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Biometrics of the mute swan *Cygnus olor* based on a sample of 45 individuals

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In the winter of 1987, 45 mute swans were found dead on the banks of the Grevelingenmeer (Lake Grevelingen) in The Netherlands. A total of 12 measurements on the specimens 'in the flesh' were taken in the field and later, after maceration, another eight measurements on the cleaned skulls were taken. The sex of all specimens was established anatomically. This article presents the results of the biometrical analysis of these measurements. The best method for establishing the sex of mute swans based on external measurements appeared to be the length of the middle toe. Several other measurements were examined and their usefulness for sexing is discussed. Mute swan specimens from the collection of the Natural History Museum Rotterdam were used to test the significance of the findings.

Biometrie van de knobbelzwaan Cygnus olor *gebaseerd op 45 individuen* - Van 45 dode knobbelzwanen, gevonden op de oevers van het Grevelingenmeer in de winter van 1987, werden zowel uitwendige lichaamsmaten als schedelmaten genomen. Bovendien werd van alle zwanen het geslacht anatomisch vastgesteld. Hierdoor konden verbanden tussen geslacht en maatgegevens worden gelegd. De belangrijkste conclusie is dat, op grond van biometrische gegevens, de meest zekere geslachtbepaling aan de hand van de lengte van de middenteen kan geschieden. Deze uitkomst werd getest aan de hand van de geslachten en maten van knobbelzwanen uit de collectie van het Natuurmuseum Rotterdam.

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Keywords: Anatidae, Anserinae, Anserini, *Cygnus olor*, mute swan, biometrics, The Netherlands.

INTRODUCTION

Most biometrical data of the mute swan *Cygnus olor* (GMELIN, 1789) known from literature are based on small numbers of specimens. Bauer & Glutz von Blotzheim (1968) used samples of less than 10 per sex and Cramp & Simmons (1977) based their account on 6-12 adults and 4-7 juveniles. Therefore, the opportunity to measure and sex a total of 45 freshly dead specimens from a single locality, is a welcome addition to the knowledge of mute swan biometrics. This article lists these biometrical data and presents new information on sex-determination based on external and internal morphometric measurements.

MATERIAL AND METHODS

The first two weeks of February 1987 were characterised by extremely low temperatures (-15˚C / 5˚F at night and - 10˚C / 14˚F during day-time) and a strong NE-wind. Due to these unfavourable weather conditions, which caused inaccessibility of food, a mass mortality of wintering mute swans took place in Lake Grevelingen (51˚.48'N 03˚.59'E), province of Zuid-Holland, The Netherlands. Between February 8th and March 14th a total of 45 dead mute swans were found on a stretch of three kilometres along the northern bank of the lake. The swans were collected and examined on location. Of each specimen a large number of external measurements was taken, the sex was established anatomically and the skull and one of the feet were collected for further study. All skulls were preserved and temporarily housed in the collect i o n s of the authors (JNJP = J.N.J. Post, Schiedam; WB= W. Beekhuizen, Leiden; EJOK = E.J.O. Kompanje, Barendrecht). Now, all material is permanently stored in the collection of W. Beekhuizen. Table 1 presents the sex-ratio and age-composition/ plumage of the sample. For comparison, the data of mute swan specimens of known sex in the collection of the Natuurmuseum Rotterdam (Natural History Museum Rotterdam, NMR) were used:

Table 1 Sex, age and plumage of 45 mute swans *Cygnus olor* used in this study. Age/plumage was determined using Cramp & Simmons (1977).

age/plumage	♂	♀
first winter (1st w)	5	4
adult (≥ 2nd winter)	27	9
total	32	13

Original material

All skulls with upper (maxilla) and lower mandible. The following data are listed successively: collection date, collection and number, former collection and number (preceded by 'ex'), a g e / plumage (1st w = first winter), sex.

