SUB-SPECIFIC DIFFERENTIATION AND DISTRIBUTION OF GREAT CORMORANTS *PHALACROCORAX CARBO* IN EUROPE

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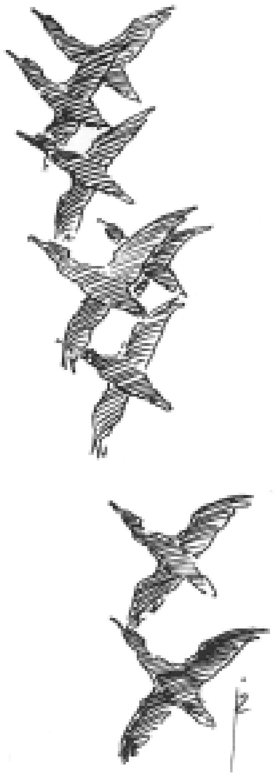

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The use of biometrics for sub-specific differentiation of Great Cormorants *Phalacrocorax carbo* in Europe was investigated using skins of known sub-species and showed that gular pouch angle is a useful character for assigning individuals to sub-species. Where further measurements of bill depth and bill length can be taken, sex-specific discriminant functions allow the majority of individuals to be correctly identified to sub-species. The identity of 261 Great Cormorants of unknown sub-species shot (under MAFF licence) on inland water bodies in England during the winters of 1997-98 and 1998–99 were investigated; 66% were *P.c. carbo* and 34% *P.c. sinensis*. This suggests that *P.c. carbo* is currently the predominant sub-species inland in England during the winter. The findings of this paper now allow for long-term and cost-effective monitoring of sub-species occurrence and population development in the UK, as well as in other European countries where the two sub-species may occur.

Key words: *Phalacrocorax carbo* - Great Cormorant - sub-species - biometrics - gular pouch

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INTRODUCTION

Following near extinction in the mid-20th century, the European population of the continental sub-species of Great Cormorant *Phalacrocorax carbo sinensis* increased dramatically, with the introduction of protective measures in various countries from 1965-1981 (e.g. van Eerden & Gregersen 1995). In the Netherlands, Germany, Denmark and Sweden the overall population increased by almost 13% annum^{-1} between 1971 and 1981 and at an annual rate of 18% in the 1980s, to reach 62 250 nests by 1991 (Bregnballe 1996). Numbers of breeding and wintering Great Cormorants *Phalacrocorax carbo* in England and Wales have also increased during the last thirty years (Kirby *et al*. 1995), but whilst coastal breeding birds increased by about 3% annum^{-1} overall, the inland breeding population is currently increasing at about 19% annum^{-1} (Wildfowl & Wetlands Trust unpubl. data).

In England, a substantial but unknown proportion of these inland breeders belong to the continental sub-species *P.c. sinensis*, based on anatomical characters and ringing recoveries (Sellers 1993; Ekins 1997) and recent molecular work using microsatellite markers and mitochondrial DNA sequencing has confirmed this (Goostrey *et al*. 1997; Winney *et al*. 2001). However, there is much controversy as to whether Great Cormorants can be reliably ascribed to sub-species based on morphological characters. Cramp & Simmons (1977) showed that *P.c. sinensis* is smaller than *P.c. carbo* in several biometric characters, although there is much overlap between sub-species and significant sex differences within each sub-species (Cramp & Simmons 1977; Koffijberg & van Eerden 1995).

Alström (1985) proposed a 'new' character for sub-species identification, namely shape of the gular pouch, an area of bare flesh on the face. It was suggested that the angle of the gular pouch behind the beak was 90° or more in *sinensis* and less than 65° in *carbo*. This was not rigorously tested and as a result was dismissed by some workers as invalid (Marion 1995), although others still regarded the gular pouch angle as a reliable indicator of sub-species identification (Sellers 1991; Ekins 1997). In this paper we examine the reliability of gular pouch angle and other biometrics for sub-specific identification of Great Cormorants in Europe. We examine variability in biometrics within sub-species and use discriminant functions to ascribe Great Cormorants shot in England under licence during the winters of 1997 to 1999 to *sinensis* or *carbo*.

