

SEXUAL DIMORPHISM IN THE CORMORANT *Phalacrocorax carbo sinensis*: POSSIBLE IMPLICATIONS FOR DIFFERENCES IN STRUCTURAL SIZE

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ABSTRACT A sample of Cormorants which accidentally had been drowned in fishermen's gear was used to study differences in morphological characters and diet between males and females. Males were significantly larger than females in all body dimensions, whereas size of juveniles and adults were the same. Discriminant analyses applied on length of body, wing and culmen, and bill depth, achieved highest classification rates by a function which makes use of body length, wing length and bill depth. Bill depth and wing length showed best segregation between both sexes in all functions. Main fish species taken were Ruffe, Perch and Smelt. No difference was found in the proportion of each fish species in the diet of males and females. For Ruffe, Perch, Eel and Smelt, only in the latter two species significant larger individuals were taken by males. Differences in structural size are discussed with respect to individual hunting performance of males and females.

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INTRODUCTION

Males and females in the Cormorant *Phalacrocorax carbo sinensis* are not simply separable by plumage characteristics. Within the breeding season they can, however, be distinguished by differences in behaviour (Kortlandt 1995, own obs.), especially during courtship. No attempts have been made so far, to analyse morphological characters of the species in more detail, despite its presumed ecological importance. As part of a long-term study on Cormorants in the area of Lake IJsselmeer, The Netherlands, a sample of Cormorants which were drowned by accident, was used to study the degree of sexual dimorphism by using several morphometric measurements.

In this paper morphological characters of Cormorants are described, and an attempt is made to provide a method for segregation of the sexes by the use of discriminant analysis. This multivariate statistical method makes use of body measurements of birds of known sex, to get optimal distinction between males and females, which can be

used to predict the sex of unknown birds. In several other species this technique has proven its use as a tool to analyse the differences in body dimensions between both sexes (e.g. Great Crested Grebe *Podiceps cristatus*, Piersma 1988a; King Cormorant *Phalacrocorax albiventer*, Malacalza & Hall 1988; Sanderlings *Calidris alba*, Maron & Myers 1984, Wood 1987; gulls Laridae, Shugart 1977, Ryder 1978, Fox *et al.* 1981, Hanners & Patton 1985; Great Skua *Catharacta skua*, Hamer & Furness 1991).

In addition an analysis of the diet composition of the individual birds was carried out, in order to assess possible sex-specific differences in choice and size of prey taken, in relation to structural size. In an earlier study, Voslamber (1988) already showed some differences between male and female Cormorants, associated with energetic needs of the birds. For grebes Podicipedidae, between species or within the geographical range of one species, some evidence has been given for distinction in the type and size of food-items taken associated with differences in body dimensions,

especially bill characters (Fjeldså 1981, 1982, 1983, Piersma 1988b).

METHODS

A sample of 116 Cormorants was available for analysis. All were collected at Lake IJsselmeer, The Netherlands, during 1980-1985. The main part (84 individuals) consisted of birds which had been drowned by accident in gill-nets and fykes, and put to our disposal by local fishermen. They were collected throughout the whole year, with main numbers in February-March and originated for the greater part from the eastern part of Lake IJsselmeer. They were stored in freezers at -20°C immediately after collection. Another 32 individuals were collected after having been washed ashore. Also these birds had been drowned in fishermen's gear, after which they had been put overboard. These were already examined in the field, because of their often poor condition.

The carcasses of the drowned birds were analysed after being thawed one day before examination. Age was determined by plumage characters (Cramp & Simmons 1977), distinguishing first winter (juveniles) and adults. A picture of the lateral view of the head was taken in part of the sample. Fresh body mass was only determined in birds with dry plumage, using an electronic balance (to the nearest g), later on corrected for mass of fresh fish in the oesophagus. Measurements taken were: body length (length of the stretched body, from tip of bill to tip of tail, in cm), wing length (maximum flattened chord, mm), sternum length, bill length (exposed culmen, 0.1 mm) and bill depth (measured perpendicular to and including the lower mandible, just behind the nostrils, 0.1 mm). Measuring was done using a stopped rule (body- and winglength) or callipers (bill depth, culmen and sternum length). Birds were sexed by gonadal inspection. Fresh fishes in the oesophagus were collected and examined with respect to total length and fresh mass (in mm, g respectively).