- 09.ii.1987 (WB 09.20, ex JNJP 430) adult ♂.
- 09.ii.1987 (WB 09.21, ex JNJP 494) adult ♀.
- 17.ii.1987 (WB 09.22, ex JNJP 495) adult ♀.
- 17.ii.1987 (WB 09.23, ex JNJP 496) 1st w ♀.
- 09.ii.1987 (WB 09.24, ex JNJP 497) 1st w ♀.
- 09.ii.1987 (WB 09.25, ex JNJP 498) adult ♀.
- 09.ii.1987 (WB 09.26, ex JNJP 499) adult ♀.
- 09.ii.1987 (WB 09.27, ex JNJP 501) adult ♀.
- 08.ii.1987 (WB 09.28, ex JNJP 503) adult ♂.
- 09.ii.1987 (WB 09.29, ex JNJP 504) adult ♂.
- 17.ii.1987 (WB 09.30, ex JNJP 505) adult ♂.
- 08.ii.1987 (WB 09.31, ex JNJP 506) adult ♂.
- 08.ii.1987 (WB 09.32, ex JNJP 507) adult ♂.
- 09.ii.1987 (WB 09.33, ex JNJP 508) 1st w ♂.
- 14.iii.1987 (WB 09.34, ex JNJP 509) adult ♂.
- 17.ii.1987 (WB 09.35, ex JNJP 510) adult ♂.
- 09.ii.1987 (WB 09.36, ex JNJP 511) adult ♂.
- 08.ii.1987 (WB 09.37, ex JNJP 512) adult ♂.
- 08.ii.1987 (WB 09.38, ex JNJP 513) adult ♂.
- 08.ii.1987 (WB 09.39, ex JNJP 514) 1st w ♂.
- 08.ii.1987 (WB 09.40, ex JNJP 515) adult ♂.
- 09.ii.1987 (WB 09.41, ex JNJP 516) adult ♂.
- 09.ii.1987 (WB 09.42, ex JNJP 517) adult ♂.
- 09.ii.1987 (WB 09.43, ex JNJP 518) adult ♂.
- 08.ii.1987 (WB 09.44, ex EJOK 87.79) adult ♂.
- 14.iii.1987 (WB 09.45, ex EJOK 87.80) adult ♂.
- 17.ii.1987 (WB 09.46, ex EJOK 87.81) adult ♂.
- 09.ii.1987 (WB 09.47, ex EJOK 87.82) adult ♂.
- 09.ii.1987 (WB 09.48, ex EJOK 87.83) 1st w ♂.
- 09.ii.1987 (WB 09.49, ex EJOK 87.85) adult ♂.
- 08.ii.1987 (WB 09.50, ex EJOK 87.86) adult ♂.
- 17.ii.1987 (WB 09.51, ex EJOK 87.87) 1st w ♂.
- 09.ii.1987 (WB 09.52, ex EJOK 87.88) 1st w ♂.
- 17.ii.1987 (WB 09.53, ex EJOK 87.89) adult ♂.
- 09.ii.1987 (WB 09.54, ex EJOK 87.90) adult ♂.
- 09.ii.1987 (WB 09.55, ex EJOK 87.91) adult ♀.
- 17.ii.1987 (WB 09.56, ex EJOK 87.92) 1st w ♀.
- 09.ii.1987 (WB 09.57, ex EJOK 87.93) adult ♀.
- 17.ii.1987 (WB 09.58, ex EJOK 87.94) adult ♀.
- 09.ii.1987 (WB 09.59, ex EJOK 87.95) adult ♂.
- 09.ii.1987 (WB 09.60, ex EJOK 87.96) adult ♀.
- 17.ii.1987 (WB 09.61, ex EJOK 87.97) adult ♂.
- 09.ii.1987 (WB 09.62, ex EJOK 87.98) 1st w ♀.
- 09.ii.1987 (WB 09.63, ex EJOK 87.100) adult ♂.
- 09.ii.1987 (WB 09.64, ex EJOK 87.101) adult ♂.

Material for comparison

Unmounted complete skeletons (one foot 'in the flesh' preserved in alcohol 70%), most with full biometrical data* from the specimen 'in the flesh', all anatomically sexed by the authors. The sample was collected (shot) as part of a pest-control programme by C. Noorlander on 18.x.1995 and 30.x.1995 near Oud-Alblas in Polder Zuidzijde, province of Zuid-Holland, The Netherlands (51º51'N;4º43'E). Listed are collection and number, fieldnumber (between parenthesis), age/plumage, sex.

- NMR 999700236 (04)*, adult ♀. - NMR 999700267 (19)*, adult ♂. - NMR 999700268 (16)*, adult ♂. - NMR 999700269 (15), adult ♀. - NMR 999700270 (13)*, adult ♀ [foot only]. - NMR 999700271 (11)*, adult ♂. - NMR 999700273 (09)*, first winter ♀. - NMR 999700274 (07)*, first winter ♂. - NMR 999700275 (05)*, adult ♂. - NMR 999700276 (03)*, adult ♂. - NMR 999700277 (02)*, adult ♂. - NMR 999700278 (01)*, adult ♂. - NMR 999700279 (06), adult ♂ - NMR 999700280 (08), adult ♀. - NMR 999700281 (12), first winter ♀. - NMR 999700282 (17), adult ♀. - NMR 999700266 (18), adult ♂. - NMR 999700272 (10), adult ♂. [* = full biometrical data]

Measurements

External measurements (1-12) were taken in the field and skull measurements (13-20) were taken after maceration. When applicable, all measurements were taken at the right side. Wing length and tail length were measured with measuring tape. All other measurements were established with vernier callipers. See Figures 1 & 2.

External

1 WING LENGTH: wing stretched and flattened. The maximum length was taken from the carpal joint to the tip of the longest primary.

2 TAIL LENGTH: measuring tape placed under the tail gland to the tip of the longest tail feather.

3 TARSAL LENGTH: measured from the external groove between the tibia and tarsus to the joint between the tarso-metatarsus and the most proximal margin of the phalanx of the middle toe.

4 MIDDLE TOE LENGTH WITHOUT NAIL: measured from the joint between the tarso-metatarsus and the most proximal margin of the phalange of the middle toe to the most proximal margin of the nail.

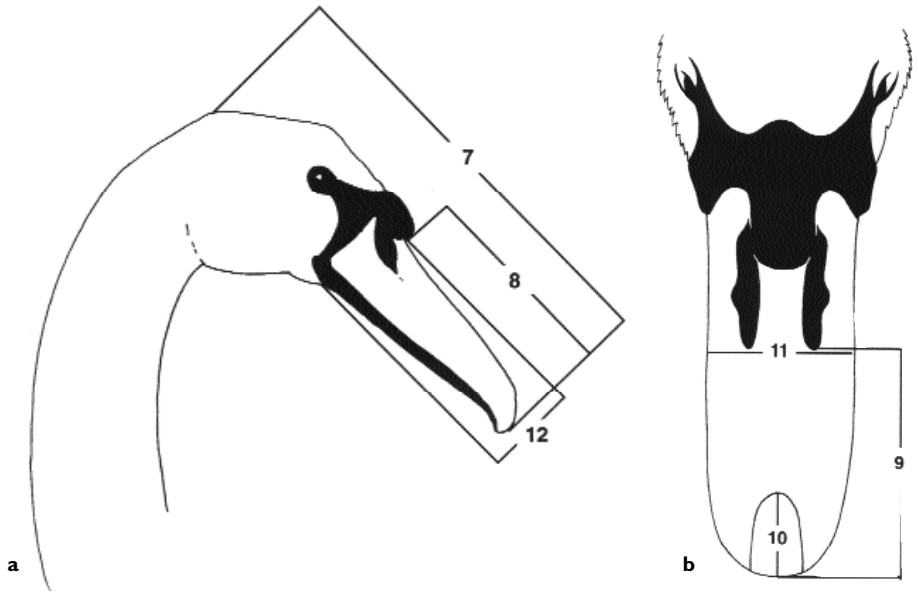


Figure 1 Head of the mute swan *Cygnus olor* with measurement points used in this study; **a** lateral view [illustration: J.N.J. Post], **b** dorsal view [illustration: Leen Zuydgeest]; 7 = head length, 8 = bill length, 9 = nalospi length, 10 = nail of the bill, 11 = bill width, 12 = bill height.