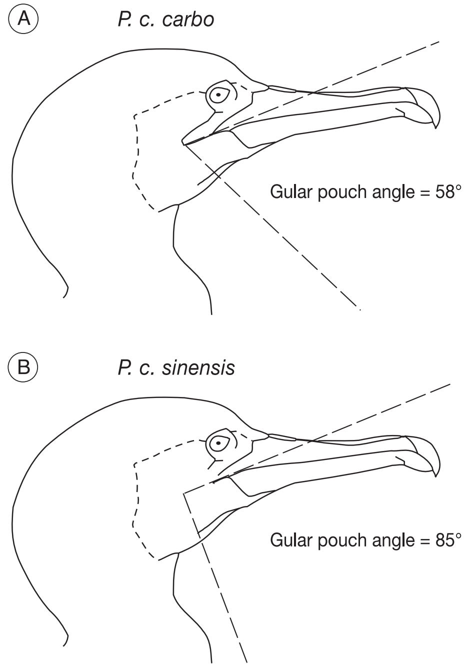

Fig. 1. Gular pouch angle in Great Cormorants *Phalacrocorax carbo carbo* and *P.c. sinensis*.

METHODS

Measurements of gular pouch angle, bill length (tip to feathers) and bill depth (minimum) were taken from 404 Great Cormorant skins from the British Museum (Natural History, Tring), the Zoological Museum of the University of Copenhagen in Denmark and the National Museum of Natural History, Leiden, in The Netherlands. This sample represented most countries within the European breeding range of the birds including Britain (England, Wales and Scotland), The Netherlands, Denmark, Norway, Sweden, Iceland and Faeroe Islands. Birds from Norway, Sweden, Iceland and Faeroe Islands, were taken from areas within the range currently exclusively occupied by *carbo* and based on this were assumed to belong to this sub-species. Outside Europe, measurements of *carbo* were also taken and included. The British museum skins were collected in the UK prior to 1980, before tree-nesting colonies became widely established and skins from Denmark and The Netherlands were taken from tree-nesting areas. These were assumed to belong to the sub-species *carbo* and *sinensis*, respectively, based on their geographical origin. Although there are relatively few *sinensis* skins in European museums from outside its European range, additional measurements were taken opportunistically.

Each sample had previously been sexed by internal examination (by museum staff). Skins showing signs of gular pouch damage or distortions, and therefore not assuming a normal attitude, were excluded from examination. Bill length was measured from the tip of the bill to the feathers at the centre of the bill and bill depth, at the narrowest point in the middle of the bill. On live or freshly dead specimens, it is important to note that the gular pouch can be distorted to change its angle by pulling it outwards and inwards. With all measurements, care was taken to ensure that the pouch assumed its normal attitude by gently stroking it downwards before measurements were taken.

Measurements of the gular angle from skins and carcases were taken to the nearest 1° using a protractor, as detailed in Figure 1. It is important to note that the baseline from which the angle is measured is not the bill line, but the line from the gape outwards. This line was chosen in preference to the bill line because it was found to result in better reproducibility between measurements. Only one facial side was used because preliminary analysis showed no significant difference in gular pouch angle between sides (Paired t-test, t = 1.01, df = 24, P = 0.32).

Statistical analysis

As data were normally distributed with homogeneous variances, gular pouch angle was compared between sub-species using t-tests. Statistical tests here were performed in the Minitab package (Minitab 1991). Backward stepwise discriminant analysis was used to combine biometrics taken from museum skins of known sex individuals to produce a multivariate function for each sex that maximised the statistical separation of the sub-species (Sokal & Rohlf 1995). The criteria for eliminating a variable from the function is if the significance of its F-test is >0.15. Data were checked in SAS (SAS Institute 1996) for the assumptions of multivariate normality and of equal covariance matrices (Khattree & Naik 2000). These discriminant functions were then used to determine the sub-specific identity of 261 Great Cormorants of unknown sub-species shot under Ministry of Agriculture, Fisheries and Food (MAFF) licences in England in the winters of 1997-98 and 1998-99. Biometrics for each bird were taken as above and birds were sexed by internal examination.