In birds examined in the field, only body length and wing length, bill depth and culmen we-

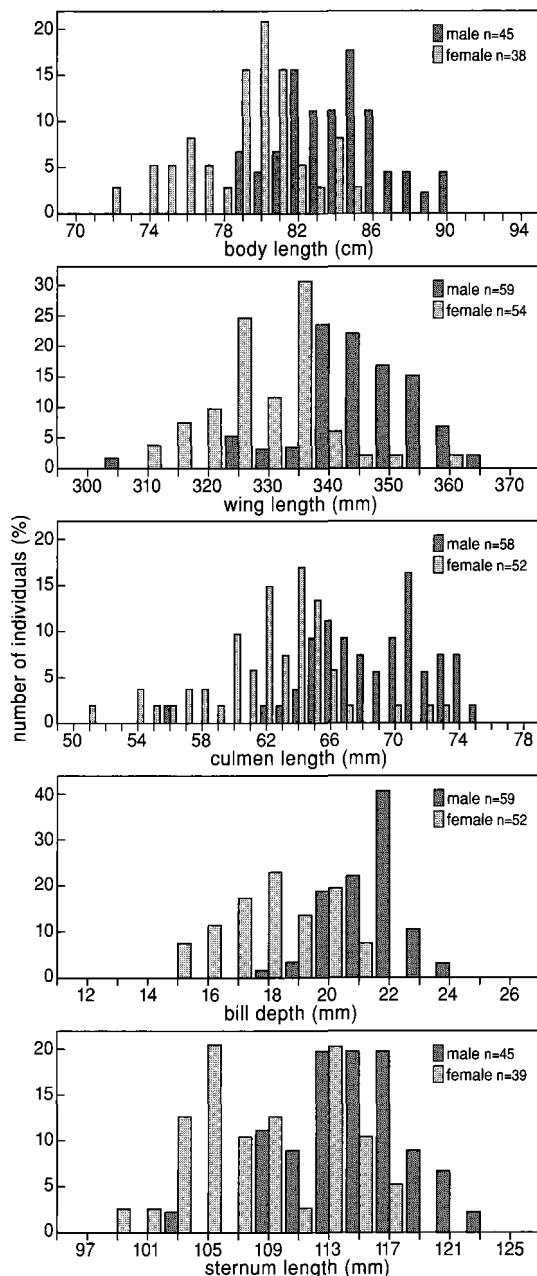


Fig. 1. Body dimensions of Cormorants from Lake IJsselmeer.

re measured, using the methods described above. Also sex was determined by internal inspection.

Table 1. Morphometrics of male and female Cormorants, AD Adults IMM immatures. Measurements given in cm (body length) or mm (all others). Differences between males and females are statistically significant for both age groups (Students *t*-test, $P < 0.0001$). For both males and females no significant differences between the age groups were found (Students *t*-test, $P > 0.05$).

	Males		Females	
	AD	IMM	AD	IMM
Body mass				
mean(\pm SD)	2605.6(\pm 417.7)	2700.6(\pm 326.3)	2145.4(\pm 398.0)	2330.0(\pm 597.0)
range	1479 - 3120	2150 - 2992	1290 - 2590	1580 - 3040
<i>N</i>	16	5	16	4
Body length				
mean(\pm SD)	84.7(\pm 2.7)	83.0(\pm 2.6)	79.0(\pm 3.0)	79.7(\pm 3.1)
range	79 - 90	79 - 88	72 - 84	74 - 85
<i>N</i>	26	19	24	14
Wing length				
mean(\pm SD)	348.2(\pm 8.5)	344.3(\pm 13.2)	328.2(\pm 10.7)	325.6(\pm 11.5)
range	327 - 364	305 - 367	306 - 364	312 - 344
<i>N</i>	38	21	34	20
Culmen length				
mean(\pm SD)	68.1(\pm 3.6)	70.6(\pm 3.1)	62.4(\pm 4.2)	63.7(\pm 3.7)
range	64.9 - 75.8	56.8 - 74.4	58.8 - 65.0	51.9 - 73.2
<i>N</i>	37	21	35	17
Bill depth				
mean(\pm SD)	21.8(\pm 1.0)	21.8(\pm 1.5)	18.4(\pm 1.8)	18.6(\pm 1.4)
range	20.2 - 24.8	18.3 - 24.2	15.2 - 21.3	16.6 - 21.3
<i>N</i>	38	21	35	17
Sternum length				
mean(\pm SD)	115.2(\pm 3.3)	114.8(\pm 4.9)	108.8(\pm 4.7)	109.9(\pm 5.4)
range	109 - 121	104 - 124	102 - 118	99 - 116
<i>N</i>	26	19	24	15

Data processing and statistical analyses were performed with the SPSS package (Norris 1990).

