ostralegus* are hard to distinguish in the field since they are virtually monomorphic, although the sexes are not completely identical. It is therefore important to ascertain which external morphometric measurements are most suitable to determine the sex of Oystercatchers in the hand. Heppleston & Kerridge (1970) concluded from an analysis of Oystercatchers of known sex that the ratio of bill length and bill depth could correctly classify 92% of the birds. However, the usefulness of the ratio was limited, since the criterium to distinguish the sexes was different for birds from two estuaries. This prompted us to determine the sex of a new, and larger, sample of Oystercatchers and try to find out whether discriminant function analyses performed on more body measures would give a rule which could be generally applied to sex Oystercatchers independently of where they occur.

Discriminant function analysis is a useful tool with which to differentiate between two groups by computing a discriminant function using two or more variables. The analysis produces a formula based on Oystercatchers of known sex which can be used to sex Oystercatchers of unknown sex with a certain probability of correct classification. Discriminant function analysis has been applied in many different birds species in order to determine the sex. It has also been done by Baker (1974) for three New Zealand species of Oystercatcher, by Hockey (1981) for the African Black Oystercatcher *H. moquini* and recently by Durell *et al.* (1993) and Lambeck *et al.* (1995) for Eurasian Oystercatchers. Heppleston & Kerridge (1970) also used a discriminant function analysis to sex Oystercatchers, but they found that the length/depth ratio of the bill was no less accurate than that obtained from the discriminant scores and proposed to use this ratio since it is easy to apply in the field.

Heppleston & Kerridge (1970) suggested that

the length/depth ratio of the bill differed between Oystercatchers from two estuaries because the populations were quite distinct. An alternative explanation is that the local differences in bill length resulted from variation in bill abrasion due to the predominant feeding technique used in each estuary. Changes in bill length range from –3.4 mm to +2.4 mm per day, i.e. 3-4% relative to bill length and are the outcome of two opposing processes: growth and abrasion (Hulscher 1985). The daily growth rate varies but amounts to 0.4 mm, on average. Abrasion rates are also variable and depend on the feeding technique used. The daily wear on the bill tip is larger in birds hammering holes in bivalves than in birds prising the bill between valves, or probing their bill in the mud when they search for worms. Consequently, bill measurements of Oystercatcher populations may vary between localities, and within localities over time, if there is a difference in the feeding mode or diet (Hulscher 1985). This implies that the criteria to distinguish the sexes based on bill length will vary correspondingly. Since the shape of the bill tip correlates with feeding technique (Hulscher 1985), we explore the possibility that inclusion of this categorical variable improves discrimination.

The paper presents the results of several discriminant function analyses based on different sets of variables. We advise which measurements have to be taken to sex Oystercatchers, but also give other formulae to be used when the optimal set of measurements is not available.

METHODS

The birds originated from the Dutch Wadden Sea and from the inland breeding areas in the northern part of The Netherlands; the main study areas are indicated on Fig. 1 of Zwarts *et al.* (1996a). The majority of the birds along the Frisian coast were found dead after severe cold spells, but a few were victims from netting. The birds from the inland breeding area were usually road casualties. The birds were sexed by dissection and gonad inspection. The sample was enlarged by observing
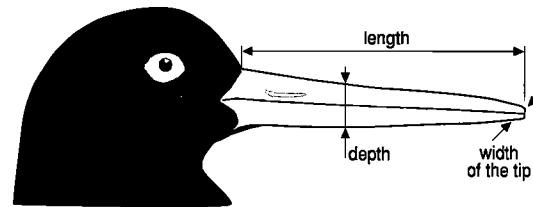

Fig. 1. The way in which the bill dimensions were measured.

copulations in colour-banded birds from the Frisian island of Schiermonnikoog.

Three age classes were distinguished according to the colour of the plumage (upperparts), eyes, legs and bill (Prater *et al.* 1977). Yearlings were defined as Oystercatchers before 1 June in the second calender year. They have a brownish plumage, brown eyes, grey legs and a grey bill tip. Subadults were 2, 3 and probably sometimes 4 years old. They were distinguishable by their brownish-black plumage, reddish eyes, grey-pink legs and orange-red bill with the distal half being dark. Adults were at least 3 years old. They had a black plumage, bright red eyes, pink legs and a red bill.

Seven measurements were taken: (1) bill length from tip to back edge of frontal shield; (2) bill length from tip to the proximal end of the nostril; (3) bill depth measured at the gonys, this being the 'deepest' point of the bill about halfway along; (4) width of the bill tip, measured 3 mm from the tip, and (5) shape of the bill tip in lateral view; (6) wing length, using the maximum chord method and (7) body weight. The bill measurements (see Fig. 1) were determined to the nearest 0.1 mm. Although bill length was measured in two ways - from tip to feather margin on the culmen and from tip to the proximal end of the nostril -, bill length to the nostril appeared to be a constant fraction of total bill length, viz. 91% (*SD* = 1.5). As it gave no additional information, it was not used in the analysis.