5 MIDDLE TOE LENGTH WITH NAIL: measured as in 4, but to the most distal margin of the nail.
6 NAIL LENGTH MIDDLE TOE: measured from the distal point to the most proximal margin of the nail.
7 HEAD LENGTH: measured from the tip of the bill to the most proximal point of the occiput (Fig. 1a).
8 BILL LENGTH: measured from the tip of the bill to the base of the knob in adults. In spec-

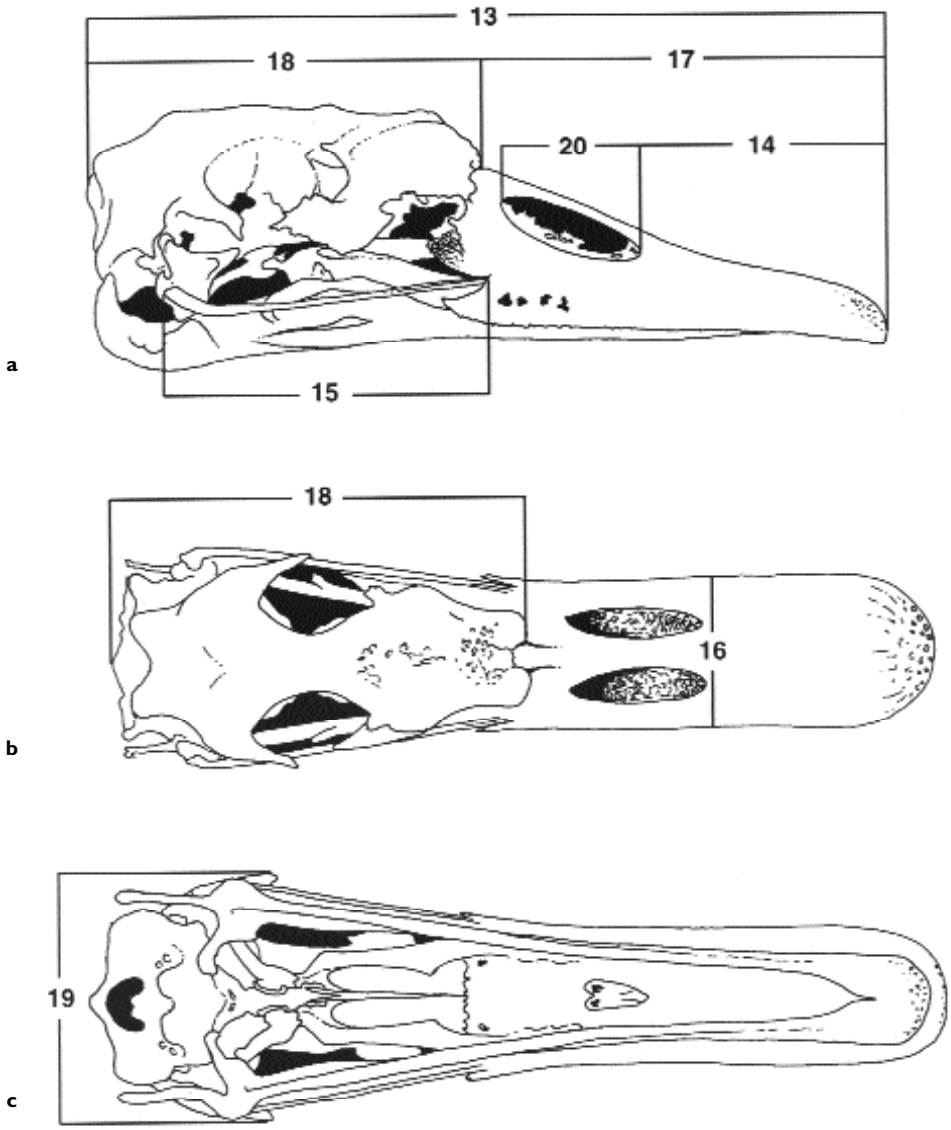


Figure 2 Skull of the mute swan *Cygnus olor* with measurement points used in this study; **a** lateral view; **b** dorsal view; **c** ventral view; 13 = skull length, 14 = nalospi length, 15 = jugal length, 16 = maxilla width, 17 = premaxilla length, 18 = cranium length, 19 = cranium width, 20 = nostril length. [illustration: J.N.J. Post]

imens with non developed knobs it is measured from the tip of the bill to the implantation of the feathers (Fig. 1a).
9 NALOSPI LENGTH: taken from the tip of the bill to the distal margin of the nostril (Fig. 1b).
10 NAIL OF THE BILL: distance between the distal point and the most proximal point of the nail of the bill (Fig. 1b).
11 BILL WIDTH: measured on the widest point of the bill just in front of the nostril (Fig 1b).
12 BILL HEIGHT: measured in front of the knob (Fig. 1a).