RESULTS

Morphometrics

Morphometric characters of the dissected Cormorants are shown in figure 1 and summarised in Table 1 for adults and immatures separately. Mean values for males are significantly larger

in all cases, both for adults as well as immatures (Student's *t*-test, $P < 0.0001$), although a considerable overlap in range occurs for all body dimensions. Sexual dimorphism is most pronounced in body mass and bill depth, being on average 15% larger in males, while body length, wing length, culmen and sternum length differ only 6% in size. Especially in wing length, most adults tend to be slightly larger than juveniles. On the other hand, culmen appears somewhat longer in immatures. Neither wing and culmen length, nor the other pa-

rameters prove to be significantly different in size, however (Student's *t*-test, $P > 0.05$). Since it is difficult to imagine that culmen will decline in size with age, the tendency found is possibly due to the amount of naked skin on the forehead, and therefore inherent to the method used to determine length of culmen.

Discriminant analysis applied on body length, wing length, sternum length, culmen and bill depth separately, shows that 71.4% to 87.4% of the entire sample (adults and immatures combined) can be sexed accurately. Body mass is omitted here for its variability through the year, despite its pronounced difference between both sexes. The single parameter which allows best segregation between males and females is bill depth, described by the function $D = 0.71 \cdot BD - 14.35$, where D is the discriminant score ($D < 0$ ♀♀, $D > 0$ ♂♂) and BD is bill depth. According to this function a correct classification rate of no

less 87.4% is obtained. With this function individuals with a bill depth larger than 20.3 mm can be classified as males. A slightly lower classification rate was calculated when using wing length, which revealed the discriminant function $D = 0.09 \cdot WL - 31.63$, in which WL is wing length. In this case individuals having a wing larger than 336.6 mm can be definitely assumed being males.

Since for each individual more than one variable is available, discriminant analysis was also performed with a combined set of morphometrics, using body length, wing length, culmen and bill depth. A stepwise approach was chosen (Wilks' method, see Norusis 1990 for details), in order to get the smallest subset of significant variables. Selecting all four variables, a discriminant function derived from the entire sample was able to sex 91.1% of all cases correctly (function 1, Table 2). The values for both sexes separately, however, show that the actual performance of the

Table 2. Variables used in analysis, discriminant functions and rates of correct classification. Pearson correlation coefficient (r), indicating the correlation of each variable to the discriminant function. Functions 1 and 2 refer to adults and immatures combined; function 3 and 4 to adults only.

function	variable	r	discriminant function	% correctly classified			N
				♂♂	♀♀	overall	
1	BL body length	0.61	$D = 0.07 \cdot BL + 0.02 \cdot WL + 0.06 \cdot CU + 0.562 \cdot BD - 28.25$	97.7	82.9	91.1	79
	WL wing length	0.65					
	CU culmen	0.59					
	BD bill depth	0.88					
2	WL wing length	0.70	$D = 0.03 \cdot WL + 0.08 \cdot CU + 0.47 \cdot BD - 24.91$	94.7	85.7	89.7	107
	CU culmen	0.61					
	BD bill depth	0.88					
3	BL body length	0.68	$D = 0.09 \cdot BL + 0.06 \cdot WL + 0.44 \cdot BD - 35.53$	100.0	92.0	96.1	51
	WL wing length	0.80					
	CU culmen	0.21					
	BD bill depth	0.77					
4	WL wing length	0.78	$D = 0.05 \cdot WL + 0.48 \cdot BD - 27.90$	94.6	85.7	90.3	72
	CU culmen	0.23					
	BD bill depth	0.88					