Six categories of the bill tip shape were distinguished, but they were assembled into three classes in this paper: blunt, pointed and intermediate

Table 1. The average body weight (g) of Oystercatchers per month (sub-adult and adult combined; data from Zwarts *et al.* (1996a) where sample size and *SD* are detailed). The birds were captured in the eastern part of the Dutch Wadden Sea, and on inland breeding areas in NE. part of The Netherlands in spring and summer.

| month	coast	inland
3	574	516
4	566	520
5	538	510
6	529	513
7	534	505
8, 9, 10	549	545
11	591	
12, 1, 2	613	

(Hulscher 1985). These three categories essentially describe the variation in height of the bill at the tip. In a small sample of Oystercatchers in which the bill tip shape had been scored too, bill height was 4.92 mm in blunt bills, 3.29 in pointed bills and 4.22 mm in intermediate bill tip shapes. Since bill tip shape has been determined in most birds, whereas height of the bill tip is known for only a minority of the sample, we used the qual-

itative variable 'bill tip shape' instead of the quantitative variable 'height of bill tip', although the latter variable does appear to be a good predictor of sex in the discriminant analysis (Durell *et al.* 1993).

Due to wear of the wing feathers, the wing length decreased by 0.34 mm per month, on average, from December, when the primaries were new, until September, when they were worn (Zwarts *et al.* 1996b). All wing lengths were standardized to 'new' feathers. Body weight was determined to the nearest gram. The body weight was variable, so standardization was necessary in birds of known sex, as well as in the birds of unknown sex for which the analysis was designed. A correction was made for loss of body weight after arrival on the roost (Zwarts *et al.* 1996d). All weights were standardized to body weight at four hours after arrival on the roost, since most of the food would have been digested by then and defecated. As body weight varied seasonally, all body weights were expressed as the deviation from the monthly average weight, as determined in the birds captured in our study areas (Table 1). The weights of coastal and inland birds differed so much that two figures had to be used. The weights of subadults and adults were pooled since they were similar. Body weights in the sexed birds

Table 2. Biometric measurements (mm ± *SD*) of ♂ and ♀ Oystercatchers, given separately for three age-classes.

	yearling			sub-adult			adult		
	$\bar{x}$	*SD*	*n*	$\bar{x}$	*SD*	*n*	$\bar{x}$	*SD*	*n*
Bill length									
♂	69.45	3.54	251	69.36	3.70	98	70.66	3.80	1009
♀	76.95	3.91	330	78.07	4.00	107	78.78	4.38	982
Bill depth									
♂	10.33	0.39	251	10.71	0.47	102	10.71	0.46	1020
♀	10.08	0.42	334	10.28	0.43	111	10.33	0.44	994
Bill tip width									
♂	1.44	0.34	94	1.40	0.41	80	1.40	0.32	790
♀	1.32	0.28	102	1.35	0.30	76	1.38	0.28	801
Wing length									
♂	251.8	6.41	205	259.4	6.99	30	262.0	6.53	736
♀	253.3	6.48	244	262.1	7.44	39	265.0	6.34	746
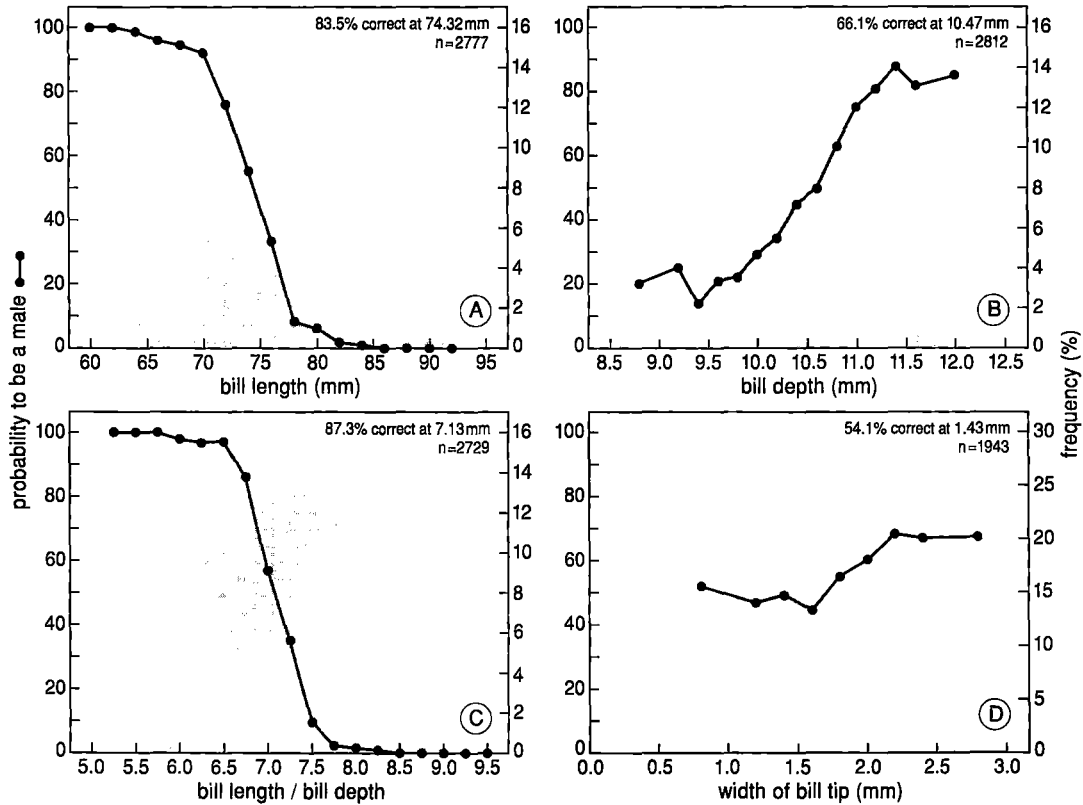
Fig. 2. Frequency distribution and probability of being a ♂ against (A) bill length, (B) bill depth, (C) ratio of bill length to bill depth and (D) bill tip width. Also given is the dividing value at which the highest percentage of birds is correctly sexed. The three age classes have been considered together.

were only used if birds were freshly dead due to a traffic accident, or capture weight was known in netted birds which were killed since they had leg cramp.