Skull

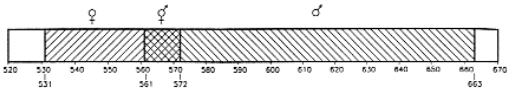
13 SKULL LENGTH: measured from the most distal tip of the premaxilla to the the most proximal point of the cranium (supra-occipital) (Fig. 2a).
14 NALOSPI LENGTH: Measured from the distal tip of the premaxilla to the distal edge of the (bony) nostril (Fig. 2a)
15 JUGAL LENGTH: measured from the distal orsigin of the jugal to the proximal point of the quadratojugal joint (Fig. 2a).
16 MAXILLA WIDTH: measured in front of the nostrils (Fig. 2b).
17 PREMAXILLA LENGTH: measured from the most distal point of the premaxilla to the position were the lacrimal, nasal and premaxilla meets (Fig. 2a).
18 CRANIUM LENGTH: is measured from the most proximal point of the cranium (supra-occipital) and the most distal point of the nasal (Figs. 2a, b).
19 CRANIUM WIDTH: measured between the distal points of both occipital wings (Fig. 2c).
20 NOSTRIL LENGTH: measured between the distal and proximal margin of the nostril (Fig. 2a).

RESULTS

Double shaded areas indicate overlap in size.

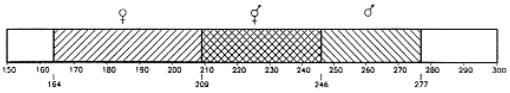
External measurements (all in mm)

1 WING LENGTH



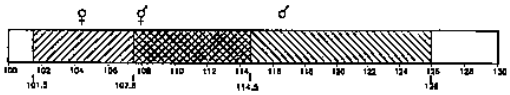
male: range 561-663, average 608 (n=32)
female: range 531-572, average 551 (n=13)
sexes combined: range 531-663, average 663 (n=45)

2 TAIL LENGTH



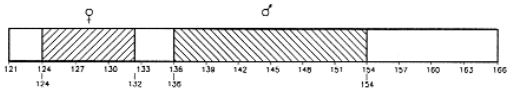
male: range 209-277, average 242 (n=28)
female: range 164-246, average 213 (n=12)
sexes combined: range 164-277, average 233 (n=40)

3 TARSAL LENGTH



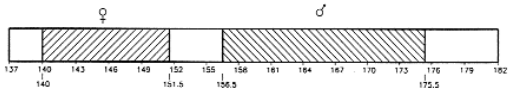
male: range 108.5-126.0, average 115.1 (n=32)
female: range 101.5-114.5, average 105.0 (n=12)
sexes combined: range 101.5-126.0, average 112.3 (n=44)

4 MIDDLE TOE LENGTH WITHOUT NAIL



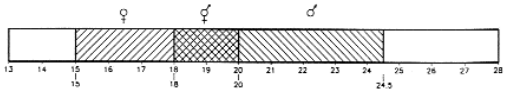
male: range 136.0-154.0, average 143.9 (n=32)
female: range 124.0-132.0, average 128.4 (n=13)
sexes combined: range 124.0-154.0, average 139.5 (n=45)

5 MIDDLE TOE LENGTH WITH NAIL



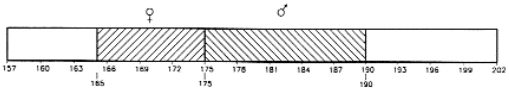
male: range 156.5-175.5, average 164.8 (n=31)
female: range 140.0-151.5, average 146.4 (n=13)
sexes combined: range 140.0-175.5, average 159.4 (n=44)

6 NAIL LENGTH MIDDLE TOE



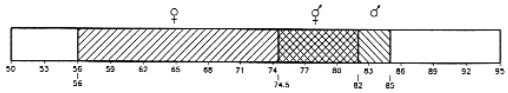
male: range 18.0-24.5, average 20.7 (n=31)
female: range 15.0-20.0, average 18.0 (n=13)
sexes combined: range 15.0-24.5, average 19.9 (n=44)

7 HEAD LENGTH



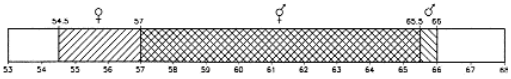
male: range 175.0-190.0, average 180.4 (n=27)
female: range 165.0-175.0, average 169.8 (n=13)
sexes combined: range 165.0-190.0, average 177.0 (n=40)

8 BILL LENGTH



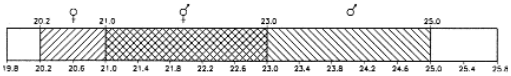
male: range 74.5-85.0, average 80.9 (n=27)
female: range 56.0- 82.0, average 74.0 (n=13)
sexes combined: range 56.0- 85.0, average 78.6 (n=40)

9 NALOSPI LENGTH



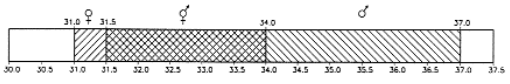
male: range 57.0- 65.5, average 61.0 (n=27)
female: range 54.5- 66.0, average 58.0 (n=12)
sexes combined: range 54.5- 66.0, average 60.1 (n=39)

10 NAIL OF THE BILL



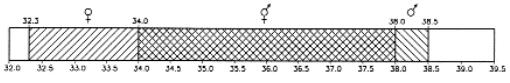
male: range 21.0- 25.0, average 22.6 (n=27)
female: range 20.2- 23.0, average 21.6 (n=13)
sexes combined: range 20.2- 25.0, average 22.3 (n=40)

11 BILL WIDTH



male: range 31.5- 37.0, average 34.5 (n=27)
female: range 31.0- 34.0, average 32.6 (n=13)
sexes combined: range 31.0- 37.0, average 33.8 (n=40)

