Skull identification key for Central European waterfowl (Aves: Anseriformes: Anatidae)

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Abstract

Although the Anseriformes are among the most thoroughly studied bird orders in Central Europe, no precise key for the identification of their skulls was available. This paper seeks to remedy this lack by presenting a dichotomous identification key for 37 species of Anseriformes from Germany. Photographs and biometric measurements of the skulls are added to support the identification process.

K e y w o r d s : Aves, Anseriformes, Anatidae, skull morphology, identification key.

Zusammenfassung

Obwohl die Entenvögel (Anseriformes) zu den gut untersuchten Vogelgruppen zählen, lag bisher kein präziser Bestimmungsschlüssel für die Schädel der mitteleuropäischen Arten vor. Mit der vorliegenden Arbeit wird diese Lücke geschlossen und ein dichotomer Schlüssel zur Bestimmung von 37 in Deutschland lebenden Entenvogelarten vorgestellt. Zur Erleichterung der Bestimmung werden Fotos und Messdaten beigefügt.

Contents

1 Introduction

Although the Anseriformes are one of the most thoroughly studied bird orders, no identification key for the skulls of Central European species was yet available. As part of a graduate thesis project at Constance University (Ellrott 2008), the skulls of 37 German waterfowl species were measured and analyzed with regard to functional anatomy, diet and feeding behavior. Based on the underlying data and measurements, a distinction can even be made between skulls of closely related species. In this paper we present a dichotomous identification key for all 37 species of the order. In addition, we include supportive morphometric data and illustrations.

The skull of the Anseriformes is desmognathous and holorhinous. It is further characterized by the following features: Processus angularis of the lower jaw strongly developed, joint area of the articulare with a distinct caudolateral to rostromedial ridge, rostropterygoid joint situated quite rostrally (features of Galloanseres); rostral end of palatina spatulate, rostropterygoid processus pedicellate, processus retroarticularis of the lower jaw sagitally compressed and knife-shaped, occipital fontanelles present, processus paracoronoideus strongly developed (Mickoleit 2004).

Goodmann & Fisher (1962) investigated the functional anatomy of the feeding apparatus of 17 species of the Anseriformes with seven species occurring in Central Europe. In this work several measurements were presented (n = 1–28).

Brown et al. (2003) presented a skull identification key for selected species of birds, including Anseriformes. The key included general skull types and the bill-cranium-relation, and was supplemented by illustrations and some basic morphometric data. Unfortunately, the number of specimens examined was not specified (except when only one specimen was available). The illustrations were not very detailed and not comparable between species. Closely related species were shown with and without bill horn. Therefore, skulls that in reality are similar, appear to be very different. Finally, some important species are missing (e. g. *Mergellus albellus*) or represented in low numbers (e. g. *Branta bernicla* with n = 1).

Jansen & Gestel (2009) present the following measurements on their "skullsite": total length; length, width and height of cranium, upper bill length, skull relation (total length / upper bill length). The photographs are clear and informative. Unfortunately, the measurements are taken from just one specimen each. In addition, despite of the enormous number of included species, some Central European species are missing.

Because Germany has a good cross-section of the Central European fauna, we based our analysis on the species list in Barthel & Helbig (2005), but we excluded very rare species in order to keep the identification key practicable (see chapter 2, "species selection").

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2 Materials und Methods

Species selection

Species selection is based on Barthel & Helbig (2005). From the 66 Anseriformes species listed in this paper, we excluded 29 species which (1) were previously recorded as introduced, arrived by assisted transport or escaped from captivity, and whose breeding population (if any) is thought not to be self-sustaining, or (2) were classified as vagrants with an average of less than five records per year since 1980.

Tab. 1. Species included in the determination key. – Nomenclature according to Bauer et al. (2005), systematic order according to Hoyo et al. (1992).

Scientific name	English name	German name
ANSERANATINAE		
Anserini		
Cygnus olor (J. K. Gmelin, 1789)	Mute Swan	Höckerschwan
Cygnus atratus (Latham, 1790)	Black Swan	Schwarzschwan
Cygnus cygnus (Linnaeus, 1758)	Whooper Swan	Singschwan
Cygnus bewickii Yarrell, 1830	Tundra Swan	Zwergschwan
Anser fabalis (Latham, 1787)	Bean Goose	Saatgans
Anser brachyrhynchus Baillon, 1834	Pink-footed Goose	Kurzschnabelgans
Anser albifrons (Scopoli, 1769)	Greater White-fronted Goose	Blässgans
Anser erythropus (Linnaeus, 1758)	Lesser White-fronted Goose	Zwerggans
Anser anser (Linnaeus, 1758)	Greylag Goose	Graugans
Branta canadensis (Linnaeus, 1758)	Canada Goose	Kanadagans
Branta leucopsis (Bechstein, 1803)	Barnacle Goose	Weißwangengans
Branta bernicla (Linnaeus, 1758)	Brent Goose	Ringelgans
Branta ruficollis (Pallas, 1769)	Red-breasted Goose	Rothalsgans
ANATINAE		
Tadornini		
Alopochen aegyptiaca (Linnaeus, 1766)	Egyptian Goose	Nilgans
Tadorna ferruginea (Pallas, 1764)	Ruddy Shelduck	Rostgans
Tadorna tadorna (Linnaeus, 1758)	Common Shelduck	Brandgans
Cairinini		
Aix galericulata (Linnaeus, 1758)	Mandarin Duck	Mandarinente
Anatini		
Anas penelope Linnaeus, 1758	Eurasian Wigeon	Pfeifente
Anas stepera Linnaeus, 1758	Gadwall	Schnatterente
Anas crecca Linnaeus, 1758	Common Teal	Krickente
Anas platyrhynchos Linnaeus, 1758	Mallard	Stockente
Anas acuta Linnaeus, 1758	Northern Pintail	Spießente
Anas querquedula Linnaeus, 1758	Garganey	Knäkente
Anas clypeata Linnaeus, 1758	Northern Shoveler	Löffelente
Aythyini		
Netta rufina (Pallas, 1773)	Red-crested Pochard	Kolbenente
Aythya ferina (Linnaeus, 1758)	Common Pochard	Tafelente
Aythya nyroca (Güldenstädt, 1770)	Ferruginous Duck	Moorente
Aythya fuligula (Linnaeus, 1758)	Tufted Duck	Reiherente
Aythya marila (Linnaeus, 1758)	Greater Scaup	Bergente
Mergini		
Somateria mollissima (Linnaeus, 1758)	Common Eider	Eiderente
Clangula hyemalis (Linnaeus, 1758)	Long-tailed Duck	Eisente
Bucephala clangula (Linnaeus, 1758)	Common Goldeneye	Schellente
Melanitta fusca (Linnaeus, 1758)	Velvet Scoter	Samtente
Melanitta nigra (Linnaeus, 1758)	Common Scoter	Trauerente
Mergellus albellus (Linnaeus, 1758)	Smew	Zwergsäger
Mergus serrator Linnaeus, 1758	Red-breasted Merganser	Mittelsäger
Mergus merganser Linnaeus, 1758	Goosander	Gänsesäger
OXYURINAE		
Oxyurini		
Oxyura jamaicensis (J.K. Gmelin, 1789)	Ruddy Duck	Schwarzkopf-Ruderente

Materials

The skull material originates mainly from the NIKOLAUS Collection (Staatliches Museum für Naturkunde, Stuttgart). We also used specimens from the following collections: Landesdenkmalamt Baden-Württemberg, Arbeitsstelle Osteologie, Konstanz; Institut für Palaeoanatomie, Domestikationsforschung und Geschichte der Tiermedizin, Universität München; Museum für Naturkunde, Berlin; SCHMITZ Collection (Universität Konstanz).

Of the 37 species selected, we measured ten specimens each, all of which met the necessary condition, i. e. no damage that could prevent proper measuring. See Tab. 1 for the nomenclature of the included species.

For photographic documentation we chose those individuals that were the most representative (i. e. with measurements close to mean values).

Abbreviations and measurements

The skulls were measured as follows (see also Fig. 1 and Tab. 2):

Skull

TL Total length (= upper bill length plus cranial length, i. e. the total length was not measured separately)

UBL Upper bill length (measured from tip of upper bill to the middle of the fissura cranio-facialis = fronto-nasal hinge)

CL Cranial length (measured from the middle of the fissura cranio-facialis to the caudal end of the cranium)

Upper bill

TOL Tomium length

PL Premaxillary length (measured between tip of upper bill and anterior end of naris)

NL Naris length

BWUB Basal width of upper bill

UBS Upper bill shape (= bill edge shape in dorsal view, divided into three categories: divergent (= D), parallel (= P) or convergent (= C) towards bill tip)

UBH Upper bill height (= bill height in apical third)

Cranium

CH Cranial height

CW Cranial width

SOW Width of supraorbital isthmus

SG Salt gland fossa (may be absent, weakly developed or distinct)

Lower bill

LBL Lower bill length

LBH Lower bill height

In a few key couplets we added (i. e. not included in Tab. 2) basal width of premaxillary (measured at the anterior end of nares) and length (cranial – rostral) of lacrimal (Fig. 3).

Tab. 2. Measurements (in mm) of the treated 37 Anseriformes species (n = 10 per species; Max = maximum; Ø = Mean, Min = Minimum; SD = Standard deviation). – For abbreviations see chapter 2 and Fig. 1.

