SKULL OF THE GREY HERON (*Ardea cinerea*): DETAILED INVESTIGATION OF THE ORBITAL REGION

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With 8 Figures
Running title: Heron skull

Summary

The skull of the grey heron (*Ardea cinerea*) was examined with an emphasis on describing the orbital region. In the young (circa sixteen to seventeen days old) heron, the frontal bone (*os frontale*) and nasal bone (*os nasale*) comprised separate paired bones, connected by sutures (*sutura interfrontalis*, *sutura internasalis*, *sutura frontonasalis plana*). In adult animals, the relationship between these bones was different: the left and right frontal bone and the left and right nasal bone had grown together, and the frontal bone and nasal bone had fused into a common frontonasal bone (*os frontonasale*). In the ectethmoid bone (*os ectethmoidale*) the main components comprised of the orbital and antorbital part of the ectethmoid plate (*lamina ectethmoidalis orbitalis et antorbitalis*), the lateral process (*processus lateralis ectethmoidalis*) and the tubercle (*tuberculum ectethmoidalis*); the left and right ectethmoid plates were fused together to form the ectethmoid sinus (*sinus ectethmoidalis*) between them. In the young heron, the anatomical and functional link between the frontal and lacrimal bones did not exist yet, nor did the osseous frame of the ectethmoid-lacrimal complex. Further research into the young heron skulls is needed. This article provides novel insights into the grey heron's orbital region.

Key words: ectethmoid bone; ectethmoid sinus; frontal bone; frontonasal bone; lacrimal bone; nasal bone; orbital region

Introduction

Herons are members of the family Ardeidae (order Pelecaniformes), and the majority of extant species are in the subfamily Ardeinae, known as true or typical herons. The grey heron (*Ardea cinerea* Linnaeus, 1758) is closely related and similar to the great blue heron (*Ardea herodias* Linnaeus, 1758), as well as to the cocoi heron (*Ardea cocoi* Linnaeus, 1766). The subfamily Ardeinae also includes the great white heron (*Ardea alba* Linnaeus, 1758). Four subspecies of the grey heron have been recognized: *A. c. cinerea* in Europe, Africa and western Asia, *A. c. jouyi* Clark, 1907 (found in eastern Asia), *A. c. firasa* Hartert, 1917 (found in Madagascar) and *A. c. monicae* Jouanin and Roux, 1963 (found on islands off Banc d'Arguin, Mauritania). The grey heron is a large bird, standing up to 100 cm tall, measuring 84–192 cm long and with a 155–195 cm wingspan. The body weight can range from 1020 g to 2073 g. The grey heron is carnivorous, feeding mainly on fish, but diet varies with habitat and season, and the species is considered highly opportunistic (for example it has been observed retrieving locusts) (Martinez-Vilalta et al., 2016).

Anatomically, in the frontal bone (*os frontale*), three surfaces are distinguished: the cerebral (*facies cerebralis*), dorsal (*facies dorsalis*) and orbital (*facies orbitalis*) (Baumel and Witmer, 1993). Herons typically have a frontal bone with a longitudinal dorsal frontal concavity (*depressio frontalis*). The ectethmoid bone (*os ectethmoidale*) of the heron was partiallly described by Adams (1955). Moreover, Payne and Risley (1976) accurately described the ectethmoid lateral process (*processus lateralis ectethmoidalis*) and the ventral ectethmoid tubercle (*tuberculum ectethmoidalis*), as well as the ectethmoid-lacrimal complex. While analyzing the skull of grey herons the data described in the works of Shufeldt (1889), Baumel and Witmer (1993), Livezey and Zusi (2006) and Hieronymus and Witmer (2010) were also considered. A more recent publication (Atalgin et al., 2014) also describes the skeletal components of grey heron’s skull.

This study expands upon our previous work (Golob et al., 2016), in which dimensions of several bones (scapula, coracoid, humerus, ulna, femur and tibiotarsus) of the adult grey herons were measured and their lengths compared to the results in the work performed by Kellner (1986). In the present study we were particularly concerned with evaluating the

relationships between the bones of orbital area and in comparing the skeletons of a young (around sixteen to seventeen days of age) grey heron with adult specimens.