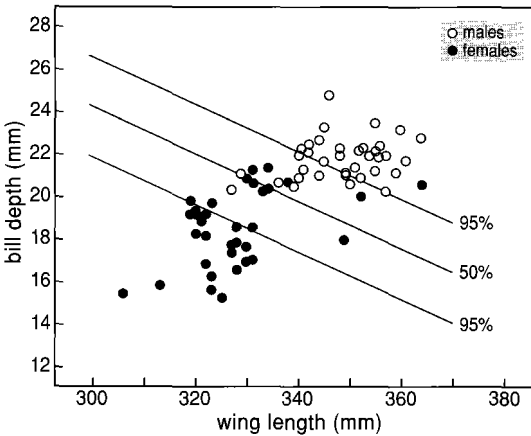


Fig. 2. Relation between wing length and bill depth, according to the function $0.05 \cdot WL = 27.90 - 0.48 \cdot BD$, where WL is wing length and BD is bill depth. 50 and 95% represent the lines at which the probability of correct sexing is 50% and 95% (discriminant score, $D = 0$ and -1.15 or $+1.15$ respectively).

analysis is much better in males than in females, rates of correctly classified individuals being 97.7% and 82.9% respectively. According to Pearson's r , which can be used as an indication for the discriminating power of each variable, bill depth proves to be the best separator, as already came out when using this parameter solely. The same calculations were also made when leaving out body length, because this was available in only part of our sample and moreover is a rather cumbersome measurement to take in live birds. In this case again all variables contributed to the discriminant function, having an overall accuracy which is slightly less compared to the first function (89.7%, function 2, Table 2). Bill depth remained first in the position of most powerful discriminators, followed by wing length and culmen. Also in this case the proportion of correctly sexed individuals was larger in males (94.7% versus 85.7% for females).

We also calculated the two functions mentioned above for adults only. Although body dimensions of adults and immatures did not show any significant differences (Table 1), there still remains the possibility that more scatter is intro-

duced when using both age groups together. The overall rates of correct classification were slightly improved compared to the combined sample, in both the 4-variate and the 3-variate case (96.1% and 90.3% of correct classification respectively, function 3 and 4, Table 2). Again best performance was shown in males. Culmen length made no significant contribution to the discriminant function in both analyses with this sample, and was not selected. When using four variables, wing length proved to have most power in discriminating between the sexes. In the 3-variate set, bill depth kept its first position in discriminating power.

From the output of the analyses, it was calculated that discriminant scores smaller than -1.15 and larger than $+1.15$ had at least a 95% probability of correct classification. As shown for function 4 in figure 2, there is a considerable part of the sample for which the discriminant scores are less reliable. Only 63% of this sample had at least a 95% probability of being sexed correctly. For the other three discriminant functions this figure ranges from 57% (function 1) to 61% (function 3).

Diet composition and prey size

Ruffe *Gymnocephalus cernuus*, Perch *Perca fluviatilis* and Smelt *Osmerus eperlanus* were the most common fish species found in the oesophagus, having a share of 20% in the total number of fish (Fig. 3). Also Eel *Anguilla anguilla* was

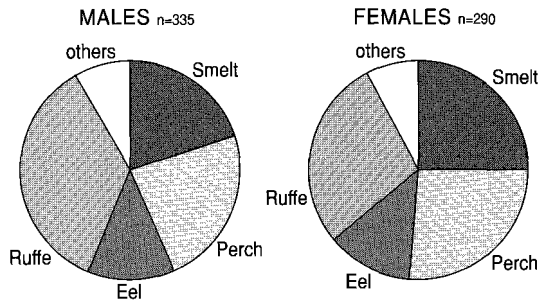


Fig. 3. Diet composition, based on fish numbers found in the oesophagus. Others represent Roach, Pike-perch, Bream, and Three-spined Stickleback.