RESULTS

Museum skins

The gular pouch angle differed significantly between cormorants of the two sub-species (t = 40.55, P < 0.0001), *P.c. carbo* having a smaller gular pouch angle than *P.c. sinensis* (Table 1). Based on this character alone cormorants with gular pouch angles of ≤ 65º can be said with a high degree of certainty, to belong to the sub-species *P.c. carbo*, and those of ≥ 73º or more to *P.c. sinensis* (Table 1). Cormorants with gular pouch angles of 66-72º cannot be reliably differentiated using gular angle alone. Comparing the biometrics of *P.c. carbo* between countries, it is clear that there is a cline of decreasing gular pouch angle with latitude (Table 2). In *P.c. sinensis*, although based on a smaller sample of birds, there is evidence of increasing gular pouch angle eastwards across its range (Figure 2 Appendix).

Table 1. Descriptive statistics of gular pouch angle measurements (in degrees) of Great Cormorant sub-species *P.c. carbo* and *P.c. sinensis* from within Europe.

Sub-species	*n*	Mean ± SE	(Range)
P.c. carbo	258	59.7 ± 1.11°	(38°-72°)
P.c. sinensis	146	86.2 ± 0.65°	(66°-111°)

Discriminant analysis

Sex-specific discriminant functions of bill depth, bill length and gular pouch angle of museum skins correctly classified over 98% of both male and female cormorants into sub-species. Each variable contributed signficiantly to the discrimination, so no variables were eliminanted from the functions.

Males are classified as belonging to the sub-species *carbo* if 0.92133 (BD in mm) + 0.36504 (BL in mm) - 0.50198 (GPA in degrees) ≥ 4.66583. As an illustration, a male cormorant with measurements (BD 12.2 mm, BL 68.4 mm, GPA 82 degrees), gives a value of 0.92133 (12.2) + 0.36504(68.4) - 0.50198(82) = -4.9534, which is less than 4.66583. Hence this bird is classified as belonging to the sub-species *sinensis*. Females are classified as belonging to the sub-species *carbo* if 0.87159(BD) + 0.56828(BL) + -0.61081(GPA) ≥ 4.87236. Using these functions, classification of 261 birds of unknown sub-species shot under MAFF licences on inland waters in England during the winters of 1997-98 and 1998-99 was made. The biometrics of classified individuals are shown in Table 3. This suggests that 66% of individuals shot belonged to the sub-species *P.c. carbo* and 34% *P.c. sinensis*.

Table 2. Biometrics of Great Cormorant *P.c. carbo* and *P.c. sinensis* sub-species taken from museum skins.

			Bill depth, mm		Bill length, mm		Gular pouch angle, degrees	
		n	mean ± SE	(range)	mean ± SE	(range)	mean ± SE	(range)
Female								
England & Wales	*carbo*	24	13.2 ± 0.2	(11.5-16.0)	69.0 ± 1.0	(62.1-79.0)	61.3 ± 1.5	(47-72)
Scotland	*carbo*	21	13.4 ± 0.2	(12.3-15.1)	72.4 ± 0.7	(68.3-81.3)	59.0 ± 1.6	(42-72)
Norway & Sweden	*carbo*	58	12.9 ± 0.1	(11.0-14.9)	68.1 ± 0.3	(62.8-77.0)	53.1 ± 0.8	(41-70)
Iceland	*carbo*	26	13.8 ± 0.2	(12.5-15.7)	68.6 ± 0.7	(61.3-74.2)	52.1 ± 1.5	(39-66)
Faeroe Is.	*carbo*	7	13.9 ± 0.4	(12.8-15.9)	72.7 ± 1.0	(68.7-76.8)	51.0 ± 2.0	(45-60)
Greenland	*carbo*	18	13.1 ± 0.3	(11.5-15.7)	66.7 ± 0.8	(60.9-74.3)	49.3 ± 1.5	(40-64)
Denmark	*sinensis*	17	11.7 ± 0.2	(10.0-13.6)	62.6 ± 1.1	(56.9-70.9)	85.7 ± 1.7	(73-96)
The Netherlands	*sinensis*	43	11.4 ± 0.1	(9.3-13.4)	61.5 ± 0.5	(56.5-69.2)	87.0 ± 1.0	(73-101)
Male								
England & Wales	*carbo*	19	14.5 ± 0.2	(12.7-16.8)	74.9 ± 0.9	(66.6-80.3)	57.6 ± 1.6	(47-69)
Scotland	*carbo*	12	15.2 ± 0.3	(13.1-16.9)	78.2 ± 1.1	(72.1-84.0)	55.2 ± 2.1	(44-70)
Norway & Sweden	*carbo*	37	14.8 ± 0.2	(12.0-16.7)	76.5 ± 0.6	(65.5-82.5)	49.3 ± 1.2	(39-69)
Iceland	*carbo*	20	15.4 ± 0.3	(12.8-17.3)	73.5 ± 0.8	(66.1-77.9)	50.9 ± 1.5	(40-65)
Faeroe Is.	*carbo*	8	16.9 ± 0.1	(16.4-17.4)	82.7 ± 0.6	(81.0-86.0)	50.0 ± 2.6	(40-60)
Greenland	*carbo*	8	14.8 ± 0.2	(14.0-15.8)	73.9 ± 0.4	(72.5-75.6)	44.8 ± 1.8	(38-51)
Denmark	*sinensis*	24	13.1 ± 0.2	(11.2-15.6)	68.1 ± 0.8	(59.7-77.0)	85.6 ± 1.6	(74-101)
The Netherlands	*sinensis*	62	12.8 ± 0.1	(10.7-14.6)	67.7 ± 0.5	(57.2-75.0)	86.0 ± 1.2	(66-111)