Materials and Methods

The skulls of four adult and young grey herons (*Ardea cinerea*), as well as one from an adult white heron (*Ardea alba*) were used in this study. The young heron had a weight of 740 g, which corresponds to the age of 16-17 days (Creutz, 1981). Their sexes were unknown. Among the adult grey herons two were kept in the Slovenian Museum of Natural History, Ljubljana, Slovenia, and the others were from the Department of Biology, Faculty of Natural Sciences and Mathematics, University of Maribor, Slovenia. The skeletons in zoological collection of the Department of Biology were prepared from herons found naturally deceased and collected in localities around Maribor. The soft tissues of the adult specimens were cleaned by dermestes beetle larvae (Dermestidae), whilst the soft tissue from the skull of the young specimen was carefully macerated (McDonald, 2006). The living grey heron (Fig 1A) was found injured, brought to a shelter (Asylum for protected wild animals, Muta, Slovenia; Animal evidence number: 0006050/015), successfully cured and returned to the wild. The study complies with all national and governement ethical guidlines.

Photographs of the skull were taken by the author Golob using a digital camera, and presented using the Adobe InDesign CS6 for primary and Adobe Photoshop CS6 for secondary step of the procedure.

The anatomical descriptions were made by direct observation. The anatomical nomenclature followed the Nomina Anatomica Avium (Baumel and Witmer, 1993).

Results

The grey heron's upper jaw was surrounded by maxillary ramphotheca (*ramphotheca maxillae*) from the apex of the beak to the craniofacial hinge (*zona flexoria craniofacialis*) and then extending to some extent latero-caudally (Fig. 1A). The ramphotheca was interrupted to accommodate for the nostrils (*nares*). From the rostral corner of the nasal aperture (*apertura nasi ossea*) towards the apex of the beak, a longitudinal nasolabial groove (*sulcus nasolabialis*) (Figs. 1A, B) was observed.

The orbital region (Fig. 1B) was limited mostly by the frontal bone (*os frontale*; dorsally and incompletely caudally), the laterosphenoid bone (*os laterosphenoidale*; the larger part of the caudal wall), the ectethmoid bone (*os ectethmoidale*; rostrally) and the lacrimal bone (*os*

lacrimale; rostrolaterally). The lacrimal bone was relatively wide and extended ventrally towards the outer edge of the jugal arch (Fig. 1, aj).

The frontal bone (*os frontale*) formed four lateral extensions: the *processus lacrimalis*, *angulus supraorbitalis rostralis*, *angulus supraorbitalis caudalis* and *processus postorbitalis* (its dorsolateral part). The left and right orbits were separated by the interorbital septum (*septum interorbitale*); it included the mesethmoid bone (*os mesethmoidale*). The mesethmoid bone extended ventrally and caudally in the supraorbital area and formed a connection with the orbital processes of the left and the right laterosphenoid bones. Superior to this connection was the supraorbital fontanelle (*fonticulus supraorbitalis*) (Fig. 1B, fonts). The supraorbital fontanelle was located in both halves of the orbit (i.e., on both the left and the right) and went from each orbitocranial opening into the cranial cavity (*fonticuli orbitocraniales*). In the caudal area of the interorbital fontanelle (Fig. 1B, fonti), a single passage into the cranium, the *foramen opticus* (Fig. 8, fo), was located.

The skull of the young grey heron (Fig. 2B) was shorter than in the adult specimens, but its breadth at the level of postorbital processes was almost the same as in the adult grey heron (Fig. 2A). The fontanelles *fonticulus frontonasalis* and *fonticulus frontoparietalis* were present (Fig. 2, fontfn and fontfp), as well as the areas of the interfrontal suture (*sutura interfrontalis*) and interparietal suture (*sutura interparietalis*). The right frontal bone (Fig. 2B, ofd) was removed from its initial position and placed on the nasal bone to show its contact surface with the nasal bone (*facies nasalis frontalis*, Fig. 2B, fnt). The frontal bone was classified into two main areas: the *pars cerebralis* and *pars orbitalis* (see below, Fig. 5).

The frontal bone was thinner in the area in contact with the nasal bone, and on its dorsal surface the nasal bone impression could be observed (*impressio nasalis*, Fig. 2B, fnf). In this area during later development, it had joined with the nasal bone (*sutura frontonasalis plana*), and a unified frontonasal bone (*os frontonasale*) had been formed (Fig. 8, ofn). The right and left nasal bones (*os nasale dextrum et sinistrum*) fitted laterally to the frontal process of the premaxillary bone (*processus frontalis premaxillare*, Fig. 3, pfpr). Rostrally, the nasal bones extended two processes: the premaxillary (*processus premaxillaris*, Fig. 3, pprn) and maxillary (*processus maxillaris*, Fig. 3, pmn). These define the rostral part of the entrance to the nasal cavity (*apertura nasi ossea*, Fig. 1B, ano); caudally, each nasal bone was prolonged to form frontal processes (Fig. 3, pfn). The frontal process of the premaxillary bone extended caudally to the internasal suture (*sutura internasalis*; Fig. 3, sutin), that is, through the craniofacial flexion zone (Fig. 2, zf).