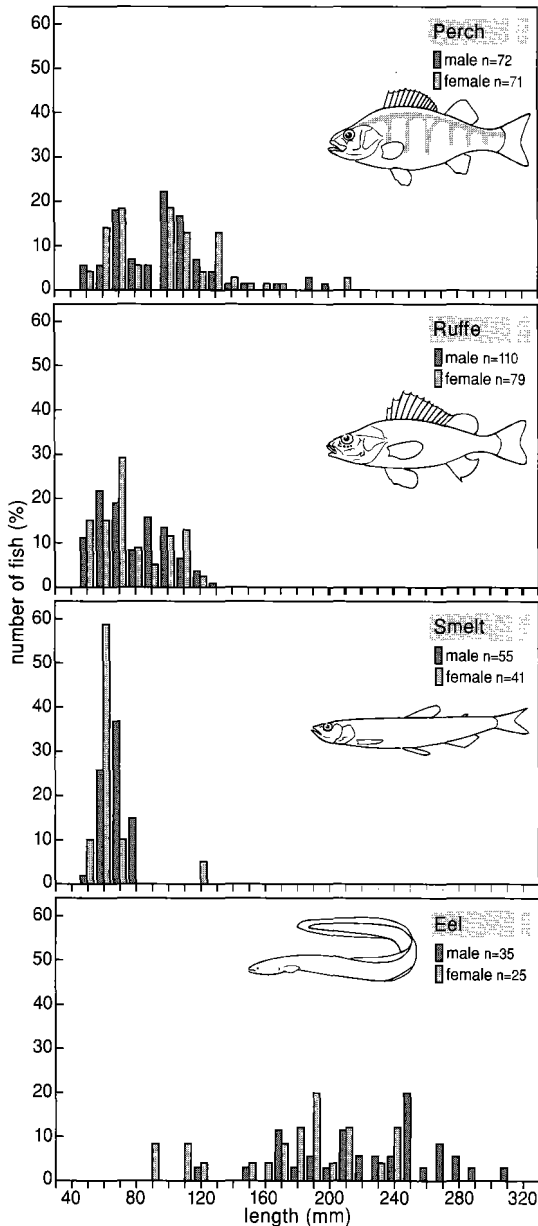


Fig. 4. Length-frequency distributions for Perch, Ruffe, Smelt and Eel, for male and female Cormorants shown separately.

present in considerable numbers (12.5 and 12.8% for males and females respectively). Less numerous fish species taken, were Roach *Rutilus rutilus*,

Pikeperch *Stizostedion lucioperca*, Bream *Abramis brama* and Three-spined stickleback *Gasterosteus aculeatus*. No differences occur in the fresh mass of each fish species found between males and females. ($\chi^2 = 9.87$, $df = 7$, $P > 0.05$).

For the most dominant fish species length-frequency distributions are presented in figure 4. Ruffe taken by male Cormorants was on average 79 mm (range 55 - 130 mm) and those taken by females 77 mm (range 62 - 121 mm), not significantly different (Mann-Whitney U -test, $U = 4085$, $P = 0.484$). The same holds for Perch, which was caught in an average size of 98 mm by males (range 57 - 205 mm) as well as females (range 59 - 217 mm).

The size classes of Smelt and especially Eel taken by males were significantly larger than those taken by females (Mann-Whitney U -test; Smelt, $U = 738$, $P = 0.039$; Eel, $U = 203$, $P = 0.0004$). Average size of Smelt taken by males and females was 72 mm (range 55 - 96 mm) and 67 mm (range 51 - 133 mm) respectively. The length-frequency distribution of Eel shows the most pronounced difference in prey size; average size being 226 mm for males (range 120 - 310 mm) and 178 mm for females (range 95 - 248 mm).

DISCUSSION

Use of discriminant analysis

Two major sources of bias have to be taken into account when using discriminant functions. As already pointed out by several other workers (e.g. Maron & Myers 1984, Piersma 1988a, Desrochers 1990), the probability of correct classification is not as high for each individual as the rates generated by the discriminant functions listed in table 2. This depends on the position of a bird along the discriminant axis, as shown in figure 2. In about 60% of our sample, the discriminant scores had at least a 95% probability of sexing males and females correctly.

Also, it is likely that the rates of correct classification are somewhat overestimated, since the

sample to generate the discriminant functions was the same as the one to test it (see also e.g. Fox *et al.* 1981, Maron & Myers 1984, Hanners & Patton 1985). Because our sample was not large enough to divide it into two parts, we used a sample of 167 adult Cormorants, shot in Germany in 1986-88, to check the validity of the discriminant functions revealed by our sample. Using discriminant functions for adult birds (function 3 and 4, Table 2), correct sexing was achieved in 88.4% and 84.4% of all cases, respectively, so somewhat below the rate of correctly classified birds in our own sample. Also in the sample from Germany, around 60% of the cases had a probability of at least 95% to be classified correctly (function 3: 58% , function 4: 63%).