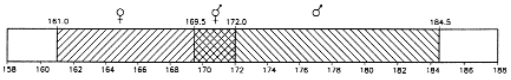
12 BILL HEIGHT



male: range 34.0- 38.5, average 36.0 (n=27)
female: range 32.3- 38.0, average 34.0 (n=13)
sexes combined: 32.3- 38.5, average 35.4 (n=40)

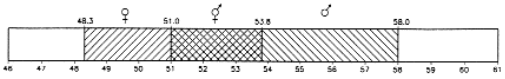
Skull measurements (all in mm)

13 SKULL LENGTH



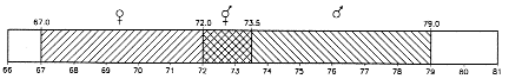
male: range 169.5-184.5, average 176.2 (n=32)
female: range 161.0-172.0, average 165.2 (n=13)
sexes combined: range 161.0-184.5, average 173,0 (n=45)

14 NALOSPI LENGTH



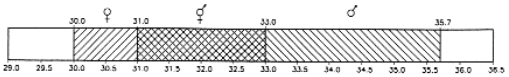
male: range 51.0- 58.0, average 54.8 (n=32)
female: range 48.3- 53.8, average 51.1 (n=13)
sexes combined: range 48.3- 58.8, average 53.7 (n=45)

15 JUGAL LENGTH



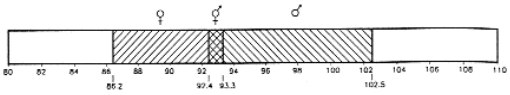
male: range 72.0- 79.0, average 76.0 (n=32)
female: range 67.0- 73.5, average 69.4 (n=13)
sexes combined: range 67.0- 79.0, average 74.1 (n=45)

16 MAXILLA WIDTH



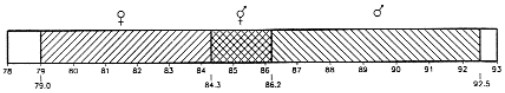
male: range 31.0- 35.7, average 33.5 (n=32)
female: range 30.0- 33.0, average 31.6 (n=13)
sexes combined: range 30.0- 35.7, average 33.0 (n=45)

17 PREMAXILLA LENGTH



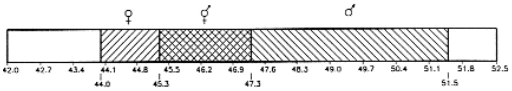
male: range 92.4-102.5, average 96.8 (n=32)
female: range 86.2-93.3, average 89.3 (n=13)
sexes combined: range 86.2-102.5, average 94.6 (n=45)

18 CRANIUM LENGTH



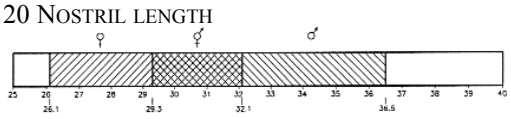
male: range 84.3-92.5, average 87.6 (n=32)
female: range 79.0-86.2), average = 82.9 (n=13)
sexes combined: range 79.0- 92.5, average 86.2 (n=45)

19 CRANIUM WIDTH



male: range 45.3-51.5, average 49.0 (n=32)
female: range 44.0-47.3, average 45.4 (n=13)
sexes combined: range 44.0-51.5, average 47.9 (n=45)

20 NOSTRIL LENGTH



male: range 29.3-36.5, average 32.6 (n=32)
female: range 26.1-32.1, average 29.9 (n=13)
sexes combined: range 26.1-36.5, average 31.8 (n=45)

CONCLUSIONS AND DISCUSSION

To ascertain which morphometric measurements are most suitable to determine the sex of mute swans, all variables were analysed separately (see RESULTS) and some were correlated. External (body) measurements and those of the skull were analysed separately.

External measurements

The length of the middle toe (with or without nail) appeared to be the only single discriminating variable for sexing mute swans, giving absolute certainty: measurements of the toes of males and females show no overlap at all, there is even a range of 4-5 mm between the largest female toe and the smallest male toe in our sample. The head length comes as second best variable for sexing, but has an overlap of one mm and is thus not absolutely reliable when large females or small males are concerned. Tarsal length and wing length have an overlap of 11 mm. All other external variables show larger ranges of overlap and are not reliable for sexing.

The relationship between the lengths of head and wing, head and bill, head and middle toe (with and without nail), and head and tarsus are not reliable to discriminate the sexes of the mute swan. Only when the lengths of middle toe and tarsus are correlated, the sexes can be determined with absolute certainty (Fig. 3).

Skull measurements

The relationships between the lengths of bill and nalospi, skull and cranium, and bill width and bill length appeared to be of no use for sexing. Cranium length and cranium width also show some overlap between the sexes (Fig. 4). When skull length and jugal length (Fig. 5), and skull length and bill length (Fig. 6) are correlated, the sexes can be trustworthy determined,