The orbital part of the (left and right) frontal bone (*pars orbitalis frontalis*) was positioned considerably beneath the nasal bone and was medially aligned with the upper margin of the ectethmoid's orbital plate (*margo dorsalis laminae ectethmoidalis orbitalis*) (Fig. 4). In the case of young grey heron, the right frontal bone matched with the fusion zone of the ectethmoid and nasal bones and the left one to a gap between the ectethmoid and nasal bones (Fig. 4).

Rostrolaterally, the orbital part of the frontal bone formed a ventromedially curved extension (*processus lacrimalis*), which with its lateral surface represented the articular surface for the lacrimal bone (*facies articularis lacrimalis*). In the young grey heron, this articular surface was narrow and poorly expressed (Fig. 5, pl); additionally, the ossified lacrimal bone was not yet present. From the ventral side (Fig. 5), the margins of the frontal bone (*margo laterosphenoidalis*, *margo temporalis*, *margo parietalis*), and the frontal extension that shaped the postorbital process (*processus postorbitalis*, Fig. 2B, ppo), were well defined. Actually, the majority of the postorbital process was formed by the laterosphenoid bone (*os laterosphenoidale*) with the only exception of the dorsolateral part that was formed by the frontal bone. Caudally, the frontal bone formed the dorsal temporal ridge (*crista temporalis dorsalis*, Fig. 2B, ctd), which lateroventrally ended with the before mentioned part of the postorbital process. Behind the dorsal temporal ridge there was the temporal fossa (*fossa temporalis*) or temporal muscle fossa (*fossa musculi temporalis*, Fig. 2B, fmt) located, which was limited in the caudal part by *crista nuchalis transversa* (Fig. 2B, cnt) and *crista temporalis ventralis* (Fig. 2B, ctv), and in the area of the ventral part of the cranium by *crista temporalis rostralis*.

In the adult grey heron, the articular surface of the frontal bone with the lacrimal bone was clearly formed (Fig. 6, fal), as was the orbitonasal opening (*foramen orbitonasalis*, Fig. 7, fon) on the medial side of the lacrimal process of the frontal bone, near the border with the lateral margin of the ectethmoid bone. At this level the lacrimal process formed a longitudinal crest (*crista processus lacrimalis*, Fig. 7, cpl).

In Fig. 8 the ectethmoid bone (*os ectethmoidale*) is shown in an artificial cross-section performed close to the left and right lateral processes (Fig. 8, plect). At the base of the lateral process, the incisura (*incisura processus lateralis*, ipl) was pronounced, and beneath the process, a low lying tubercle (*tuberculum ectethmoidalis*, tect) was located. The orbital plates (*laminae orbitales*, loect) and antorbital plates (*laminae antorbitales*, laect) surrounded the ectethmoid sinus (*sinus ectethmoidalis*, sinect). The left and right orbital plates were dorsally connected by a thin, transverse bony *lamina dorsalis* (presumably the *mesethmoidalis*).

The frontonasal bone (*os frontonasale*, Fig. 8, ofn) was formed by the orbital (*lamina orbitalis*, lo) and nasal lamina (*lamina nasalis*, ln), which were connected by the middle layer (*synostosis frontonasalis*, sfn). The latter presented a common pneumatized bone tissue.

Discussion

The distribution of the maxillary ramphotheca of the grey heron (*Ardea cinerea)* was similar to that observed in the striated heron (*Butorides striata*) (Hieronymus and Witmer, 2010). It covers the beak as a simple ramphotheca, and the longitudinal nasal sulcus (*sulcus nasi*: Livezey and Zusi, 2006; *sulcus nasolabialis*: Hieronymus and Witmer, 2010) is present. The ramphotheca surrounds the upper jaw from the apex of the beak to the craniofacial flexion zone (*zona flexoria craniofacialis*) and on the lateral side extends a little more caudally. It covers a large proportion of the lacrimal bone (*os lacrimale*) and thus indicates the lateral surface of the rostral area of the orbit.