SPSS (Norušis 1990) was used for all statistical analyses.

RESULTS

Table 2 summarizes all data by showing the average length and depth of the bill, the width of the bill tip, and the average wing length for ♂ ♂ and ♀ ♀ in the three age classes.

Separation of the sexes based on single variables

Bill length varies between 60 and 92 mm (Fig. 2A). Individuals with a bill shorter than 64 mm or longer than 84 mm are definitely ♂ ♂ or ♀ ♀, respectively. This means that, if bill length is used as the single measurement, the sex is known with certainty for only 5% of the population, since such extremely short or long bills are rare. Nonetheless, 83.5% of the population would be correctly categorized if a bill length of 74.32 mm is taken as the boundary between ♂ ♂ and ♀ ♀. Bill depth varies between 8.5 and 12.2 mm. It gives less information than bill length, although it is clear that ♀ ♀ more often have slender bills (Fig.
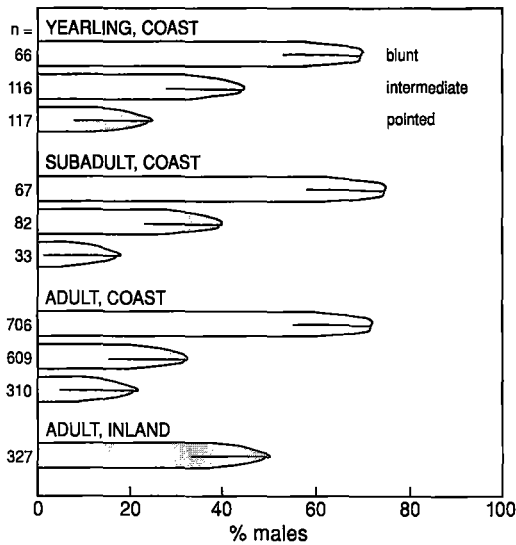
Fig. 3. The proportion of Oystercatchers that had been ♂ ♂ as a function of bill tip shape, shown separately for the three age classes; number of cases is given.

2B). If the ratio bill length/bill depth is used to distinguish both sexes, the percentage of correctly classified cases increases to 87.3% (Fig. 2C), which is clearly still below the level obtained by Heppleston & Kerridge (1970). The width of the bill tip is of no importance in dividing the sexes (Fig. 2D).

The shape of the bill tip differs between male and female Oystercatchers feeding in the intertidal zone (Fig. 3). In all age classes, ♂ ♂ more often have blunt bills and ♀ ♀ pointed bills. The shape of the bill tip can thus be used to sex Oystercatchers observed in the field. Assuming that in these coastal birds each adult with a blunt bill is a ♂ and each bird with an intermediate or pointed bill tip shape is a ♀, 70% of the Oystercatchers would be correctly sexed. However, shape of the bill tip gives no information about the sex in inland Oystercatchers, since all these birds acquire pointed bills (Hulscher 1985).