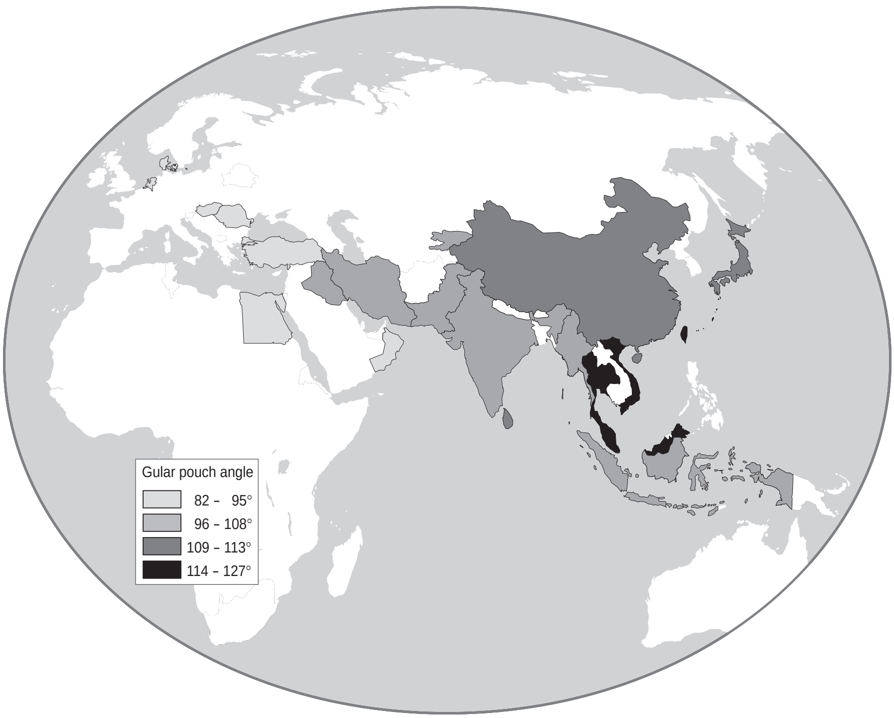

Fig. 2. Geographical variation in mean gular pouch angle in *P.c. sinensis*. Countries for which there is no data or the species is absent are shown in white.

Table 3. Biometrics of 261 Great Cormorants shot under MAFF licences on inland waters in England during the winters of 1997-98 and 1998-99 and classified to sub-species according to discriminant functions generated from individuals of known sub-species at the British Museum (Natural History, Tring), the Zoological Museum of Natural History, Copenhagen and the Natural History Museum, Leiden. Males are classified as belonging to the sub-species *carbo* if 0.92133(BD) + 0.36504(BL) + -0.50198(GPA) ≥ 4.66583. Females are classified as belonging to the sub-species *carbo* if 0.87159(BD) + 0.56828(BL) + -0.61081(GPA) ≥ 4.87236.