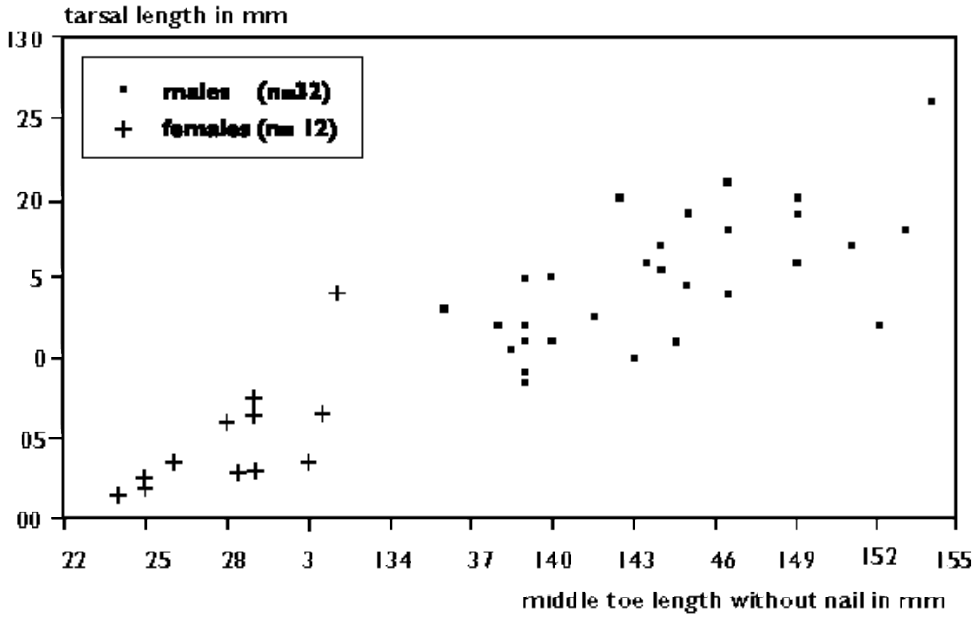


Figure 3 Relationship between middle toe length without nail and tarsal length in a sample of 44 mute swans *Cygnus olor*.

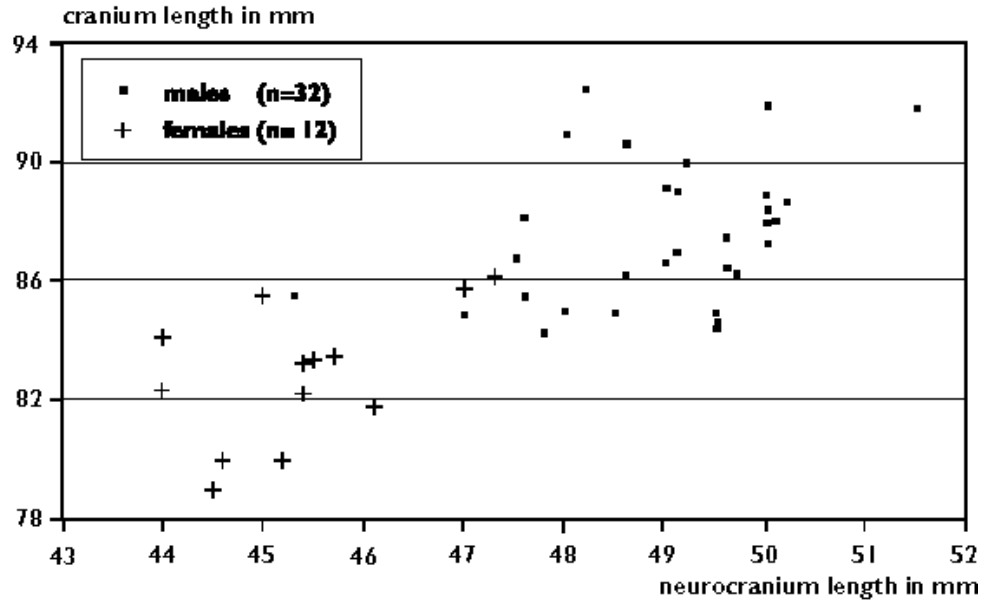


Figure 4 Relationship between cranium length and cranium width in a sample of 45 mute swans *Cygnus olor*.

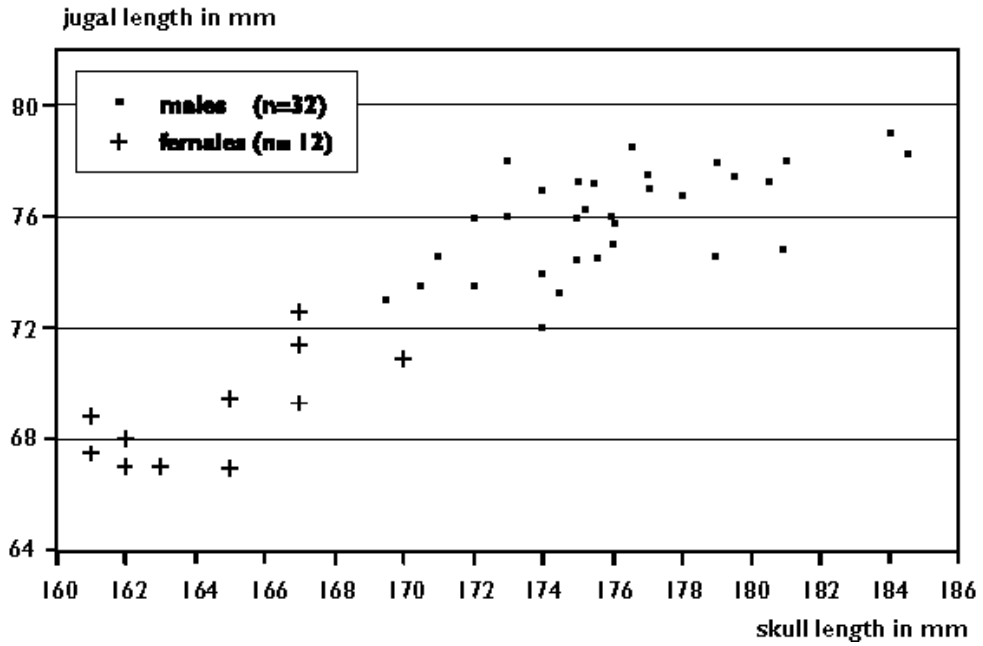


Figure 5 Relationship between skull length and jugal length in a sample of 45 mute swans *Cygnus olor*.

there is however a slight (1-2 mm) overlap when large females and small males are concerned. Ageing skulls, based on measurements, is virtually impossible as there appeared to be only minor differences in size of all measured variables between first winter, second winter and adult birds. The shape of the bony knob is however a useful feature for ageing (see below, Figs. 7 & 8).