Morphometrics

Males in the European Cormorant exceed females in all sizes, as already shown for other Cormorant species (e.g. King Cormorant, Malacalza & Hall 1988, Brothers 1985; Blue-eyed Cormorant *Phalacrocorax atriceps*, Bernstein & Maxson 1982, 1984). Most body dimensions are closely to those given for *Phalacrocorax carbo sinensis* by Cramp & Simmons (1977), taking into account some discrepancies in measuring methods. Discriminant analyses on four main morphometric characters, body length, wing length, culmen and bill depth, prove that wing length and bill depth are the most powerful parameters in separating the sexes. This holds true for single-use as well in combination with the others. Wing length seems to be a more representative indication for overall structural size than body length. Malacalza & Hall (1988) calculated discriminant functions for the King Cormorant, in which after body mass, bill depth had most discriminating power, followed by culmen. However, wing length showed no significant contribution to analyses in this species.

The 9% smaller rates on average, of correct classification in females, as revealed by the different discriminant functions presented in Table 2, suggest that there is more size variation in females than in males, i.e. in our sample large fe-

males outnumber small males (cf. Table 1). No significant difference in body dimensions appeared between immatures and adults. This is not surprising since half (47%) of all immatures in our sample consisted of individuals in their 2nd calendar-year, by which most Cormorants can be assumed as fullgrown.

Bill depth may be measured in different ways. It was determined at the base of the nostrils in our entire sample, but in some cases also in the middle of the bill (males: mean 15.2 mm \pm 0.6; females 12.8 mm \pm 0.7). Using this parameter in a single discriminant analysis for adults and immatures combined, males and females were correctly sexed in 100.0 and 94.1% of all cases ($n = 37$) respectively, according to the function $D = 1.45 \cdot BDC - 20.35$ in which D is the discriminant score and BDC is bill depth at centre of the bill. In both sexes even a correct classification rate of 100.0% was achieved (function $D = 1.76 \cdot BDC - 24.67$) when only considering data of adults ($n = 30$). In both functions birds having a bill depth > 14.0 mm half way, are thus assumed to be males.

As partly described by the analysis mentioned above, male and female Cormorants show a distinct difference in bill shape (Fig. 5). Males have a more 'massive', rather straight-edged bill, while the bill of females looks more slender and concave. Moreover the forehead of females often is more rounded compared to males. Van Eerden & Munsterman (1995) used the combination of body size, bill shape and the round appearance of the forehead in the field situation, to determine different use of roosts and sex ratio in several parts of the wintering range of *sinensis*. From 21 birds, marked with colour rings and of known sex (according to their behaviour in the breeding colonies in The Netherlands and Denmark), only 2 individuals (9.5%) were not sexed correctly in this way. These birds, a male and a female, were both immatures.

Diet composition and prey size

The diet composition, as shown by analysis of fresh fish in the oesophagus, coincides closely with recent large-scale studies on food of Cormo-

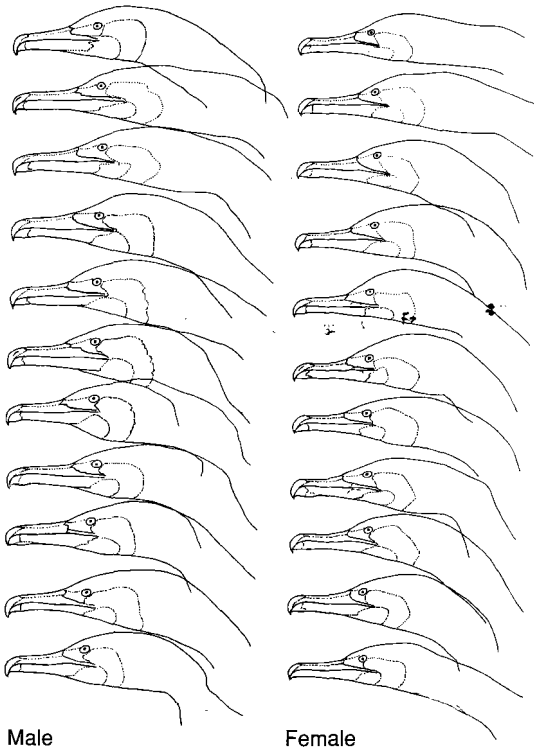


Fig. 5. Side-view of Cormorants' heads, for males and females separately; redrawn from slides taken of part of the sample used. Notice the saddle-shaped and more slender bill in females. The roundness of the forehead is not well visible in the sample of largely wetted carcasses.

rants in Lake IJsselmeer (Voslamber 1988, Platteeuw *et al.* 1992), with Perch, Ruffe and Smelt as main fish species taken. An important exception is the relatively large proportion of Eel found in our sample. This is probably a result of the way in which the birds were collected. Eel-fishing is performed nowadays by a small group of solitary hunting Cormorants, often along the shores where large numbers of fykes can be found.