		Bill depth, mm		Bill length, mm		Gular pouch angle, degrees	
	n	mean ± SE	(range)	mean ± SE	(range)	mean ± SE	(range)
Female							
P.c. carbo	71	13.4 ± 0.1	(11.9-15.0)	61.8 ± 0.4	(55.1-69.4)	53.9 ± 0.9°	(37°-69°)
P.c. sinensis	34	12.4 ± 0.2	(10.6-14.1)	57.6 ± 0.5	(52.4.3-64.5)	75.7 ± 1.5°	(64°-92°)
Male							
P.c. carbo	102	15.3 ± 0.1	(13.3-17.4)	68.1 ± 0.3	(58.7-74.1)	52.6 ± 0.8°	(36°-72°)
P.c. sinensis	54	13.9 ± 0.1	(12.1-16.1)	63.2 ± 0.4	(55.8-69.1)	74.4 ± 1.2°	(60°-100°)

Appendix. Gular pouch angle measurements (in degrees) of *P.c. sinensis* by country taken from museum skins. Measurements (mean ± SE where applicable).

Country	*n*	Mean
Turkey	1	82°
Denmark	41	85.7 ± 1.14°
Egypt	2	86.0 ± 4.00°
Hungary	1	86°
Netherlands	105	86.4 ± 0.79°
Oman	2	89.5 ± 14.5°
Romania	2	92.0 ± 7.00°
Iran	1	96°
Iraq	6	102.7 ± 5.54°
Myanmar	9	104.4 ± 4.21°
Kyrgyzstan	2	105.0 ± 6.00°
India	17	106.4 ± 4.21°
Pakistan	3	107.7 ± 9.84°
Indonesia	4	108.0 ± 1.22°
Japan	4	109.8 ± 6.36°
China	9	110.8 ± 3.66°
Sri Lanka	1	113°
Taiwan	1	116°
Thailand	7	116.29 ± 3.93°
Malaysia	4	118.3 ± 7.80°
Viet Nam	2	126.5 ± 2.50°

DISCUSSION

This study confirms that gular pouch angle is a useful character for discriminating Great Cormorant sub-species. Where measurements of bill depth and length are taken from individuals of known sex, an even higher level of discrimination can be obtained. Interestingly, the angle of the gular pouch decreases with latitude in the sub-species *P.c. carbo*, whilst it increases in *P.c. sinensis* eastwards across its range. If the gular pouch functions to dissipate heat (Cramp & Simmons 1977), it could be speculated that the gular pouch angle (and surface area of gular pouch tissue) increases in hotter countries where heat loss is important, but decreases in colder countries where it is more important to retain heat.

Discriminant analysis of biometrics taken from Great Cormorants shot under MAFF licence on inland waters in England during the winters of 1997-98 and 1998-99, suggests that over 70% of the wintering population belong to the sub-species *P.c. carbo*, whilst about 20% is of the sub-species *P.c. sinensis*. This is similar to the estimated 74% *P.c. carbo* from mitochondrial DNA sequencing for twenty Great Cormorants shot under MAFF licence on inland waters in Warwickshire during the winters of 1995-1996 and 1996-1997 (Winney *et al*. 2001). Past studies have estimated the British inland wintering Great Cormorant population to contain 5-10% *P.c. sinensis* (Kirby *et al*. 1995) and analysis of ringing recoveries for 1980-1994 suggested that less than 2% are *P.c. sinensis* (Wernham *et al*. 1997). However, the occurrence of *P.c. sinensis* in this study is likely to be higher because the sample was taken from England, where inland, predominantly *P.c. sinensis* breeding population growth is occurring. With additional growth of continental populations, the number of continental breeders wintering in the UK may have also increased.