Bill length does not depend only on sex and

Fig. 4. Average bill length (± SE) as a function of bill tip shape, given separately for ♂ ♂ and ♀ ♀, divided into three age classes; number of cases (*n*) is given. The dividing level predicted by discriminant function analysis is given as the border between shaded and unshaded fields, but also as a figure, along with the percentage of correctly classified birds, in the right-hand boxes.
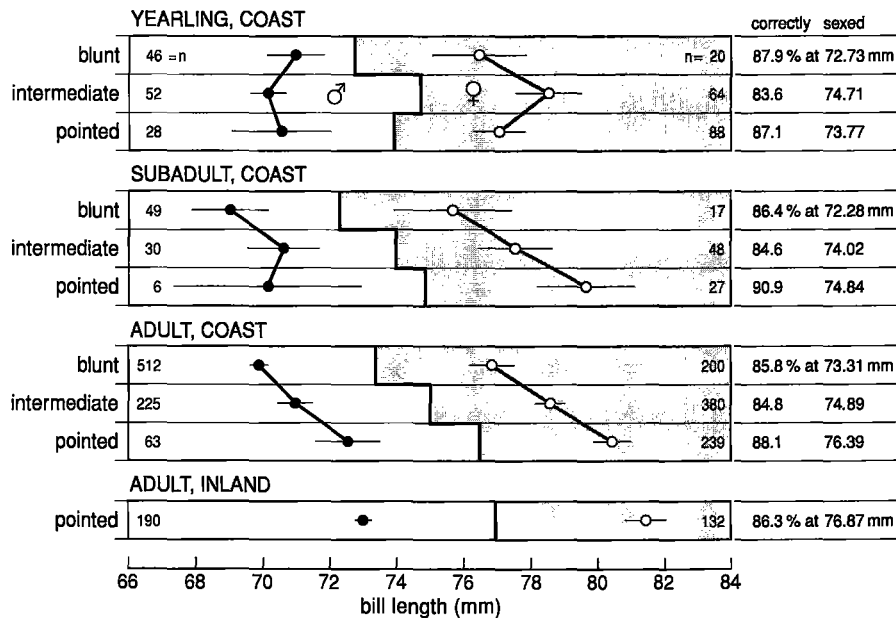
Fig. 5. Average bill depth (± *SE*) as a function of bill tip shape, given separately for ♂ ♂ and ♀ ♀, divided into three age classes; number of cases (*n*) is given. The dividing level predicted by discriminant function analysis is given as the border between shaded and unshaded fields, but also as a figure along with the percentage of correctly classified birds in the right-hand boxes.
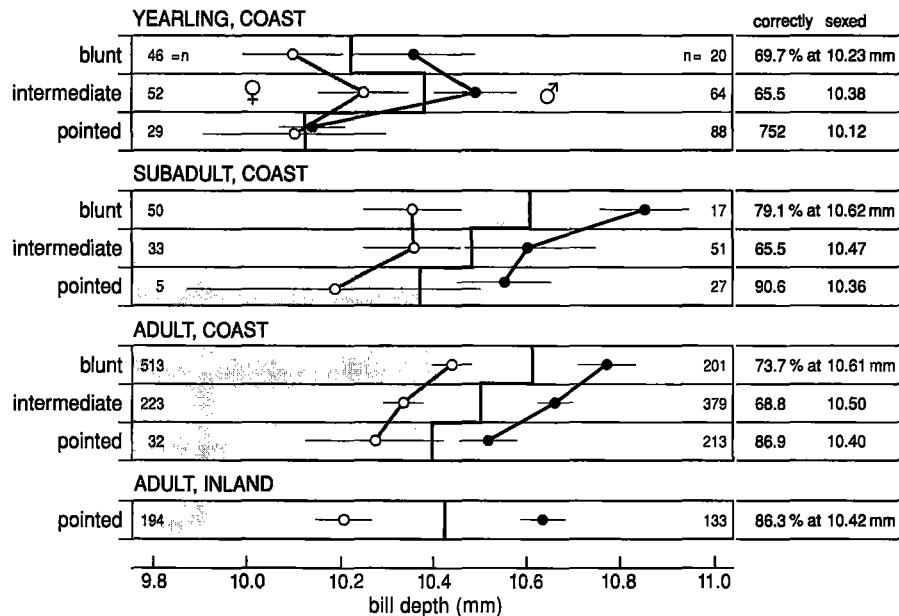
age, but also on the shape of the bill tip. Figure 4 shows the dividing limits, as determined by discriminant function analysis, for three age classes and three types of bill tip shape. If only bill length is known, 87-91% of the individuals can be correctly classified if the bill is pointed, but this decreases to 84-87% for birds with blunt or intermediate bills. A likely explanation for this difference is that the degree of abrasion of the bill and hence its length is more variable in birds with a blunt or intermediate bill, compared to birds with a pointed bill. When Oystercatchers leave the tidal wintering area in spring for inland breeding areas, they acquire a pointed bill tip and longer bill (Hulscher 1985). The bill length of both sexes may become even longer than those birds with pointed bills on the coast, but these differences are not significant (Fig. 4).

Birds with blunt bill tips more often have a sturdy bill than birds with pointed bills. The aver-

age difference in bill depth between adults with blunt and pointed bill tips is significant, yet amounts to only 0.2 mm (Fig. 5). As the same figure shows, the criteria for separating the sexes are also dissimilar for birds having a different bill tip shape. Consequently, more birds can be correctly sexed on the basis of bill depth if it is done separately for birds with a different bill tip shape (compare Fig. 2B with Fig. 5).

Local differences in mean bill length and bill depth disappear if birds with the same bill tip shape are compared (Figs. 4 & 5). This is also true for the ratio bill length/bill depth. The dividing level of this ratio differs for inland and coastal birds, being 7.37 (92% correctly sexed) and 7.09 (86% correctly sexed), respectively. However, the dividing level of inland birds is close to those of the coastal birds with pointed bills, i.e. 7.31. In contrast, the dividing level is 7.13 for coastal birds with an intermediate bill tip shape and still
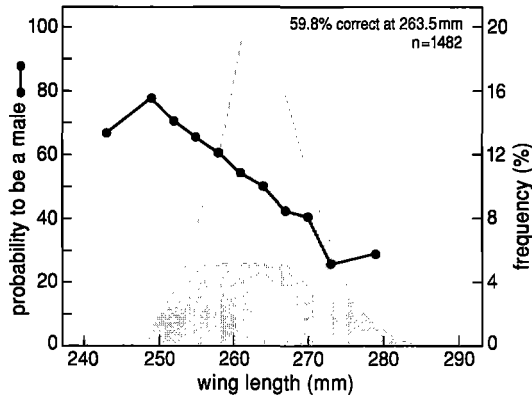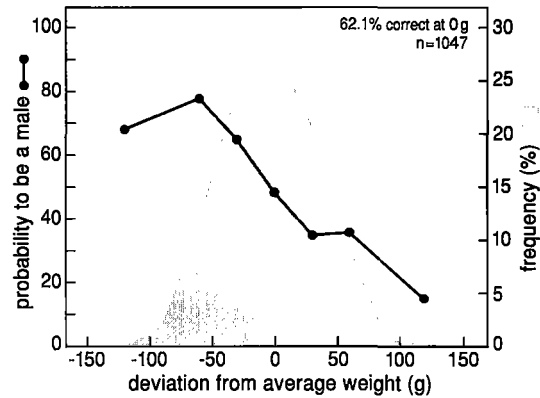
Fig. 6. Frequency distribution of wing length and the proportion being a ♂ in adult birds. The dividing level at which the highest percentage of birds is correctly sexed is also given.