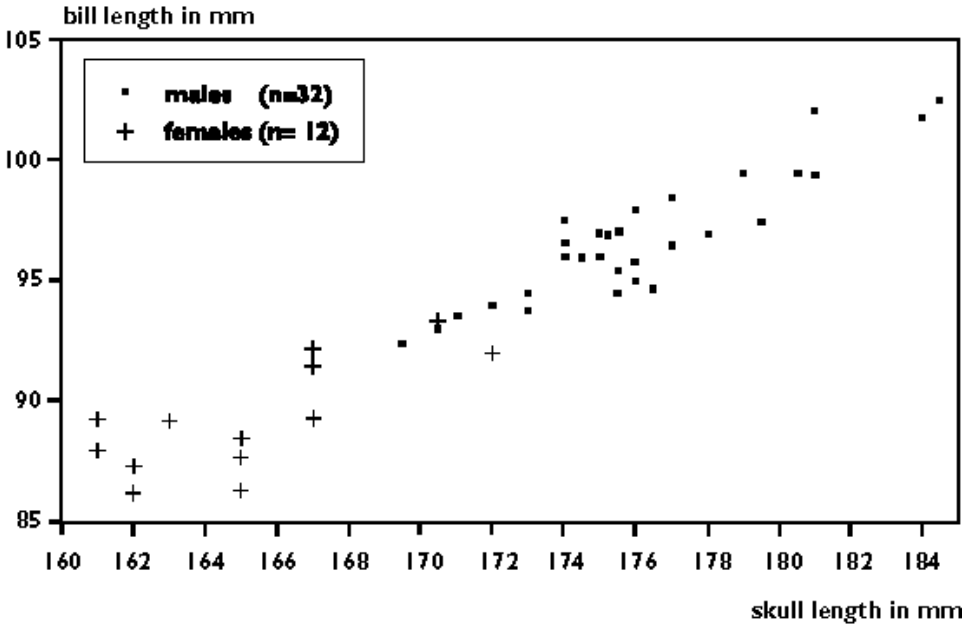


Figure 6 Relationship between skull length and bill length in a sample of 45 mute swans *Cygnus olor*.

Comparison with museum specimens

External measurements of eight male and four female mute swan specimens housed in the Natural History Museum Rotterdam (NMR) are given in Table 2. The data of this test sample are analysed and compared with the above mentioned findings. In the original material, the length of the middle toe without nail discriminates the sexes at the value of 136 mm (≥ 136 mm = ♂; ≤ 132 mm = ♀). In the the test sample (Table 2) the largest female toe measures 135.6 mm and the smallest male toe has a lenght of 140.6 mm, so still at a value of 136 mm the sexes could be separated. The 'free range' between the sexes has, however, narrowed considerably.

Table 2 External measurements of 12 mute swan specimens in the Natural History Museum Rotterdam. All in mm, averages and ranges (between parenthesis). Based on NMR-collection numbers 999700267,-268,-269,-270,-271,-273,-274,-275,-236,-276,-277,-278.

sex	wing length	tail length	tarsal length	middle toe length without nail	middle toe length with nail	nail length middle toe
female (n=4)	599.3 (578-625)	215.0 (201-227) n=3	110.5 (105.9-114.0)	133.7 (132.6-135.6)	152.0 (147.6-155.0)	21.3 (20.1-22.5)
male (n=8)	613.6 (590-635)	233.8 (210-257) n=6	119.1 (114.6-123.6)	146.4 (140.6-155.0)	162.1 (153.0-170.1)	23.0 (20.6-25.6)
sexes combined (n=12)	608.9 (578-635)	227.6 (201-257) n=9	116.2 (105.9-123.6)	142.1 (132.6-155.0)	158.7 (147.6-170.1)	22.4 (20.1-25.6)

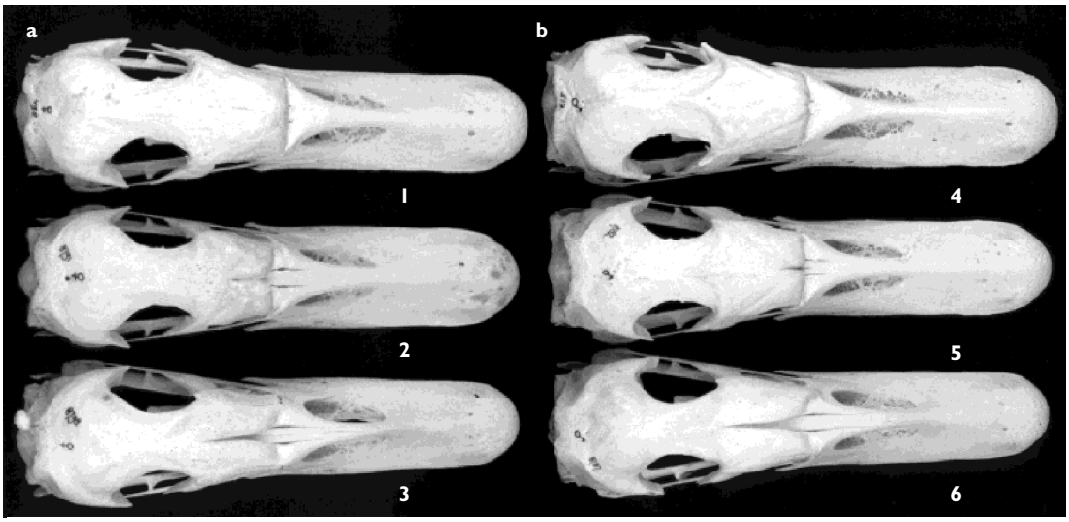


Figure 7 Skulls of the mute swan *Cygnus olor*; **a** dorsal view of ♀ skulls: **1** first winter (WB 09.62); **2** second winter (WB 09.55); **3** adult winter (WB 09.25). **b** dorsal view of ♂ skulls: **4** first winter (WB 09.51); **5** second winter (WB 09.47); **6** adult winter (WB 09.42). Collection numbers between parenthesis. [photograph Rob 't Hart]