In this study we assume that cormorants belong clearly to one or other of the two sub-species. However, hybridisation between the two sub-species of Great Cormorant has been demonstrated at inland colonies in England through recent molecular studies (Goostrey *et al*. 1997; Winney *et al*. 2001), although the level of hybridisation occurring and the influence of this on Great Cormorant biometrics is unknown. For this reason, the discriminant functions here may not be reliable if tested on samples that contain hybrids, although further research combining genetics and biometrics would be required to examine this further.

Due to significant differences in the population status and biology of the two sub-species of Great Cormorant now found in the UK and their changing and complex population dynamics, the findings of this paper present important management and conservation implications. Whilst the inland breeding, predominantly *P.c. sinensis* population is increasing rapidly, the coastal *P.c. carbo* population is relatively vulnerable to years of poor breeding or survival (Newson 2000), and in parts of its range, such as north-east Scotland, long-term population decline is occurring (Budworth unpubl. data). With significant differences in several aspects of the biology of the two sub-species, including survival, dispersal, reproductive output, timing of breeding and habitat use (Marion 1995; Bregnballe *et al*. 1997; Hughes *et al*. 1999; Wernham & Peach 1999; Frederiksen & Bregnballe 2000a & 2000b; Newson 2000) and also food consumption due to a difference in body mass (Marquiss *et al*. 1998; Russell unpubl. data), a method for ready differentiation of these two groups was required. The findings of this paper now allow for long-term and cost-effective monitoring of sub-species occurrence and population development in the UK, as well as in other European countries where the two sub-species may occur. This will be important for improving our current understanding of the dynamics and possible introgression of the two sub-species, and for assessing differences in diet, energy consumption, habitat use and distribution. It will also be useful in determining the effect that any management action may have on the two sub-species.

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REFERENCES

Alström P. 1985. Artsbestämning av storskarv *Phalacrocorax carbo* och toppskarv *P. aristotelis*. Vår Fågelvärld 44: 325–350.

Bregnballe T. 1996. Udviklingen i bestanden af Mellemskarv i Nord- og Mellemeuropa 1960-1995. Dansk Orn. Foren. Tidsskr. 90:15-20.

Bregnballe T., M. Frederiksen & J. Gregersen 1997. Seasonal distribution and timing of migration of Cormorants *Phalacrocorax carbo sinensis* breeding in Denmark. Bird Study 44: 257-276.

Cramp S. & K.E.L. Simmons 1977. Handbook of the birds of Europe, the Middle East and North Africa, 1. Oxford Univ. Press, Oxford.

van Eerden M.R. & J. Gregersen 1995. Long-term changes in the northwest European population of Great Cormorants *Phalacrocorax carbo sinensis*. Ardea 83: 61-79.

Ekins G.R. 1997. Origins of ringed Cormorants *Phalacrocorax carbo* at Abberton Reservoir, Essex, England, October 1992-July 1993. Ekol. Polska 45: 139-151.

Frederiksen M. & T. Bregnballe 2000a. Evidence for density-dependent survival in adult Cormorants from a combined analysis of recoveries and resightings. J. Anim. Ecol. 69: 737-752.

Frederiksen M. & T. Bregnballe 2000b. Diagnosing a decline in return rate of one-year-old Cormorants: mortality, emigration or delayed return? J. Anim. Ecol. 69: 753-761.

Goostrey A., D.N. Carss, L.R. Noble & S.B. Piertney 1997. Population introgression and differentiation in the Great Cormorant *Phalacrocorax carbo* in Europe. Molecul. Ecol. 7: 329-338.

Hughes B., J. Bruce, G.R. Ekins & S.E. Newson 1999. Movements and distribution of inland breeding Cormorants in England. WWT Wetlands Advisory service report to English Nature.

Khattree R. & D.N. Naik 2000. Multivariate data reduction and discrimination with SAS software. SAS Institute.

Kirby J.S., A.S. Gilburn & R.M. Sellers 1995. Status, distribution and habitat use by Cormorants *Phalacrocorax carbo* wintering in Britain. Ardea 83: 93-102.

Koffijberg K. & M.R. van Eerden 1995. Sexual dimorphism in the Cormorant *Phalacrocorax carbo sinensis*: Possible implications for differences in structural size. Ardea 83: 37-46.