		Skull			Upper Bill						Cranium				Lower Bill	
		TL	**UBL**	**CL**	**TOL**	**PL**	**NL**	**BWUB**	**UBS**	**UBH**	**CH**	**CW**	**SOW**	**SG**	**LBL**	**LBH**
Cygnus olor	Max	184.2	97.5	88.4	98.4	56.8	35.5	34.7		12.6	34.3	45.7	21.7		171.0	18.9
	Ø	**178.6**	**93.3**	**85.3**	**95.0**	**52.8**	**31.7**	**33.3**	**P = 100 %**	**11.0**	**32.8**	**44.0**	**20.1**	**Absent**	**165.7**	**17.7**
	Min	172.1	89.1	82.1	91.8	49.7	27.8	31.0		10.2	31.3	41.9	17.6		159.0	16.4
	SD	4.9	3.1	2.0	2.3	2.1	2.1	1.2		0.8	0.8	1.3	1.4		4.1	0.8
Cygnus cygnus	Max	195.1	97.1	98.3	102.6	49.9	39.3	32.8		12.2	39.0	48.0	20.1		189.0	19.4
	Ø	**180.0**	**88.9**	**91.0**	**93.4**	**44.3**	**35.4**	**30.5**	**P = 100 %**	**10.6**	**36.8**	**44.9**	**17.9**	**Absent**	**169.5**	**17.2**
	Min	167.5	79.5	83.2	86.0	38.9	32.9	28.1		8.8	34.8	42.7	15.3		152.8	15.6
	SD	8.8	5.0	4.2	5.3	3.0	1.8	1.5		1.0	1.3	1.6	1.3		10.7	1.1
Cygnus bewickii	Max	169.2	81.4	87.9	86.5	38.9	34.6	30.5		12.6	36.3	44.7	17.9		160.0	17.1
	Ø	**156.5**	**74.4**	**82.1**	**80.1**	**36.5**	**30.4**	**29.0**	**P = 100 %**	**10.0**	**34.3**	**41.6**	**15.5**	**Absent**	**146.1**	**15.7**
	Min	144.7	69.3	75.4	74.4	33.6	26.9	27.7		8.0	32.5	38.3	13.8		132.7	14.0
	SD	7.5	4.3	3.5	4.3	2.0	2.2	1.0		1.3	1.2	1.9	1.3		8.6	0.9
Anser fabalis	Max	125.0	68.2	59.0	60.6	33.0	23.6	26.4		7.5	34.4	35.7	15.4		111.2	17.3
	Ø	**116.9**	**61.4**	**55.5**	**55.2**	**29.5**	**21.8**	**24.4**	**C = 100 %**	**6.7**	**32.4**	**33.2**	**13.5**	**Absent**	**102.3**	**15.8**
	Min	110.8	56.8	53.3	50.1	27.1	19.4	22.8		6.1	30.9	26.5	11.1		93.9	15.1
	SD	5.8	4.0	2.1	3.6	2.0	1.2	1.1		0.5	1.1	2.5	1.3		5.5	0.7
Anser brachyrhynchus	Max	108.6	53.3	55.5	46.5	23.9	20.1	24.4		7.6	32.0	34.9	15.5		91.8	13.6
	Ø	**100.7**	**48.2**	**52.5**	**43.1**	**21.4**	**17.8**	**22.0**	**C = 100 %**	**6.4**	**30.0**	**31.8**	**13.2**	**Absent**	**85.9**	**12.4**
	Min	92.8	43.2	49.7	39.2	19.0	15.5	18.5		5.2	28.1	28.9	10.0		78.4	11.8
	SD	5.0	3.0	2.3	2.2	1.5	1.5	1.7		0.7	1.4	1.8	1.5		4.5	0.6

		Skull			Upper Bill						Cranium				Lower Bill	
		TL	UBL	CL	TOL	PL	NL	BWUB	UBS	UBH	CH	CW	SOW	SG	LBL	LBH
Anser albifrons	Max	110.0	55.3	55.8	50.3	25.8	19.5	24.1		6.8	30.7	32.3	13.8		94.7	13.3
	Ø	**104.7**	**51.8**	**52.9**	**46.8**	**24.1**	**18.9**	**23.0**	**C = 100 %**	**6.2**	**29.5**	**31.1**	**12.4**	**Absent**	**89.2**	**12.6**
	Min	98.7	48.3	50.4	43.8	22.8	17.6	21.7		5.1	27.3	29.6	10.8		82.8	11.2
	SD	3.4	2.1	1.6	2.1	1.1	0.6	0.7		0.5	0.8	0.9	0.9		3.5	0.5
Anser erythropus	Max	94.1	44.3	49.8	37.7	19.2	16.9	21.2		6.4	26.8	30.1	12.5		76.4	10.9
	Ø	**88.5**	**40.5**	**48.0**	**35.0**	**16.7**	**15.8**	**19.5**	**C = 100 %**	**5.5**	**25.9**	**28.7**	**11.3**	**Absent**	**72.8**	**10.0**
	Min	85.1	38.1	45.5	32.6	15.1	14.7	17.3		4.9	24.9	27.1	9.8		68.1	9.2
	SD	3.0	2.0	1.6	1.7	1.1	0.8	1.2		0.4	0.6	0.9	0.7		2.6	0.6
Anser anser	Max	133.9	72.1	61.8	62.9	33.4	26.9	31.6		8.6	35.0	37.6	18.0		113.7	17.6
	Ø	**124.7**	**65.2**	**59.5**	**58.3**	**30.6**	**23.6**	**28.6**	**C = 100 %**	**8.2**	**33.4**	**36.1**	**15.0**	**Absent**	**107.6**	**16.5**
	Min	117.6	60.0	57.0	55.3	28.7	21.6	25.7		7.8	31.6	34.2	13.8		102.3	15.6
	SD	4.4	3.4	1.5	2.2	1.4	1.6	1.6		0.3	1.1	1.0	1.2		2.7	0.5
Branta canadensis	Max	136.9	68.5	68.4	62.0	33.8	29.1	27.8		7.7	35.5	38.8	15.9		119.3	15.3
	Ø	**128.5**	**63.9**	**64.6**	**59.3**	**29.0**	**25.6**	**25.2**	**C = 70 %**	**7.0**	**33.4**	**36.4**	**13.5**	**Distinct or weak**	**113.6**	**14.2**
	Min	118.8	58.8	59.9	53.1	25.4	23.7	20.5	P = 30 %	6.1	31.9	33.8	11.8		104.3	12.8
	SD	4.7	2.8	2.9	2.6	2.3	1.8	1.9		0.5	1.1	1.3	1.2		4.2	0.6
Branta leucopsis	Max	91.5	40.1	51.9	34.2	16.9	16.5	19.0		6.0	28.3	31.2	12.8		76.1	10.4
	Ø	**86.9**	**37.1**	**49.8**	**31.7**	**15.6**	**15.2**	**17.5**	**C = 100 %**	**5.5**	**26.6**	**28.9**	**10.8**	**Weak or absent**	**71.2**	**9.8**
	Min	83.2	34.5	48.1	29.7	14.3	13.8	16.5		4.8	25.5	27.5	9.0		68.3	8.8
	SD	2.8	1.7	1.3	1.4	0.7	1.0	0.7		0.4	0.9	1.1	0.9		2.7	0.5
Branta bernicla	Max	98.8	46.8	53.6	41.6	18.1	21.0	19.6		6.4	25.7	29.4	9.8		85.6	10.4
	Ø	**92.1**	**41.6**	**50.5**	**37.1**	**16.5**	**18.5**	**18.4**	**C = 100 %**	**5.6**	**24.9**	**28.4**	**8.7**	**Distinct**	**77.8**	**9.2**
	Min	87.4	39.3	48.1	34.6	15.8	17.5	17.2		5.2	23.9	27.3	7.4		72.2	8.4
	SD	3.3	2.1	1.8	1.8	0.8	1.0	0.8		0.3	0.6	0.8	0.8		4.1	0.6
Branta ruficollis	Max	79.9	33.8	46.4	28.3	13.6	14.5	18.3		5.8	25.4	26.6	11.3		68.0	9.4
	Ø	**76.8**	**32.0**	**44.8**	**26.3**	**12.8**	**13.5**	**16.8**	**C = 100 %**	**5.4**	**24.0**	**25.1**	**9.8**	**Weak**	**62.2**	**8.5**
	Min	72.2	29.4	42.7	23.2	11.0	12.6	15.4		4.7	23.2	24.1	8.7		58.7	8.3
	SD	2.7	1.4	1.4	1.4	0.7	0.7	0.9		0.3	0.7	0.9	0.8		2.6	0.3
Alopochen aegyptiaca	Max	115.8	53.4	62.5	53.0	30.4	18.9	22.4		8.2	29.1	32.4	14.8		100.9	11.9
	Ø	**111.6**	**51.3**	**60.3**	**49.7**	**28.7**	**17.5**	**21.2**	**P = 90 %**	**7.4**	**28.1**	**31.5**	**12.8**	**Absent**	**96.3**	**10.9**
	Min	107.8	48.6	58.1	47.5	26.8	14.9	19.7	C = 10 %	6.8	27.3	29.7	11.1		92.6	10.1
	SD	2.5	1.4	1.6	1.6	0.9	1.2	0.7		0.4	0.6	0.8	1.1		2.9	0.6
Tadorna ferruginea	Max	106.9	47.9	59.7	53.5	30.4	14.1	19.9		8.4	24.7	28.6	12.4		98.9	10.2
	Ø	**101.9**	**45.1**	**56.8**	**49.9**	**28.0**	**13.4**	**18.4**	**P = 100 %**	**7.2**	**23.9**	**27.5**	**10.9**	**Absent**	**92.3**	**9.7**
	Min	94.1	41.7	52.4	44.9	24.8	12.6	17.2		6.3	23.2	25.6	9.6		84.4	9.1
	SD	3.7	1.7	2.1	2.4	1.6	0.5	0.8		0.6	0.5	0.8	1.0		4.1	0.3
Tadorna tadorna	Max	105.4	49.2	56.2	58.2	33.0	14.3	18.3		6.3	23.6	28.4	7.7		102.8	12.1
	Ø	**97.7**	**44.5**	**53.2**	**53.4**	**29.7**	**12.8**	**17.1**	**D = 100 %**	**5.2**	**22.7**	**26.9**	**7.1**	**Weak**	**93.9**	**10.3**
	Min	89.1	39.8	49.3	48.1	26.4	11.2	15.7		3.8	21.8	25.3	6.1		84.9	9.3
	SD	4.9	2.6	2.4	3.1	1.8	0.9	0.8		0.7	0.7	0.9	0.5		5.3	0.8
Aix galericulata	Max	81.7	34.6	47.1	35.3	20.3	10.6	14.9		4.6	23.1	24.0	9.4		67.1	7.1
	Ø	**78.2**	**33.0**	**45.2**	**33.3**	**19.1**	**9.8**	**14.2**	**C = 80 %**	**4.3**	**22.7**	**23.2**	**8.8**	**Absent**	**64.2**	**6.7**
	Min	74.5	30.3	43.0	30.7	17.0	9.3	13.8	P = 20 %	3.7	22.0	22.2	7.4		61.3	6.3
	SD	2.1	1.1	1.3	1.3	0.8	0.4	0.3		0.3	0.3	0.7	0.6		1.8	0.3
Anas penelope	Max	89.1	39.4	49.7	41.2	26.6	10.1	16.1		5.4	22.7	23.9	6.6		78.6	8.7
	Ø	**84.4**	**36.4**	**48.0**	**38.3**	**24.4**	**9.3**	**15.2**	**P = 100 %**	**4.9**	**21.8**	**23.4**	**6.0**	**Weak**	**74.2**	**8.3**
	Min	81.0	34.3	46.5	35.6	22.0	8.3	13.9		4.6	21.1	22.6	5.5		70.6	7.9
	SD	2.3	1.3	1.2	1.5	1.2	0.5	0.7		0.3	0.4	0.5	0.4		2.3	0.3