Fig. 7. Frequency distribution of the relative body weight and the proportion being a ♂ in sub-adult and adult birds. The dividing level at which the highest percentage of birds is correctly sexed is also given. The monthly average weight of birds along the coast and inland (Table 1) have been subtracted from the individual body weight in order to correct for seasonal variation and for the differences between the coastal and inland birds.

lower, 6.93 for birds with blunt bills. The problem that a different dividing level has to be used for each site to distinguish the sexe, is solved, at least for our study areas, if birds are first separated according to bill tip shape.

Wing length increases with age (Table 2), so the optimal separation limit between ♂♂ and ♀♀ also changes, although there remains a large overlap as shown for adults in Fig. 6. The percentage of correctly classified individuals amounts to 55.5% at the dividing level of 249.8 mm for yearlings, 59.4% at 261.9 mm for subadults to 59.8% at 263.5 mm for adults.

Sample size of body weights is much smaller than for the biometric measurements, since the weights of all birds found dead are omitted, with the exception of fresh casualties (Table 1). As there are so a few yearlings among these casualties, the body weight of this age class is not analysed. The data for subadults and adults can be pooled since their average body weights per month do not differ. Females weigh, on average 20 g more than ♂♂, but the overlap in the frequency distribution is so large (Fig. 7) that body weight deviations from the monthly mean cannot be used as a single predictor of the sex.

Separation of the sexes based on more variables

The previous section shows that if one measure is known, the percentage of birds sexed correctly varies between 84% for bill length and not more than 54% for the width of the bill tip, while the ratio bill length/bill depth gives an accurate prediction 87% of the cases (Fig. 2). Table 3 gives 14 equations for separating the sexes using different combinations of variables. Even if bill tip shape is not known, it is still possible to sex 91-92% of the birds correctly from bill length, bill height and wing length. However, a separate equation is necessary for inland and coastal birds if the bill tip shape has not been determined. If bill tip shape and body weight are known, only bill length and bill depth are required: 94-95% of the birds are sexed correctly, and there is no improvement if more variables, such as wing length, are added to the equation.

Table 3 gives the unstandardized discriminant function coefficients. When applied to individuals, the resulting discriminant score varies be-

Table 3. Results of 14 discriminant function analyses using three variables. The table gives the unstandardized discriminant function coefficients. The score is negative or positive for ♂ ♂ and ♀ ♀ respectively, whereas the sex is unknown if the score is zero. The last two columns show the percentage correctly classified and the number of birds used in the analysis. An example: using formula 5 in an adult bird with a pointed bill tip, a bill length of 80 mm, a bill depth of 10 mm and a wing length of 280 mm, $D = -7.438 + 0.225 \times 80 - 1.682 \times 10 + 0.033 \times 260 = 2.322$. The outcome is positive, so the bird is a ♀. The probability (P) that this bird is incorrectly sexed will be 0.48%, using the equation to convert D in P (Fig. 8).

age	area	bill shape	constant	bill length	bill depth	wing length	body weight	n	correct %	formula nr
yearling	coast	pointed	3.696	+0.356	-0.461	-0.099		63	90.5	1
,,	,,	interm.	-6.759	+0.228	-2.072	+0.044		51	90.2	2
,,	,,	blunt	-15.387	+0.325	-1.037	+0.093		54	92.6	3
,,	,,	all	-6.263	+0.275	-1.278	+0.003		444	89.2	4
(sub)adult	,,	pointed	-7.438	+0.225	-1.682	+0.033		181	92.8	5
,,	,,	interm.	-6.082	+0.260	-1.396	+0.047		449	91.1	6
,,	,,	blunt	-2.300	+0.262	-1.545	+0.003		473	90.3	7
,,	,,	all	-3.826	+0.244	-1.441	-0.003		1195	90.7	8
,,	inland	all	-14.501	+0.243	-1.233	+0.033		259	92.3	9
,,	coast	pointed	-2.564	+0.257	-1.968		+0.006	115	93.0	10
,,	,,	interm.	-5.335	+0.258	-1.662		+0.006	331	94.6	11
,,	,,	blunt	-4.814	+0.301	-1.598		+0.001	345	93.3	12
,,	,,	all	-4.971	+0.266	-1.574		+0.003	803	93.2	13
,,	inland	all	-5.829	+0.249	-1.287		+0.008	180	95.0	14
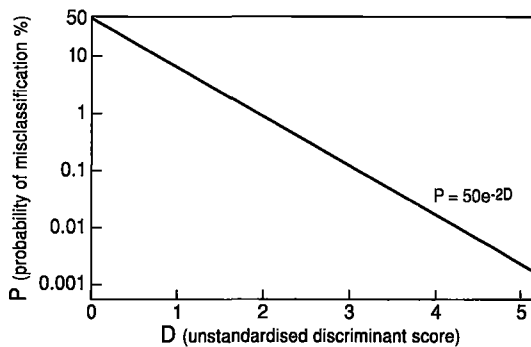
Fig. 8. The relationship between the probability of misclassifying the sex of an Oystercatcher and the discriminant score.

tween -4 and +4. Negative scores refer to ♂ ♂, positive ones to ♀ ♀. The probability (%, P) of being assigned to the wrong group is a function of the absolute value of the discriminant score (D) (Fig. 8). So if for an individual the score $D = 0$, P

= 50 and the sex is unknown. The risk of misclassification, P, decreases to 40, 30, 20, 10, 5 and 1%, with $D = 0.11$, 0.26, 0.46, 0.80, 1.15 and 1.96, respectively.