Marion L. 1995. Where two subspecies meet: origin, habitat choice and niche segregation of Cormorants *Phalacrocorax c. carbo* and *P.c. sinensis* in the common wintering area (France), in relation to breeding isolation in Europe. Ardea 83: 103-114.

Marquiss M., D.N. Carss, J.D. Armstrong & R. Gardiner 1998. Fish-eating Birds and Salmonids in Scotland: report on fish eating birds research (1990-97). The Scottish Office Agriculture, Environment and Fisheries Department. ITE, Banchory, and Freshwater Fisheries Laboratory, Pitlochry. SOAEFD, Edinburgh.

Minitab 1991. Minitab Reference Manual. Release 8. Rosemont: Minitab.

Newson S.E. 2000. Colonisation and range expansion of Great Cormorants *Phalacrocorax carbo* in England and Wales. Ph.D.-thesis, Univ. Bristol, Bristol.

SAS Institute. 1996. SAS/STAT software: changes and enhancements through release 6.11. SAS Institute, Cary, North Carolina, USA.

Sellers R.M. 1991. Breeding and wintering status of Cormorants in the British Isles. In: van Eerden M.R. & M. Zijlstra (eds) Proceedings of Workshop 1989 on Cormorants *Phalacrocorax carbo*: 30-35. Rijkswaterstaat Directorate Flevoland, Lelystad.

Sellers R.M. 1993. Racial identity of Cormorants *Phalacrocorax carbo* breeding at the Abberton reservoir colony, Essex. Seabird 15: 45-52.

Sokal R.R. & F.J. Rohlf 1995. Biometry, 3rd ed. W.H. Freeman, New York.

Wernham C.V., M. Armitage, B. Hughes, R. Hughes, S.J. Holloway, M. Kershaw, J.R. Madden, J.H. Marchant, W.J. Peach & M.M. Rehfisch 1997. Population, distribution, movements and survival of fish-eating birds in Britain. Report to the Department of the Environment and the Environment Agency.

Wernham C.V. & W.J. Peach 1999. Use of ring recoveries to monitor long-term changes in the survival rates of British and Irish Cormorants *Phalacrocorax carbo*. Bird Study 46: S189-197.

Winney B J, C.D. Litton, D.T. Parkin & C.J. Feare 2001. The subspecific origin of the inland breeding colonies of the Cormorant *Phalacrocorax carbo* in Britain. Heredity 86: 45-53.

SAMENVATTING

In dit artikel wordt verslag gedaan van een onderzoek naar het gebruik van biometrische gegevens en andere uiterlijke kenmerken om de verschillende ondersoorten van de Aalscholver *Phalacrocorax carbo* in Europa te onderscheiden. Aan de hand van huiden (balgen) van vogels waarvan de ondersoort vaststond, werd vastgesteld dat de vorm van de onbevederde keelzak, of liever gezegd de hoek die gevormd wordt tussen de onbevederde keelzak en de mondhoek (Fig. 1), een goed kenmerk is om de ondersoorten *sinensis* en *carbo* uit elkaar te houden. Als er daarnaast de mogelijkheid bestaat om maten te nemen, dan kunnen snavelhoogte (gemeten op het dunste punt, in het midden) en snavellengte (tip tot veerrand) gebruikt worden om met behulp van een geslachtsspecifieke discriminantanalyse tot een juiste diagnose te komen. Met behulp van de hiervoor genoemde gegevens werd vervolgens de subspecifieke identiteit bepaald van 261 Aalscholvers die in de winter van 1997/98 en van 1998/99 in Engelse binnenwateren waren geschoten. Daaruit bleek dat 66% van de vogels behoorde tot de ondersoort *P. c. carbo* en 34% tot de continentale vorm *P. c. sinensis*. Dit resultaat suggereert dat de nominaatvorm in de winter op de Engelse binnenwateren momenteel de meest voorkomende soort is. De hier beschreven methode om ondersoorten vast te kunnen stellen, kan worden gebruikt om tegen geringe kosten een monitoringprogramma voor de lange termijn op te zetten. Op deze wijze kan inzicht worden verworven in de subspecifieke verschillen in voorkomen en populatieontwikkeling in Groot-Brittannië en in andere Europese landen waar beide ondersoorten kunnen voorkomen. (CJC)

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