		Skull			Upper Bill						Cranium				Lower Bill	
		TL	UBL	CL	TOL	PL	NL	BWUB	UBS	UBH	CH	CW	SOW	SG	LBL	LBH
Anas stepera	Max	100.5	47.8	52.6	51.5	34.4	12.0	16.3		6.0	22.0	23.7	8.1		93.2	9.4
	Ø	**96.3**	**45.3**	**51.0**	**48.1**	**31.7**	**11.4**	**15.6**	**P = 100 %**	**5.4**	**21.3**	**23.1**	**7.3**	**Absent**	**87.4**	**8.6**
	Min	92.3	42.7	48.4	45.2	30.6	10.2	14.6		4.9	20.8	22.3	6.8		81.8	8.0
	SD	2.4	1.5	1.1	1.7	1.1	0.6	0.6		0.4	0.4	0.5	0.4		3.1	0.4
Anas crecca	Max	81.9	39.0	43.9	42.9	28.5	9.8	13.0		5.6	20.9	21.2	7.2		74.5	7.4
	Ø	**79.0**	**36.5**	**42.5**	**39.9**	**26.3**	**8.5**	**12.5**	**P = 100 %**	**4.9**	**20.2**	**19.6**	**6.4**	**Absent**	**70.4**	**6.7**
	Min	76.2	34.2	41.3	37.9	24.4	7.5	11.2		4.5	19.0	18.3	5.1		68.1	6.3
	SD	1.9	1.5	0.8	1.5	1.2	0.7	0.5		0.3	0.5	0.8	0.6		2.1	0.3
Anas platyrhynchos	Max	117.4	57.6	59.8	62.6	38.2	15.7	21.3		8.6	27.2	28.9	10.6		107.3	10.6
	Ø	**109.5**	**53.1**	**56.5**	**58.4**	**36.1**	**13.7**	**19.3**	**P = 60 %**	**7.8**	**26.3**	**26.6**	**9.8**	**Absent**	**99.7**	**9.9**
	Min	103.5	48.3	54.3	53.1	32.8	11.9	18.3	D = 40 %	7.1	25.4	25.2	8.3		92.4	8.6
	SD	4.4	2.9	1.7	3.2	2.0	1.0	0.9		0.4	0.5	1.1	0.6		4.6	0.6
Anas acuta	Max	111.3	54.5	56.7	61.2	39.0	13.5	17.4		8.2	25.0	26.9	10.0		103.1	10.3
	Ø	**104.5**	**50.6**	**53.9**	**55.9**	**35.9**	**12.4**	**16.5**	**P = 50 %**	**6.7**	**23.8**	**25.8**	**9.0**	**Absent**	**96.0**	**9.6**
	Min	95.9	45.8	50.2	51.1	32.6	10.8	15.7	D = 50 %	5.2	23.0	23.7	8.2		86.9	8.8
	SD	4.4	2.5	2.0	3.0	1.8	0.9	0.5		1.0	0.5	1.0	0.6		4.5	0.4
Anas querquedula	Max	83.5	40.5	43.5	44.2	29.3	10.0	14.6		6.7	20.3	21.0	6.9		74.9	7.4
	Ø	**80.3**	**37.8**	**42.4**	**41.8**	**27.0**	**9.5**	**13.8**	**P = 90 %**	**5.6**	**19.8**	**19.9**	**6.2**	**Absent**	**71.9**	**6.7**
	Min	76.6	36.1	40.3	39.5	24.7	8.7	13.1	D = 10 %	4.9	19.4	18.3	5.6		69.3	6.2
	SD	1.9	1.2	0.9	1.4	1.2	0.4	0.5		0.6	0.3	0.9	0.4		1.6	0.3
Anas clypeata	Max	121.5	66.6	54.9	71.8	49.2	15.2	16.1		10.0	22.9	22.8	7.5		112.6	8.7
	Ø	**112.8**	**60.8**	**52.0**	**66.0**	**43.8**	**13.9**	**15.2**	**D = 100 %**	**8.2**	**21.8**	**21.9**	**6.8**	**Absent**	**104.8**	**8.1**
	Min	106.2	56.9	49.3	59.2	40.3	12.2	14.3		6.8	21.0	21.1	5.3		99.3	7.4
	SD	5.2	3.4	2.0	4.2	2.9	0.8	0.6		0.9	0.5	0.6	0.7		4.8	0.4
Netta rufina	Max	104.1	53.3	51.9	53.8	32.5	15.7	24.4		5.5	23.7	27.3	8.9		93.7	9.8
	Ø	**100.1**	**50.4**	**49.8**	**51.4**	**30.6**	**14.1**	**22.6**	**C = 80 %**	**4.1**	**22.7**	**26.3**	**8.0**	**Absent (or weak)**	**89.3**	**9.2**
	Min	94.4	46.9	47.5	48.2	27.9	12.8	21.4	P = 20 %	3.3	21.8	25.4	6.9		84.4	8.7
	SD	2.9	1.9	1.3	1.7	1.4	0.8	0.9		0.7	0.5	0.6	0.5		2.5	0.3
Aythya ferina	Max	104.4	51.5	53.4	54.9	32.6	14.2	19.4		7.7	25.5	27.5	9.1		96.1	11.1
	Ø	**99.2**	**47.3**	**51.9**	**51.0**	**30.1**	**13.1**	**18.7**	**P = 100 %**	**6.7**	**24.7**	**26.9**	**7.9**	**Absent (or weak)**	**90.6**	**10.5**
	Min	95.5	44.6	50.3	47.2	28.1	12.2	16.9		5.2	24.1	26.2	6.9		86.9	9.7
	SD	2.5	1.8	1.0	1.9	1.2	0.6	0.7		0.7	0.4	0.4	0.7		2.6	0.5
Aythya nyroca	Max	89.0	43.0	46.0	46.0	27.5	11.9	18.2		7.1	23.1	24.7	8.6		79.3	8.6
	Ø	**85.4**	**40.9**	**44.5**	**43.9**	**25.9**	**10.8**	**16.5**	**P = 80 %**	**5.8**	**22.2**	**23.7**	**8.2**	**Absent**	**76.2**	**7.9**
	Min	80.7	38.3	42.4	40.9	24.2	9.8	13.8	D = 20 %	5.1	21.5	22.8	7.8		71.0	7.2
	SD	2.3	1.2	1.1	1.4	0.9	0.6	1.3		0.6	0.5	0.5	0.2		2.2	0.4
Aythya fuligula	Max	97.0	45.9	51.1	50.8	27.8	13.7	22.0		7.6	24.1	26.1	8.3		88.6	10.9
	Ø	**87.7**	**40.3**	**47.4**	**44.9**	**25.6**	**11.6**	**19.3**	**D = 70 %**	**6.8**	**22.3**	**24.7**	**7.6**	**Absent or weak**	**78.4**	**9.0**
	Min	83.9	37.4	44.8	41.9	23.9	10.7	17.9	P = 30 %	6.2	21.2	23.9	7.2		74.6	8.3
	SD	3.4	2.1	1.5	2.2	1.1	0.8	1.1		0.5	0.8	0.7	0.3		3.7	0.7
Aythya marila	Max	99.1	46.1	53.0	51.5	28.5	13.8	21.5		8.9	24.5	28.8	7.5		91.6	11.7
	Ø	**95.5**	**44.0**	**51.5**	**49.3**	**26.9**	**13.0**	**20.0**	**D = 100 %**	**7.7**	**23.4**	**26.8**	**7.0**	**Distinct or weak**	**87.0**	**10.3**
	Min	89.6	41.4	48.2	45.6	25.2	12.3	18.3		5.9	22.1	25.1	6.3		80.9	9.0
	SD	2.7	1.4	1.4	1.7	1.0	0.5	1.2		1.0	0.7	1.0	0.4		3.1	0.7
Somateria mollissima	Max	130.6	58.7	73.2	61.9	26.9	25.7	26.0		10.1	28.8	34.9	8.5		120.5	17.2
	Ø	**125.7**	**56.0**	**69.7**	**59.1**	**25.7**	**23.0**	**24.0**	**C = 50 %**	**8.7**	**27.7**	**32.6**	**7.8**	**Distinct**	**114.2**	**15.5**
	Min	120.5	53.5	66.8	56.5	24.4	21.5	22.6	P = 50 %	7.3	26.8	30.5	6.4		107.9	14.6
	SD	3.0	1.8	2.0	1.6	0.9	1.1	1.2		0.9	0.5	1.3	0.7		3.3	0.7