DISCUSSION

Bill length is the most important single discriminating variable for sexing Oystercatchers. Bill depth and body weight add some further information, but not much. The discriminant functions based on these three variables (Table 3, formulae 1-9) are only slightly better than the ratio bill length/bill depth (Fig. 2C). Figs. 2, 4-7 and Table 3 give the percentage of correctly sexed birds. Since the calculations are based upon the sample itself, the number of correctly sexed birds may be biased. The appropriate way to test the validity of the formulae given is to split up the data, perform the calculations on one half of the data and test

Table 4. The percentage of Oystercatchers that were correctly sexed in the 'test sample' of birds found dead after a cold spell on Texel, using the formulae given in Figs. 2 & 4 and Table 3; data of Cor Smit (unpubl.); *n* = 242. The last column shows the percentage of Oystercatchers that had been correctly sexed in the samples on which the formulae are based ('base sample'), taken from Fig. 2 (the first three lines), Fig. 4 (line 4) and formulae 1-8 in Table 3 (last line).

variable	test sample	base sample
bill length	81.8%	83.5%
bill depth	57.1%	66.1%
bill length/bill depth	86.3%	87.3%
bill length per shape	79.4%	74.9%
formulae 1-8	84.1%	90.5%

the resulting formulae on the other. When we use the discriminant functions calculated separately for the large subsample of mainland birds to predict the sex of the Oystercatchers captured on Schiermonnikoog, we find that the proportion of correctly sexed birds is equal to that obtained from the formulae based on the island sample itself. We conclude from this that the discriminant functions given above can be generally applied to all birds in our study areas, and that no more birds can be correctly classified when separate formulae are used for each region.

Can the formulae be used to determine the sex of Oystercatchers from elsewhere? Cor Smit collected 242 dead Oystercatchers after a cold spell on Texel, 100 km west of our study areas and made most of the same biometric measurements. Table 4 compares the percentage of correctly sexed Oystercatchers when our formulae applied to his sample and on our own base sample. The predictive value of most formulae is high with one exception, bill depth. The explanation is that the entire frequency distribution of bill depth on Texel, and also the means per age class, sex and bill tip shape, are 0.5 mm below those in our study area. The bill is conical and hence more difficult to measure in a standard way than, for instance, bill length. Therefore, it is possible that the bill depth there was systematically measured

another way and that the bills were not actually more slender. The conclusion is that the discriminant function given above would predict the sex of Oystercatchers on Texel equally well as in our study area.

If the bill tip shape is not known, using the dividing level based upon the data given in this paper, this may lead to serious mistakes if applied to local populations. For instance, the dividing level for the ratio bill length/bill depth is 7.389 in our inland birds and 7.075 in the coastal birds in the Wadden Sea. If the Wadden Sea values were to be used for our inland birds, the proportion of wrongly sexed birds would increase from 9 to 20%. This percentage would increase even further to 36 and 55%, were the dividing level determined by Heppleston & Kerridge (1970) for the Ythan estuary and Morecambe Bay, respectively, to be used on the inland population.

The dividing level for bill length depends on the shape of the bill tip (Fig. 4), and, as shown before, this is also true for the ratio bill length/bill depth. The dividing levels are different for inland and coastal birds because all inland birds, but

Table 5. Correlations between repeated measurements of single biometric variables, or of discriminant scores after three variables were entered into a discriminant function analysis, in 1143 individuals captured at least twice (data from Zwarts *et al.* 1996a). Body weight was converted into deviation from average monthly weight (Table 1). The third column gives the percentages of birds assigned twice to the same sex according to the different discriminant function analyses, and the last column the expected percentage of correctly sexed birds, taken from Fig. 2 (lines 1-3), Fig. 5 (line 4), Fig. 6 (line 5) and Table 3 (lines 6-7) .

variables	*r*	similar	correct
bill length	+0.95	92.1%	83.5%
bill depth	+0.81	83.4%	66.1%
bill tip width	+0.43	74.6%	54.1%
wing length	+0.77	81.9%	62.1%
body weight	+0.65	74.7%	59.7%
formulae 5-9	+0.91	91.7%	89.4%
formulae 10-14	+0.92	91.5%	91.9%

only a minority of the coastal birds, had pointed
bill tips. The differences disappear, however, if
only birds with pointed bill tip shapes are com-
pared (Fig. 4 and text). From this, we conclude
that to sex Oystercatchers, the shape of the bill
also has to be recorded.

Unfortunately, Heppleston & Kerridge (1970)
did not record bill tip shape, but it is likely that in
the Ythan estuary and the Morecambe Bay more
Oystercatchers have blunt bills than in the Wad-
den Sea. The Oystercatchers in our coastal study
sites open bivalves by prising the bill between
valves and only very rarely hammer on these prey
(Zwarts & Drent 1981, Hulscher & Ens 1992);
that is why most birds have an intermediate bill
tip shape (Fig. 3; Hulscher & Ens 1991). Ham-
merers have shorter, and probably also more
sturdy, bills, which would make their ratio bill
length/bill depth even lower (Durell et al. 1993).
Many Oystercatchers from Morecambe Bay and
Ythan estuary may exclusively hammer bivalves
(Drinnan 1957, Heppleston 1971). If so, this
would may explain the low dividing level of the
ratio bill length/bill depth in both areas: 6.74 and
6.32, respectively (Heppleston & Kerridge 1970),
this compared with the value of 6.93 for the birds
with blunt bills in the Wadden Sea .