Diet composition between males and females showed no significant differences with respect to the proportion of species taken. In Ruffe and Perch, fish of the same size were selected by both sexes. On the contrary, in Eel and Smelt males tended to have taken significant larger prey than

females; average fish length being 7% larger in Smelt and 21% in Eel.

To what extent can difference in prey-size selection be explained by differences in morphometrics? Fjeldså (1981, 1982, 1983) has shown links between diet composition and bill size between and within several species of grebes. These studies, as well as pointed out by Goodman & Fischer (1962), have shown that bill depth is an important factor in determining the snapping power of a bill. Taking into account the different bill characters between male and female Cormorants, males should have a better handling performance for more powerful fish than females. Eel is likely to be a fish for which this theory fits. Females, having on average a smaller and less powerful bill, will face more problems in handling a large Eel, which can easily result in losing the prey during handling and/or a higher chance of being robbed by another individual (Van Eerden own obs.).

For Smelt the situation is more complex. For this species differences in bill characters definitely cannot explain a variation in the size of prey taken, since Smelt is an easy prey to handle compared to Eel. Piersma (1988b) has pointed to the importance of diving performance in Red-necked Grebes *Podiceps grisegena* and Slavonian Grebes *Podiceps auritus*, in which the superior diver (in this case the Slavonian Grebe) was able to catch somewhat larger Smelt. Unfortunately no information is available for Cormorants about possible sex-specific differences in diving performance. Since the smaller Smelt occur higher up in the water column (Van Eerden own obs.), the differences found may reflect a tendency for females do dive less deeply than males do.

Our data suggest that actual differences between prey intake by male and female Cormorants virtually can be more explained from the actual hunting performance with respect to a specific fish species, rather than the size of fish alone. However, it should be stressed, that only four fish-species could be taken into account. These have all a rather elongated body shape. In several cyprinid fish species, especially Bream, but also

in the larger Perch and Pikeperch however, it seems possible that male Cormorants, with a larger gape-width, are able to take and swallow larger prey than females. It is not unlikely that any different, sex-specific foraging skills could also play a role in foraging success and/or prey choice in individual birds. This ecological segregation might also affect the behaviour of males and females within flocks of social fishing individuals as well as the distribution of both sexes in wintering areas.

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SAMENVATTING

In dit artikel wordt een analyse gemaakt van morfologische kenmerken van manlijke en vrouwelijke Aalscholvers. Als basis hiervoor diende een set biometrische gegevens afkomstig van Aalscholvers die op het IJsselmeer waren verdrongen in visnetten. Verder is de slokdarminhoud gebruikt om eventuele verschillen in dieet te kunnen vaststellen, die kunnen samenhangen met verschillen in morfologie.

Op grond van lichaamsmaten blijken manlijke vogels significant groter en zwaarder dan vrouwelijke (Fig. 1, Tabel 1), waarbij het grootste verschil is gevonden in gewicht en snavelhoogte. Verschillen tussen volwassen en onvolwassen vogels konden niet worden aangetoond. Met behulp van discriminant analyse zijn een aantal functies (lineaire combinaties) van de biometrische gegevens berekend die het beste onderscheid maken tussen beide sexen (Tabel 2). Deze bleken in

staat in 90-96% van alle gevallen het juiste geslacht te kunnen bepalen. Snavelhoogte en vleugellengte blijken het onderscheid tussen manlijk en vrouwelijk het beste aan te geven.

Het dieet bestond voornamelijk uit Pos, Baars, Spiering en Paling. Tussen beide sexen werden geen significante verschillen in voedselkeuze vastgesteld. Van Spiering en Paling werden door manlijke vogels significant grotere individuen gevangen. Bij Paling lijkt het aannemelijk dat manlijke vogels, die een sterkere snavel bezitten, beter in staat zijn grote Paling te hantieren en door te slikken dan vrouwelijke vogels. Deze zullen langere tijd nodig hebben een dergelijke prooi te verwerken, met een hoger risico op verlies. Bij predatie op Spiering lijkt eerder een verschil in duikdiepte een rol te spelen.

Gesuggereerd wordt, dat verschillen in dieet eerder samenhangen met sexe-specifieke verschillen in jachtgedrag dan grootte van de prooi alleen.