		Skull			Upper Bill						Cranium				Lower Bill	
		TL	UBL	CL	TOL	PL	NL	BWUB	UBS	UBH	CH	CW	SOW	SG	LBL	LBH
	Max	83.1	32.0	51.4	39.4	16.0	14.1	17.4		8.3	21.4	27.0	6.0		75.5	8.0
Clangula hyemalis	**Ø**	**79.5**	**30.6**	**48.9**	**37.2**	**15.2**	**13.0**	**16.5**	**P = 100 %**	**7.4**	**20.6**	**25.7**	**5.2**	**Distinct**	**72.2**	**7.4**
	Min	75.2	28.4	46.4	34.8	14.3	12.0	15.4		6.6	19.8	24.4	4.7		68.4	6.9
	SD	2.7	1.1	1.8	1.5	0.6	0.5	0.6		0.6	0.5	0.7	0.4		2.4	0.3
	Max	92.9	38.2	55.9	44.2	15.7	15.7	20.9		9.8	27.7	28.9	17.1		81.5	10.1
Bucephala clangula	**Ø**	**86.1**	**34.4**	**51.7**	**40.7**	**14.4**	**13.7**	**18.9**	**P = 80 %**	**8.6**	**25.5**	**27.0**	**13.1**	**Absent**	**75.6**	**8.8**
	Min	80.5	31.4	48.2	37.6	13.2	12.2	16.7	C = 20 %	7.1	23.2	25.6	11.2		69.8	7.9
	SD	4.8	2.3	2.7	2.7	0.7	1.0	1.4		0.8	1.5	1.2	2.0		4.8	0.8
	Max	114.7	55.8	59.5	62.7	28.8	17.1	27.0		8.3	27.4	30.3	10.3		106.8	12.8
Melanitta fusca	**Ø**	**108.5**	**51.8**	**56.6**	**58.4**	**26.6**	**16.3**	**24.2**	**P = 80 %**	**7.4**	**26.1**	**29.0**	**8.9**	**Distinct**	**99.7**	**11.4**
	Min	100.3	47.3	53.1	53.8	23.9	15.5	21.8	D = 20 %	6.6	24.8	27.2	7.7		92.8	10.2
	SD	5.5	3.5	2.2	3.5	1.8	0.5	1.9		0.7	1.0	1.1	0.7		5.4	0.9
	Max	103.7	50.8	52.9	56.2	24.9	14.8	22.6		7.9	26.4	28.3	8.5		96.8	11.1
Melanitta nigra	**Ø**	**97.3**	**45.8**	**51.4**	**51.3**	**22.5**	**13.5**	**20.5**	**P = 90 %**	**5.6**	**24.9**	**26.8**	**7.1**	**Distinct**	**89.8**	**10.6**
	Min	91.8	41.5	48.9	47.3	20.7	12.5	17.0	C = 10 %	4.1	23.8	25.3	6.0		82.6	9.8
	SD	4.0	2.9	1.2	3.0	1.4	0.8	1.7		1.2	0.7	0.9	0.7		4.5	0.4
	Max	78.9	38.3	41.6	35.0	17.5	11.9	12.1		2.6	20.6	25.2	7.6		70.3	8.3
Mergellus albellus	**Ø**	**75.2**	**35.9**	**39.3**	**32.5**	**16.6**	**10.6**	**11.6**	**C = 100 %**	**2.3**	**19.9**	**23.7**	**6.5**	**Absent**	**66.1**	**7.6**
	Min	70.0	32.4	37.5	29.4	15.0	9.3	9.8		2.0	19.4	22.7	5.8		59.2	5.8
	SD	2.9	1.8	1.2	1.7	0.8	0.9	0.7		0.2	0.4	0.7	0.6		3.5	0.7
	Max	118.5	72.3	47.4	66.8	45.0	17.1	14.5		2.5	20.4	30.0	7.5		114.4	8.6
Mergus serrator	**Ø**	**108.4**	**64.0**	**44.4**	**60.2**	**39.1**	**14.7**	**13.0**	**C = 100 %**	**2.3**	**19.9**	**27.3**	**6.6**	**Absent**	**103.5**	**7.7**
	Min	97.7	56.0	41.7	51.4	34.1	13.2	11.5		2.1	19.2	25.5	6.0		90.4	6.9
	SD	6.7	5.2	1.7	4.9	3.4	1.1	0.9		0.2	0.4	1.2	0.5		7.3	0.5
	Max	124.0	70.6	54.1	64.4	36.8	18.3	17.5		2.8	22.3	32.2	12.5		117.4	10.6
Mergus merganser	**Ø**	**115.6**	**64.4**	**51.1**	**59.5**	**33.6**	**16.4**	**15.3**	**C = 100 %**	**2.3**	**21.1**	**30.7**	**11.4**	**Mostly weak**	**109.0**	**9.1**
	Min	103.4	55.6	47.0	51.6	28.7	14.1	13.0		1.9	19.8	29.1	9.4		96.3	7.5
	SD	8.2	5.6	2.7	5.2	3.0	1.4	1.6		0.3	0.8	1.1	0.9		8.0	1.1
	Max	85.7	40.7	45.7	43.9	22.4	15.8	18.5		7.5	22.5	23.5	8.5		77.1	9.7
Oxyura jamaicensis	**Ø**	**82.7**	**38.1**	**44.6**	**41.7**	**21.2**	**14.4**	**17.5**	**D = 100 %**	**6.1**	**21.1**	**22.8**	**6.2**	**Absent**	**74.6**	**8.7**
	Min	79.8	36.2	43.6	39.8	20.0	13.0	16.5		4.9	20.2	22.3	5.5		72.5	8.1
	SD	1.6	1.3	0.7	1.1	0.8	0.7	0.6		0.7	0.6	0.5	0.8		1.4	0.4

3 Identification key

The complete data set of all 37 species (each based on 10 specimens) is presented in Tab. 2.

1 Upper bill narrow, < 9 mm wide (measured in the middle of the bill between tip and naris). ..... (M e r g i n i) **2**
– Upper bill broadened, duck- or goose-like, > 9 mm wide..... **4**
2 Premaxillary anterior to naris relatively short: PL < 1.5 times NL (Fig. 5a); UBL < 40 mm. – Fig. 44..... ***Mergellus albellus***
– Premaxillary anterior to naris relatively long: PL > 2 times NL (Fig. 5b, c); UBL > 40 mm. **3**
3 SOW < 7.5 mm; PL (Ø 39.1 mm) about 2.5 times NL (Ø 14.7 mm); bill tip slightly down curved (Fig. 5c). – Fig. 45. ..... ***Mergus serrator***
– SOW > 9 mm; PL (Ø 33.6 mm) about 2 times NL (Ø 16.4 mm); bill tip often distinctly down curved (Fig. 5b). – Fig. 46. ..... ***Mergus merganser***
4 UBL > 140 mm and length of lacrimal (cf. Fig. 3) > 25 mm. [In large geese (*Anser*), the cross-section of the premaxillary is thickened and spongious, whereas in *Cygnus* it is flattened; *Cygnus atratus* (only a single skull studied): UBL ca. 142 mm, length of lacrimal ca. 23 mm, SG distinct]. .... (A n s e r i n i : *Cygnus*) **5**
– UBL < 140 mm and length of lacrimal < 23 mm. **7**
5 Braincase flattened in lateral view, dorsal roof of the braincase with a slight transverse depression dorsally (Fig. 3a); protrusion above the bill usually present (particularly in males); processus orbitalis of lacrimal without rostral extension. – Fig. 8. ..... ***Cygnus olor***
– Braincase rounded in lateral view and without a transverse depression dorsally (Fig. 3b); protrusion above the bill absent or slightly developed; processus orbitalis of lacrimal with rostral extension. **6**
6 Bill long: TOL mostly > 85 mm (86–102 mm), PL 38.9–50.0 mm; processus orbitalis of lacrimal with a wide constriction (width of constriction 6.5–10.0 mm) (Fig. 3b). – Fig. 9. ..... ***Cygnus cygnus***
– Bill shorter: TOL mostly < 85 mm (75–86 mm), PL 33.6–38.9 mm; processus orbitalis of lacrimal with a narrow