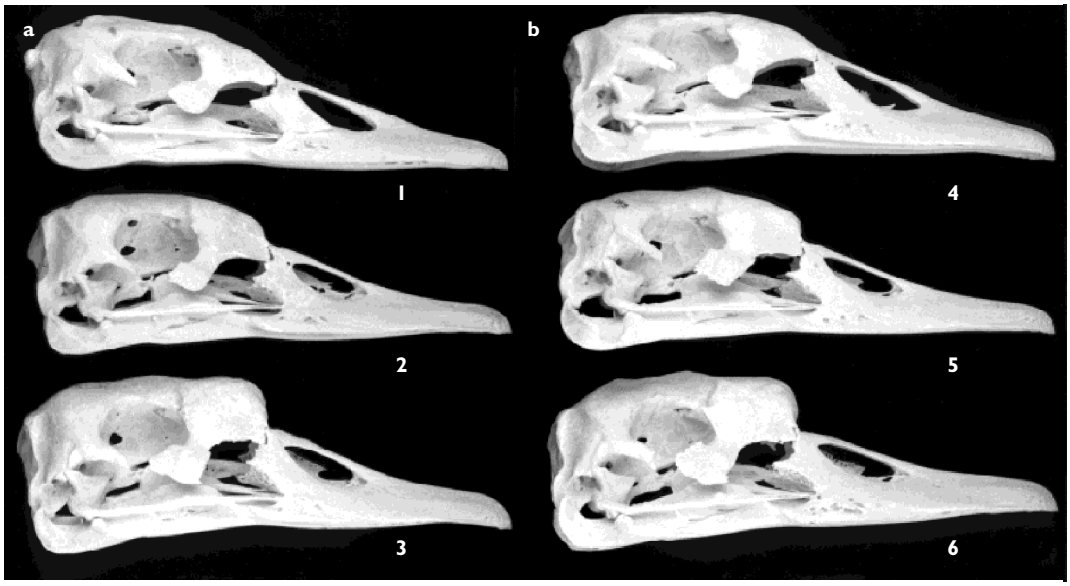


Figure 8 Skulls of the mute swan *Cygnus olor*; **a** lateral view of ♀ skulls: **1** first winter (WB 09.62); **2** second winter (WB 09.55); **3** adult winter (WB 09.25). **b** lateral view of ♂ skulls: **4** first winter (WB 09.51); **5** second winter (WB 09.47); **6** adult winter (WB 09.42). Collection numbers between parenthesis. [photograph Rob 't Hart]

In conclusion, we state that the above mentioned skull measurements (Figs. 5 & 6) are of use for sexing mute swans. As for external measurements, the middle toe length without nail taken from the specimen in the flesh, however, gives absolute certainty in sexing first winter and adult mute swans. Standard body measurements, such as wing and tail, are not reliable for sex determination as these variables show considerable overlap and are susceptible to wear.

Fieldworkers handling mute swans e.g. for ringing purposes, can thus reliably sex specimens by simply measuring the middle toe. A toe without nail measuring less than 136 mm belongs to a female, while male mute swans have a middle toe length of 136 mm or more. Sexing mute swans in the field based on the size of the black bill knob (usually larger in males according to Delacour 1954, Cramp & Simmons 1977 and Madge & Burn 1988) is according to our findings not reliable. Of 18 freshly dead specimens in our test sample, only 12 (66.7%) could be correctly sexed based on the size of the bill knob: after inspection of the gonads, six specimens appeared to be of the opposite sex (Table 3).

Table 3 Sex of 18 mute swan specimens in the Natural History Museum Rotterdam (collected 18 and 30.x.1995 near Oud-Alblas, Zuid-Holland, The Netherlands), based on the size of the bill knob, and based on the gonads.

collection and (field)number (between parenthesis)	sex based on size of the bill knob	sex based on gonads
NMR 999700278 (01)	♂	♂
NMR 999700277 (02)	♂	♂
NMR 999700276 (03)	♀	♂
NMR 999700236 (04)	♀	♀
NMR 999700275 (05)	♂	♂
NMR 999700279 (06)	♀	♂
NMR 999700274 (07)	♂	♂
NMR 999700280 (08)	♀	♀
NMR 999700273 (09)	♀	♀
NMR 999700272 (10)	♂	♂
NMR 999700271 (11)	♂	♂
NMR 999700281 (12)	♂	♀
NMR 999700270 (13)	♂	♀
NMR 999700269 (15)	♀	♀
NMR 999700268 (16)	♀	♂
NMR 999700282 (17)	♂	♀
NMR 999700266 (18)	♂	♂
NMR 999700267 (19)	♂	♂

Morphological notes

In addition to the biometrics, we also examined the preserved skulls to find morphological differences between the sexes and between the age-classes as listed in Table 1. Male and female skulls could, however, not be separated morphologically (Figs. 7 & 8). As for age, the bony knob shows a characteristic development during lifetime. This morphogenesis, which is almost i d e n t i cal in male and female, is clearly shown in Figure 8.

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