The question remains, however, whether this
difference between the Scottish, English and
Dutch Oystercatchers can be fully attributed to
variation in the shape of the bill tip due to a differ-
ence in feeding method. The bill lengths of arctic-
breeding Oystercatchers are very short (Lambeck
& Wessel 1993, Lambeck et al. 1995). Bill length
probably increases in Oystercatchers from the
arctic to the southern temperate zone (Cramp &
Simmons 1983, Lambeck & Wessel 1993, Lam-
beck et al. 1995). Most of the birds in the eastern
part of the Dutch Wadden Sea breed nearby in the
northern Netherlands (Hulscher et al. 1996,
Zwarts et al. 1996a), whereas many birds winter-
ing in Great Britain originate from Norway (Dare
1970, Anderson & Minton 1978). If so, they
would have a relatively short bill and this would
cause a shift downward in the dividing levels be-
tween the sexes of birds wintering in Britain. This

suggestion implies that it is not yet clear to what
degree the different dividing levels of Oyster-
catchers wintering in the Ythan estuary, More-
cambe Bay and in the Wadden Sea are due to the
different populations involved (the original
hypothesis of Heppleston & Kerridge 1970) or to
differences in the shape of the bill tip, such as
proposed in this paper. In any case, the formulae
10-14 from Table 3 cannot be used for Oyster-
catchers breeding in Iceland and Faeroer since
their wings are longer than for the race breeding
on the continent (Cramp & Simmons 1983).

The conclusion remains however that, at least
at the scale of the Wadden Sea and surrounding
breeding areas, local and temporal differences be-
tween discriminant functions disappear when bill
tip shape is taken into account, and thus that bill
length of an individual varies with the shape of
the bill tip. To investigate the intra-individual var-
iability, we determined the probability that birds
captured more than once would be assigned to
different sexes. We selected the 1143 birds which
were captured at least twice from the data pre-
sented by Zwarts et al. (1996a). Over a period of
20 years, 847 birds were captured twice, 204
birds three times, and 63 , 21, 7 and 1 Oyster-
catcher four, five, six or seven times, respectively.
The time between two successive captures varied
between one month and 15 years and amounted to
23 months, on average. To simplify the analysis,
we only compared the biometrics, and assigned
sex, of birds between successive captures.

Table 5 shows the correlations between the
measurements of retrapped individuals. The bill
does not vary much in length, as shown by the
high correlation of +0.95. The correlation is smal-
ler for the repeated measurements on bill depth,
which may probably be attributed to the larger er-
ror of measurement: the range of bill depth is only
3.5 mm, against 33 mm in the bill length (Fig. 2).
The error is probably also relatively large in
measurement of the width of the bill, although it
is clear that the width of the bill tip varies accord-
ing to the feeding method used (Swennen et al.
1983, Hulscher 1985, Durell et al. 1993). The ex-
pectation was that the wing length of individuals

would not vary much, since the wing length of individual adults does not vary much during the year or over the years (Zwarts *et al.* 1996b). However, the wing length appears to be more variable than the bill length, presumably because the error of measurement is again larger than for bill length. The body weight varies during the year, but when that is corrected for, body weight varies over the short-term (Zwarts *et al.* 1996c). Hence we did not expect to find a high correlation between successive body weights corrected for the seasonal trend (Table 1). Nevertheless, the correlation is quiet high, so the individual differences in body weight are apparently rather consistent.

The main conclusion from Table 5 is that the most important variables in predicting the sex are not as variable as we had expected before the data were analysed. The final step is to calculate the discriminant scores of the retrapped individuals using formulae given in Table 3 and compare these for successive captures (last two lines in Table 5). The correlations are still higher than for most of the single variables used as predictors. The probability of a retrapped bird being assigned to another sex fits well with the calculated probability that this would occur, as predicted by the discriminant function analysis. When the discriminant scores are recoded into the predicted sex, 91 to 93% of the retrapped birds were assigned to the same sex as on the occasion before. This is more than the percentage of correctly sexed birds (Table 5), because the smallest ♀♀ or largest ♂♂ are consistently incorrectly sexed, due to the overlap in the body measurements of both sexes.

The general conclusion of this paper is that, although bill length and body weight of individual Oystercatchers are variable, these intra-individual variations are not very large compared to inter-individual differences and can be corrected for. There are local and temporal differences in the level at which the sexes can be separated, but if the calculations are done for separate categories of bill tip shape, this problem is solved.

ACKNOWLEDGEMENTS

REFERENCES

Anderson K.R. & C.D.T. Minton 1978. Origins and movements of Oystercatchers on the Wash. Br. Birds 71: 439-447.

Baker A.L. 1974. Criteria for aging and sexing New Zealand Oystercatchers. N. Z. J. Mar. Freshwater Res. 8: 211-221.

Cramp S. & K.E.L. Simmons (eds) 1983. The birds of the western Palaearctic, 3. Oxford University Press, Oxford.

Dare P.J. 1970. The movements of Oystercatchers *Haematopus ostralegus* visiting or breeding in the British isles. Fishery Invest. (Ser. II) 25: No 9.