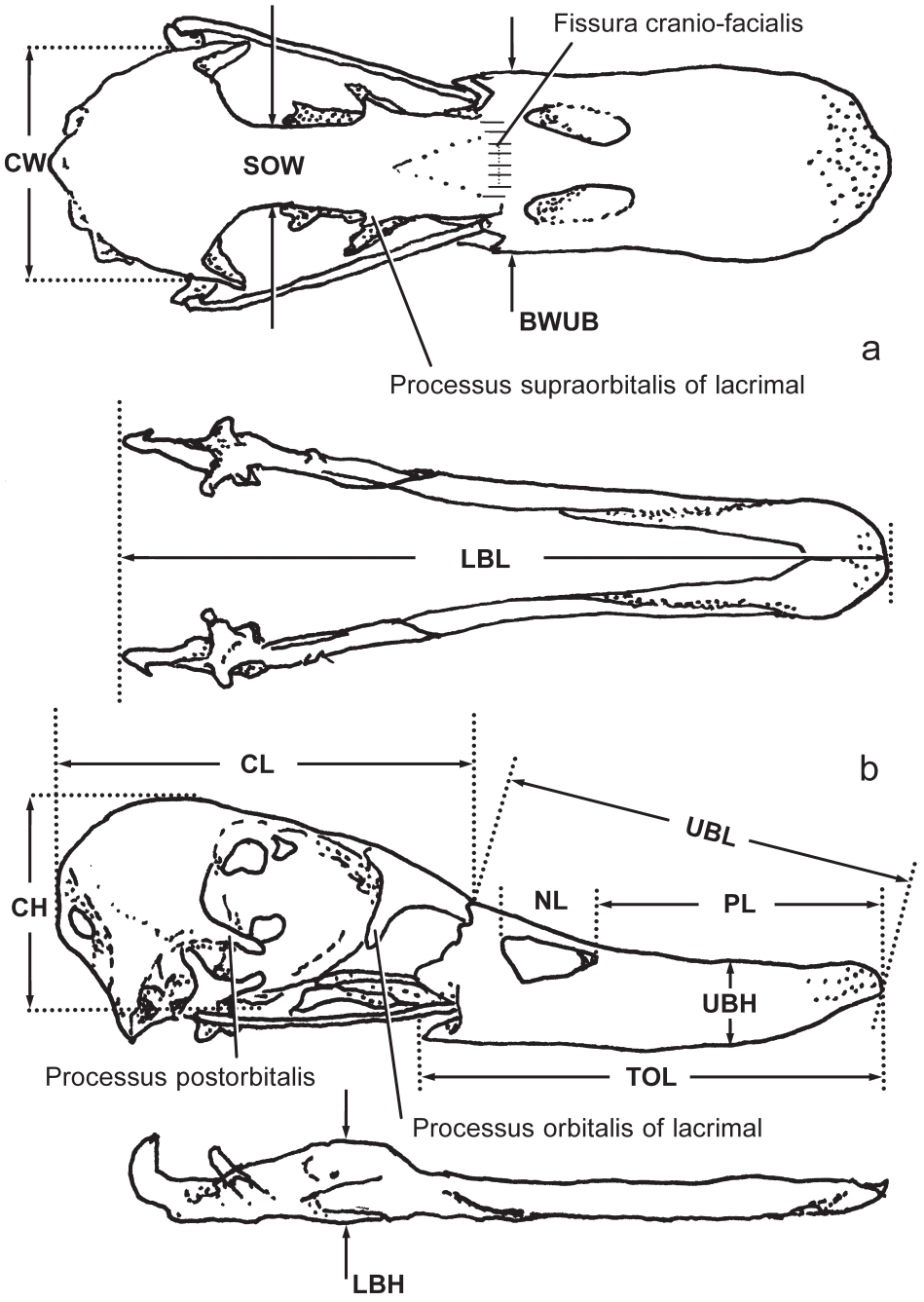


Fig. 1. Measurements of a duck skull (*Aythya fuligula*) in (a) dorsal and (b) lateral view. – For abbreviations see chapter 2.

constriction (width of constriction 4.5–7.0 mm). – Fig. 10. ... . ***Cygnus bewickii***

7 Skull with at least two of the following three features: Edges of upper bill convergent in dorsal view; lower edge of upper bill in lateral view concave over nearly its entire length; premaxillary anterior to naris entirely filled with inner spongy bone structure and bill tip curved rostrally. .... (A n s e r i n i) **8**

– Skull with at least two of the following three features: Edges of upper bill parallel or divergent in dorsal view; lower edge of upper bill straight or convex in lateral view; premaxillary anterior to naris single-layered at least in some lateral parts. **16**

8 Processus supraorbitalis of lacrimal (cf. Fig. 1) slightly developed or blunt; SG always absent (Fig. 4a) (*Anser*). [Processus supraorbitalis may be distinct in domestic breeds of *Anser anser*, wild relatives have a maximum TL of 135 mm.]..... **9**

– Processus supraorbitalis of lacrimal distinct and curved backwards; SG distinct or slightly developed (Fig. 4b). ..... (*Branta*) **13**

9 Frontal region posterior to the fissura cranio-facialis medially slightly bulged in the midline (Fig. 7a, b). **10**

– Frontal region posterior to the fissura cranio-facialis straight or concave (Fig. 7c–e)..... **11**

10 TOL 32–38 mm (see also Fig. 7a). – Fig. 14..... ***Anser erythropus***

– TOL 43–51 mm (see also Fig. 7b). – Fig. 13.... ***Anser albifrons***

11 PL 19–24 mm; culmen above the naris convex (Fig. 7e). – Fig. 12. ..... ***Anser brachyrhynchus***

– PL > 26 mm..... **12**

12 Basal width of premaxillary 15–18 mm (measured at the anterior end of nares); NL 19–24 mm (Fig. 7d). – Fig. 11. ..... ***Anser fabalis***

– Basal width of premaxillary 18–21 mm; NL 21–27 mm (Fig. 7c). – Fig. 15..... ***Anser anser***

13 TOL > 50 mm. – Fig. 16. ..... ***Branta canadensis***

– TOL > 45 mm..... **14**

14 TL < 80 mm. – Fig. 19..... ***Branta ruficollis***

– TL > 80 mm. **15**

15 SG distinct; CH 23–26 mm. – Fig. 18. ..... ***Branta bernicla***

– SG weakly developed or absent; CH 25–29 mm. – Fig. 17.... ***Branta leucopsis***

16 Processus supraorbitalis of lacrimal prominent, spine-shaped (Figs. 36, 43); edges of upper bill divergent and NL > 12 mm; SG mostly distinct. ..... (M e r g i n i without *Mergus*, *Mergellus*, and *Bucephala*) **17**

– Processus supraorbitalis of lacrimal not prominent (if prominent, as occasionally in *Aythya marila* and *A. fuligula*, then edges of upper bill divergent and NL < 15 mm); SG mostly absent..... **19**

17 TL < 85 mm. – Fig. 37..... ***Clangula hyemalis***

– TL > 120 mm. – Fig. 36..... ***Somateria mollissima***

– TL 90–115 mm. ..... (*Melanitta*) **18**

18 Minimum distance between nostrils > 2.5 mm; males with lateral protuberances near bill base. – Figs. 40, 41. ..... ***Melanitta fusca***

– Minimum distance between nostrils < 2.5 mm; males with a pair of distinct protuberances between the nares and the fissura cranio-facialis. – Figs. 42, 43..... ***Melanitta nigra***

19 Processus orbitalis of lacrimal elongated, sword-shaped, reaches or extends beyond the vertical axis through the centre of the orbit; premaxillary anterior to naris nearly as long as naris. – Figs. 38, 39..... ***Bucephala clangula***

– Processus orbitalis of lacrimal thin or with broadened tip, never reaches the vertical axis through the centre of the orbit; premaxillary anterior to naris at least 1.5 times NL. .. **20**

20 Upper bill flattened, its edges divergent and bill tip conspicuously upturned; PL ca. 1.5 times NL; processus orbitalis of lacrimal short, blunt; posterior edge of orbit conspicuously rounded. – Fig. 47. ..... ***Oxyura jamaicensis***

– Upper bill shaped differently; PL at least 2 times NL; processus orbitalis of lacrimal elongated; posterior edge of orbit (except in *Tadorna tadorna*) not conspicuously rounded..... **21**

21 Bill narrow, i. e. < 13 mm wide in rostral third of the bill a n d bill edges convergent; SOW < 7.3 mm. – Fig. 23. ..... ***Aix galericulata***

– Bill relatively wide, i. e. width in rostral third of the bill > 13 mm (if < 13 mm, then upper bill edges not convergent); SOW > 7.3 mm..... **22**

22 Upper and lower bill entirely upturned; posterior edge of orbit conspicuously rounded. – Fig. 22..... ***Tadorna tadorna***

– Upper and lower bill not conspicuously upturned; posterior edge of orbit not conspicuously rounded. **23**

23 Braincase stout, CW > 29 mm; bill goose-like, i. e. edges slightly convergent and curved at bill tip; front very wide in lacrimal area (Fig. 2). – Fig. 20..... ***Alopochen aegyptiaca***

– Braincase less stout, CW < 29 mm; bill duck-like, i. e. ± flattened at bill tip (sometimes slightly curved in nail region); front less wide in lacrimal area..... **24**

24 Processus orbitalis of lacrimal narrow, its edges parallel or pointed apically. ..... (A y t h i n i) **25**

– Processus orbitalis of lacrimal apically plane and broadened..... (A n a t i n i + *Tadorna ferruginea*) **29**

25 Upper bill very flat, edges convergent, bill tip acuminate, BWUB > 21 mm. – Fig. 31. ..... ***Netta rufina***

– Upper bill edges parallel or divergent, BWUB < 21 mm..... (*Aythya*) **26**

26 Upper bill edges parallel a n d TOL > 47 mm. – Fig. 32. ..... ***Aythya ferina***

– Upper bill edges divergent (if parallel then TOL < 47 mm).. **27**

27 Maximum upper bill width < 20 mm; ridge between nares and bill tip rather flattened, < 7.1 mm high. – Fig. 33. ..... ***Aythya nyroca***

– Maximum upper bill width > 20 mm; ridge between nares and bill tip less flattened, usually > 7.1 mm high..... **28**

28 TL < 89 mm; width of fissura cranio-facialis < 11 mm; SG absent or very slightly developed; processus supraorbitalis of lacrimal mostly small. – Fig. 34..... ***Aythya fuligula***

– TL > 89 mm; width of fissura cranio-facialis > 11 mm; SG usually conspicuous; processus supraorbitalis of lacrimal mostly elongated. – Fig. 35..... ***Aythya marila***

29 TL < 90 mm. **30**

– TL > 90 mm. **32**

30 CW > 22 mm, CH > 21 mm; processus supraorbitalis of lacrimal distinct. – Fig. 24..... ***Anas penelope***

– CW < 22 mm, CH < 21 mm; processus supraorbitalis of lacrimal short. **31**

31 Upper bill slightly diverging; maximum upper bill width 13.6–16.3 mm. – Fig. 29. ..... ***Anas querquedula***

– Upper bill edges parallel; maximum upper bill width 12.3–13.6 mm. – Fig. 26..... ***Anas crecca***

32 Bill extremely widened rostrally; maximum bill width 27–33 mm. – Fig. 30..... ***Anas clypeata***

– Bill edges at most slightly divergent; maximum bill width < 25 mm. **33**

33 CH < 22.5 mm; rostral ventral edge of lacrimal and processus orbitalis meet at a distinct angle (ca. 100°, see arrow in Fig. 6a). – Fig. 25..... ***Anas stepera***

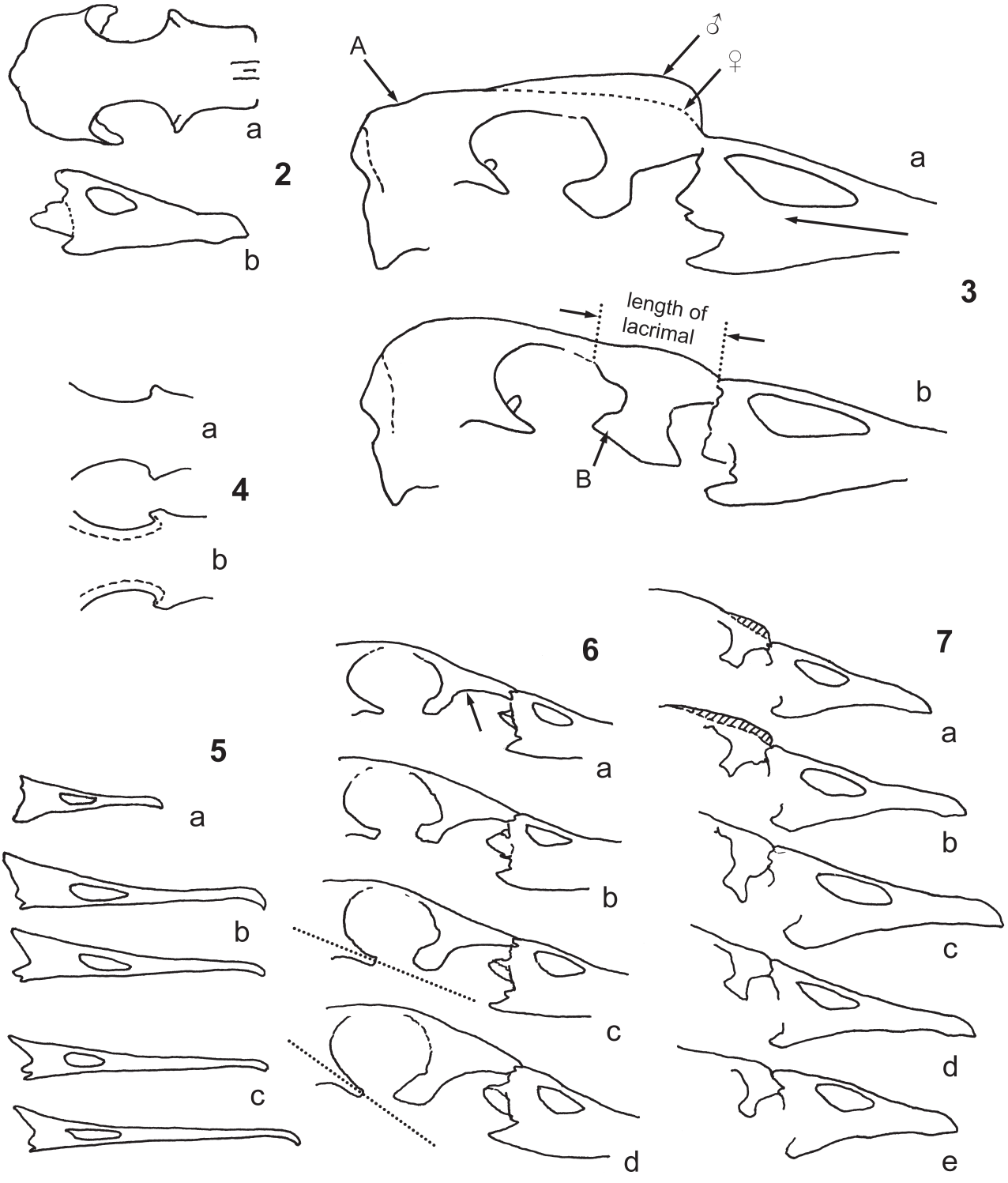
– CH > 22.5 mm; rostral ventral edge of lacrimal and processus orbitalis meet in a slight curve (Fig. 6b–e). **34**

34 Dorsal contour of lacrimal slightly convex in lateral view; longitudinal axis of processus postorbitalis directed below the posterior extension of the tomium (Fig. 6d); PL < 31 mm. – Fig. 21..... ***Tadorna ferruginea***

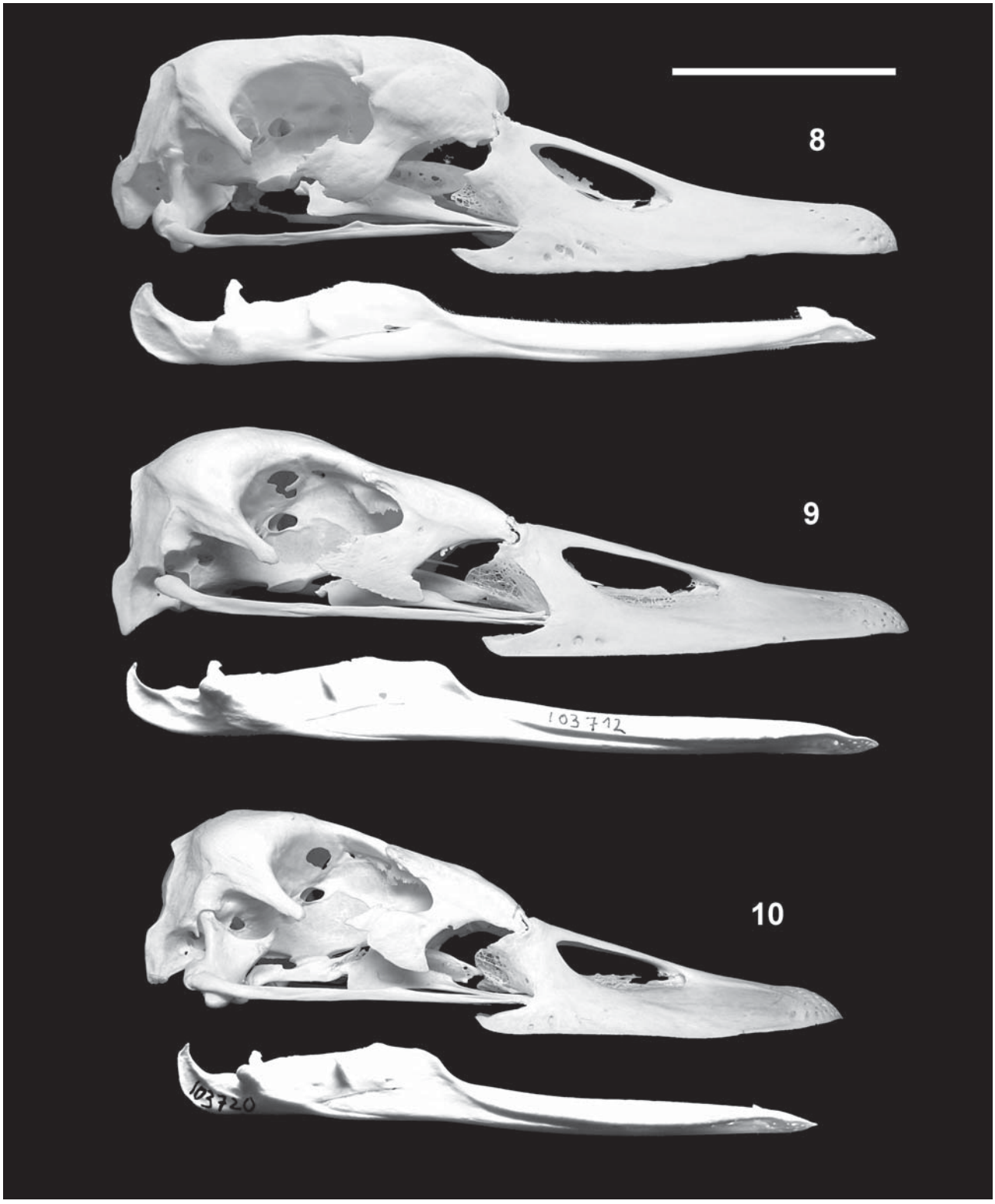
– Dorsal contour of lacrimal straight or protruding only posteriorly in lateral view; processus postorbitalis projects more caudally towards the posterior extension of the tomium (Fig. 6c); PL > 31 mm..... **35**

35 BWUB > 18 mm; dorsal contour of lacrimal straight in lateral view (Fig. 6c). – Fig. 27..... ***Anas platyrhynchos***

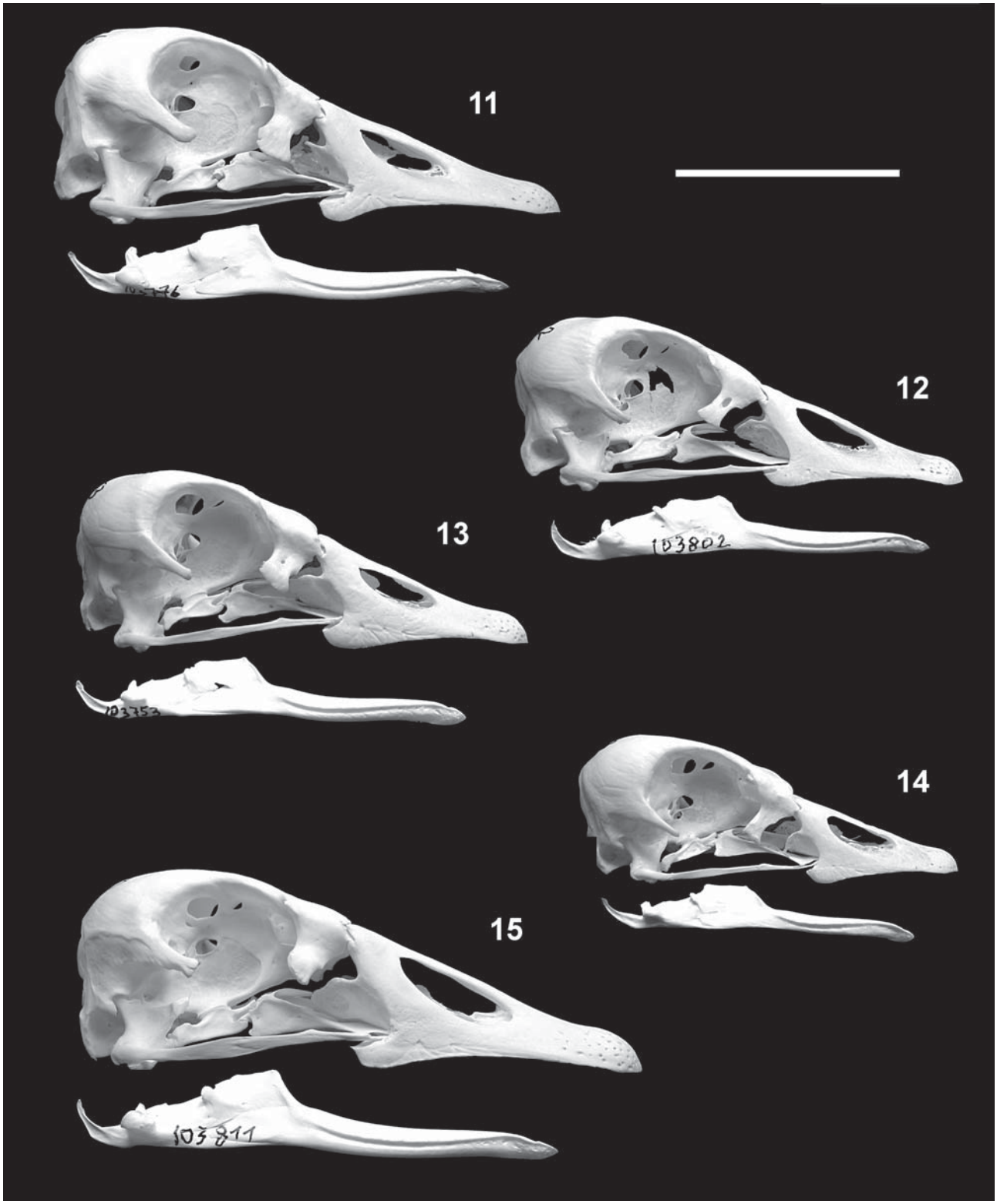
– BWUB < 18 mm; dorsal contour of lacrimal slightly convex in lateral view (Fig. 6b). – Fig. 28..... ***Anas acuta***