Drinnan R.E. 1957. The winter feeding of the Oystercatcher (*Haematopus ostralegus*) on the Edible Cockle (*Cardium edule*). J. Anim. Ecol. 26: 441-469.

Durell S.E.A. le V. dit, J.D. Goss-Custard & R.W.G. Caldow 1993. Sex-related differences in diet and feeding method in the Oystercatcher *Haematopus ostralegus*. J. Anim. Ecol. 62: 205-215.

Heppleston P.B. 1971. The feeding ecology of Oystercatchers (*Haematopus ostralegus*) in winter in Northern Scotland. J. Anim. Ecol. 40: 651-672.

Heppleston P.B. & D.F. Kerridge 1970. Sexing Oystercatchers from the bill measurements. Bird Study 17: 48-49.

Hockey P.A.R. 1981. Morphometrics and sexing of the African Oystercatcher. Ostrich 52: 244-247.

Hulscher J.B. 1985. Growth and abrasion of the Oystercatcher bill in relation to dietary switches. Neth. J. Zool. 35: 124-154.

Hulscher J.B. & B.J. Ens 1991. Somatic modifications of feeding system structures due to feeding on different foods with emphasis on changes in bill shape in Oystercatcher. Acta XX Congr. Int. Ornithol. 20: 889-896.

Hulscher J.B. & B.J. Ens 1992. Is the bill of the male Oystercatcher a better tool for attacking Mussels than the bill of the female? Neth. J. Zool. 42: 85-100.

Hulscher J.B., K-M. Exo & N. Clark 1996. Why do Oystercatchers migrate? In: J.D. Goss-Custard (ed.) The Oystercatcher: from individuals to populations: 155-185. Oxford University Press, Oxford.

Lambeck R.H.D. & E.G.J. Wessel 1993. A note on Oystercatchers from the Varangerfjord, NE Norway. Wader Study Group Bull. 66: 74-79.

Lambeck R.H.D., V.V. Bianki, H. Schekkerman, E.G.J. Wessel, P.M.J. Herman & A.S. Koryakin 1995. Biometrics and migration of Oystercatchers (*Haematopus ostralegus*) from the White Sea region (NW Russia). Ring. & Migration 16: 140-158.

Norušis M.J. 1990. SPSS/PC+ Advanced Statistics V4.0. SPSS Inc., Chicago.

Prater A.J., J.H. Marchant & J. Vuorinen 1977. Guide to the identification and ageing of Holarctic waders. BTO guide 17, Tring.

Swennen C., L.L.M. de Bruijn, P. Duiven, M.F. Leopold & E.C.L. Marteijn 1983. Differences in bill form of the Oystercatcher *Haematopus ostralegus*; a dynamic adaptation to specific foraging techniques. Neth. J. Sea Res. 17: 57-83.

Zwarts L. & R.H. Drent 1981. Prey depletion and the regulation of predator density: Oystercatchers (*Haematopus ostralegus*) feeding on Mussels (*Mytilus edulis*). In: N.V. Jones & W.J. Wolff (eds) Feeding and survival strategies of estuarine organisms: 193-216. Plenum Press, New York.

Zwarts L., J.B. Hulscher, K. Koopman, T. Piersma & P.M. Zegers 1996a. Seasonal variation in body weight, nutrient stores and mortality of Oystercatchers *Haematopus ostralegus*. Ardea 84A: 327-356.

Zwarts L., J.B. Hulscher, K. Koopman & P.M. Zegers 1996b. Body weight in relation to variation in body size of Oystercatchers *Haematopus ostralegus*. Ardea 84A: 21-28.

Zwarts L., J.B. Hulscher, K. Koopman & P.M. Zegers 1996c. Short-term variation in the body weight of Oystercatchers *Haematopus ostralegus*: effect of exposure time by day and night, temperature and wind force. Ardea 84A: 357-372

Zwarts L., J.B. Hulscher & P.M. Zegers 1996d. The weight loss in Oystercatchers *Haematopus ostralegus* on the roost and after capure. Ardea 84A: 13-20.

SAMENVATTING

Mannetjes en vrouwtjes Scholekster zijn in het veld, en zelfs in de hand, nauwelijks van elkaar te onderscheiden. Toch zijn er in de uitwendige maten kleine verschillen die kunnen worden gebruikt om met een zekere waarschijnlijkheid de kans te berekenen dat een vogel tot een bepaalde sekse behoort. Mannetjes hebben een kortere en dikkere snavel (Fig. 1) en als ze op het wad voedselzoeken vaker een stompe punt (Fig. 4). Ze zijn minder zwaar (Fig. 7) en hebben een iets kortere vleugel (Fig. 6). Tabel 3 geeft 14 formules waarmee precies kan worden uitgerekend de kans dat een vogel een ♂ of een ♀ is, op basis van de gemeten snavellengte, snavelhoogte, vleugellengte en lichaamsgewicht (gecorrigeerd voor het seizoensverloop: Tabel 1). Het is daarbij van belang de vorm van de snavelpunt te onderscheiden. Afhankelijk van welke lichaamsmaten beschikbaar zijn, varieert het percentage juist gesekste vogels tussen 89 en 95%. De snavellengte en gewicht van elk individu variëren in de loop van de tijd. Toch blijken individuen die meer dan één maal werden gevangen in 92% van de gevallen tot dezelfde sekse te worden gerekend.