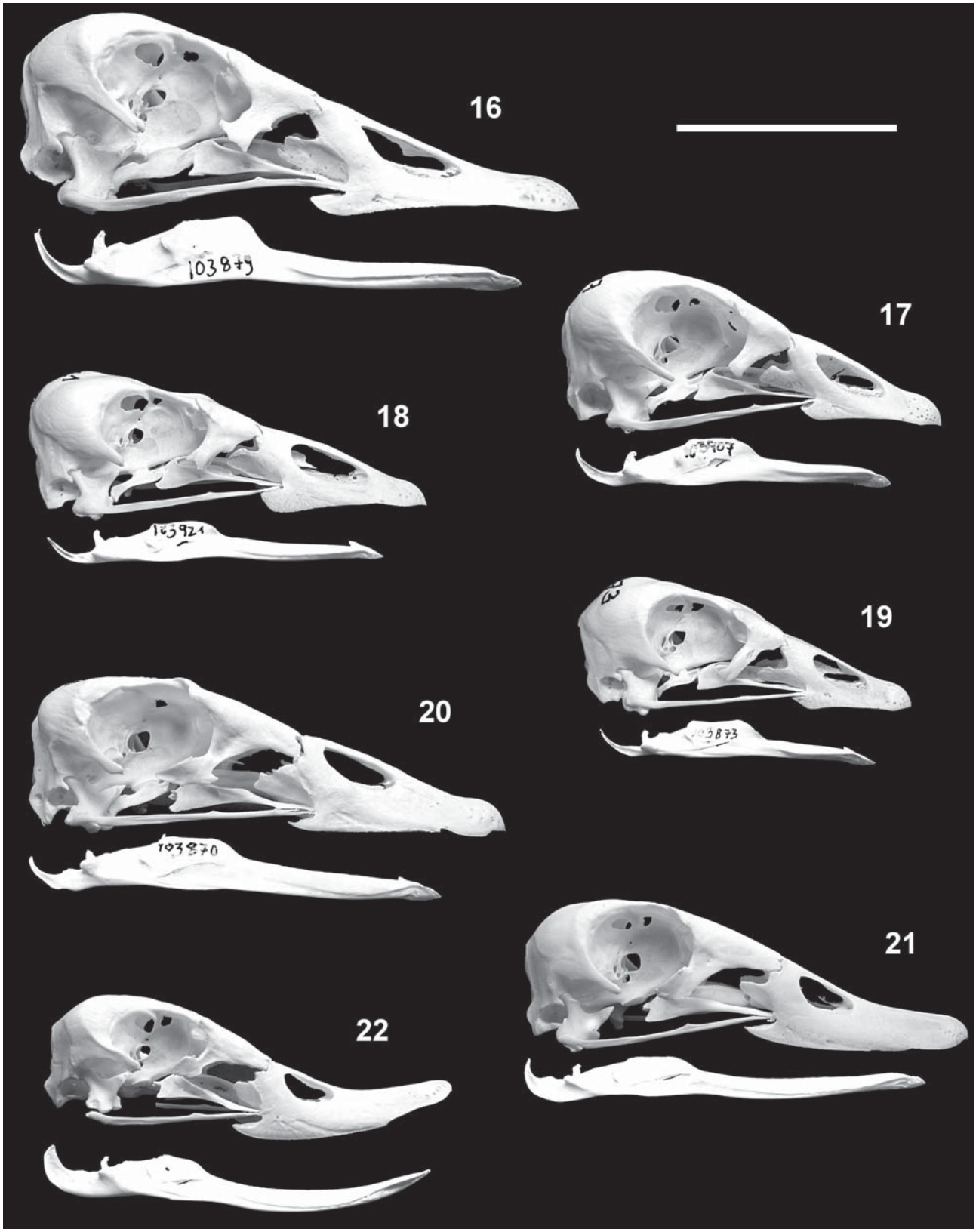
Figs. 2–7. Details of skulls of Anseriformes. – **2**. *Alopochen aegyptiaca*, (a) cranium in dorsal view, (b) upper bill. **3**. Cranium and basal part of upper bill of (a) *Cygnus olor* and (b) *C. cygnus* [A = transverse depression, B = rostral extension of processus orbitalis]. **4**. Interorbital isthmus, (a) without (*Anser*) and (b) with (*Branta*) salt gland fossa. **5**. Upper bills of (a) *Mergellus albellus*, (b) *Mergus merganser* (with variation), (c) *M. serrator* (with variation). **6**. Lacrimal region of (a) *Anas stepera*, (b) *A. acuta*, (c) *A. platyrhynchos*, (d) *Tadorna ferruginea*. **7**. Upper bill of (a) *Anser erythropus*, (b) *A. albifrons*, (c) *A. anser*, (d) *A. fabalis*, (e) *A. brachyrhynchus.*



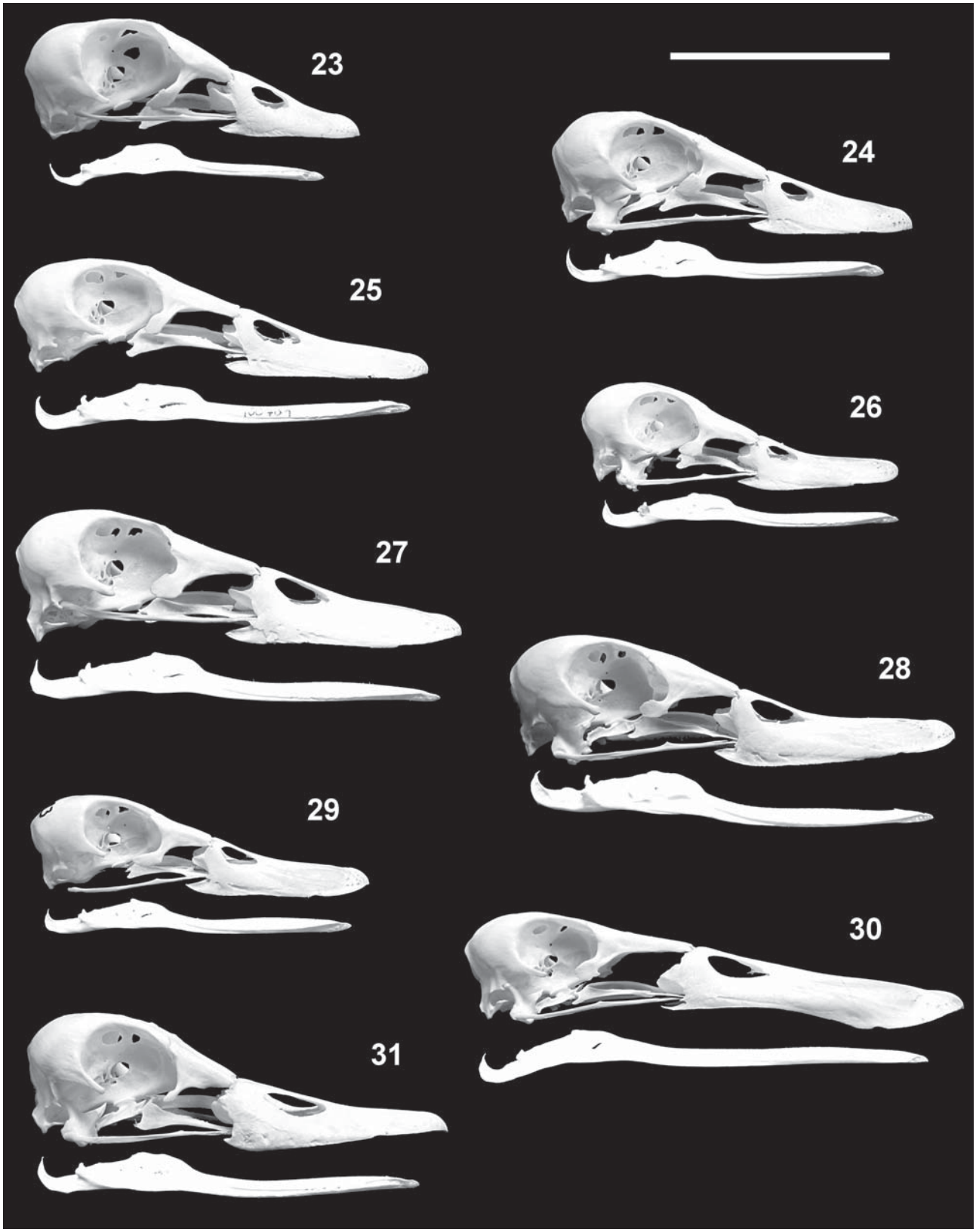
Figs. 8–10. Skulls of Anseriformes, lateral view. – **8**. *Cygnus olor*. **9**. *C. cygnus*. **10**. *C. bewickii*. – Scale: 5 cm.



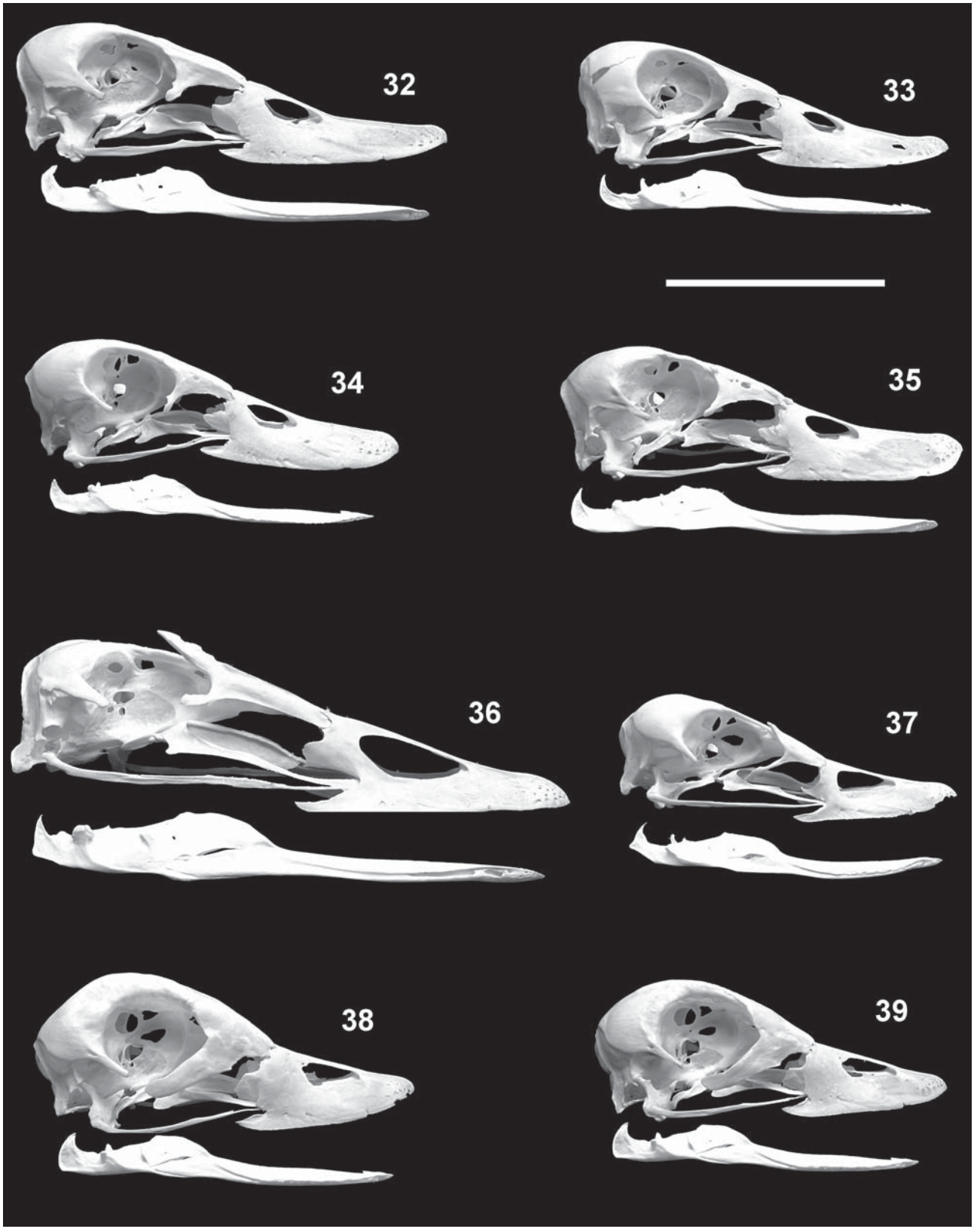
Figs. 11–15. Skulls of Anseriformes, lateral view. – **11**. *Anser fabalis*. **12**. *A. brachyrhynchus*. **13**. *A. albifrons*. **14**. *A. erythropus*. **15**. *A. anser*. – Scale: 5 cm.



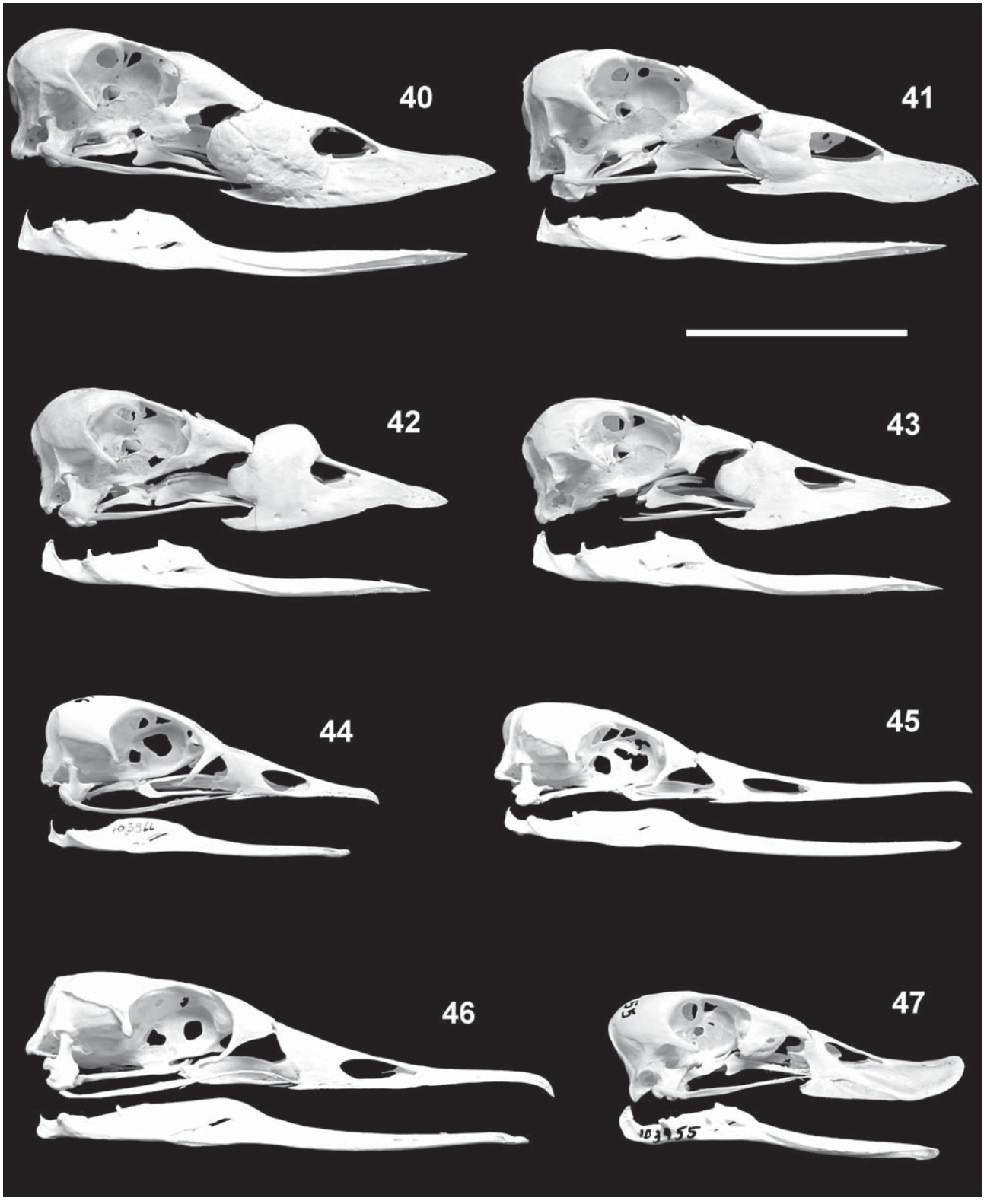
Figs. 16–22. Skulls of Anseriformes, lateral view. – **16**. *Branta canadensis*. **17**. *B. leucopsis*. **18**. *B. bernicla*. **19**. *B. ruficollis*. **20**. *Alopochen aegyptiaca*. **21**. *Tadorna ferruginea*. **22**. *T. tadorna*. – Scale: 5 cm.



Figs. 23–31. Skulls of Anseriformes, lateral view. – **23**. *Aix galericulata*. **24**. *Anas penelope*. **25**. *A. stepera*. **26**. *A. crecca*. **27**. *A. platyrhynchos*. **28**. *A. acuta*. **29**. *A. querquedula*. **30**. *A. clypeata*. **31**. *Netta rufina*. – Scale: 5 cm.



Figs. 32–39. Skulls of Anseriformes, lateral view. – **32**. *Aythya ferina*. **33**. *A. nyroca*. **34**. *A. fuligula*. **35**. *A. marila*. **36**. *Somateria mollissima*. **37**. *Clangula hyemalis*. **38**. *Bucephala clangula* ♂. **39**. *B. clangula* ♀. – Scale: 5 cm.



Figs. 40–47. Skulls of Anseriformes, lateral view. – **40**. *Melanitta fusca* ♂. **41**. *M. fusca* ♀. **42**. *M. nigra* ♂. **43**. *M. nigra* ♀. **44**. *Mergellus albellus*. **45**. *Mergus serrator*. **46**. *M. merganser*. **47**. *Oxyura jamaicensis*. – Scale: 5 cm.

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