The frontal bone (*os frontale*) surrounds a large part of the orbit, forming the majority of the dorsal surface and the dorsocaudal wall of the orbit. Caudolaterally, at the cerebral part, the frontal bone participates in forming the postorbital process (*processus postorbitalis*). The base of the process is formed by the laterosphenoid bone (*os laterosphenoidale*), and the frontal bone is located dorsally as a kind of cover or lid. Livezey and Zusi (2006) reported that such a situation is common in most birds.

In the young heron, the nasal surfaces of the frontal bones fit with the nasal bones on their ventral surface (*sutura frontonasalis plana*). This fact, as well as the existence of the frontonasal and frontoparietal fontanelles (*fonticulus frontonasalis et fonticulus frontoparietalis*), and the loose mutual contact between the frontal bones (*sutura interfrontalis*), potentially enables adjustment of the complex of dorsal orbital bones to brain development and growth, and perhaps even to the feeding mechanism of young herons. In adult herons, both pairs of frontal and nasal bones are fused into a single frontonasal bone (*os frontonasale*).

In the supraorbital area, i.e. as part of it, there are two anguli of the frontals, the caudal and rostral (*angulus supraorbitalis caudalis et rostralis*). The caudal angulus has also been termed the supraorbital process by Payne and Risley (1976), and the *angulus postocularis* by Livezey and Zusi (2006). In front of the rostral supraorbital angulus the frontal bone is rotated ventrally and forms the lacrimal process (*processus lacrimalis frontalis*), which serves for articulation with the lacrimal bone. This process is well developed in the adult subjects, while it appeared as a low crest in the sixteen to seventeen days old grey heron. Thus the functional

relation between the frontal and lacrimal bones developes with the grey herons aged more than seventeen days. Later development is also observed in relation to the composed lacrimal process of frontal bone, among others a pronounced medial longitudinal crest; the latter rises above the passage for nerves (*foramen orbitonasalis*). The ectethmoid-lacrimal complex was absent in the young grey heron: neither the lacrimal bones nor the lateral process of the ectethmoid bones were observed.

The lateral process of the ectethmoid (*processus lateralis ectethmoidalis*) is well developed in the adult grey herons. At its base, a marked incisura (*incisura processus lateralis*) and a tubercle below (*tuberculum ectethmoidalis*) are obvious. In the great white heron the incisura and tubercle are absent, and the lateral process of the ectethmoid is smaller than in the grey herons. The absence of a tubercle in the great white heron was already described by Payne and Risley (1976). In the great white heron, the surfaces of the lateral orbital process of the lacrimal bone (*processus orbitalis lateralis*) and the lateral process of the ectethmoid bone (*processus lateralis ectethmoidalis*) are situated slightly further apart than in the grey herons. The left and right ectethmoid bones are fused in adult grey herons and form the intermediate space (*sinus ectethmoidalis*). Shufeldt (1889) has described the heron's ectethmoid bone as an unusually thick and bulky bone, which spreads out a wide base for the frontals to rest upon, including a cancellous internal structure. However, that research did not highlight a space (sinus) inside.

Our description of the bones in the juvenile grey heron has interesting value because the study of juvenile birds is relatively rare. Zusi and Livezey (2006) pointed out that the sutures of the cranium of most neognathous birds undergo rapid synostosis during development, resulting in the complete concealment of sutures by adulthood, often in less than one year. Shufeldt (1889) studied the immature skeleton of yellow-crowned night heron (*Nyctanassa violacea*), treating it as "a bird of the year". He observed that all cranial sutures have entirely disappeared.

Consequently, the relations among the ossa cranii in many neognathous taxa remain undetermined. Zusi and Livezey (2006) cited the skeletons of immature birds, when they studied the palatine bone (*os palatinum*), including skeletons of the great blue heron (*Ardea herodias*) and the boat-billed heron (*Cochlearis cochlearis*). However, there is no report or comment on the osteology of the heron's orbital region.

In the rostrolateral area of the grey heron's orbit a prominent skeletal base arises enabling articulation between the lacrimal bone and the frontal/nasal bones (*facies articularis frontonasalis lacrimalis*), and between the lacrimal and ectethmoid bones (*ectethmoid-*

lacrimal complex) during growth from seventeen days of age onwards. Moreover, a clear craniofacial hinge also develops (*zona flexoria craniofacialis*), thus allowing reliable, movable skull mechanisms. In the case of our young heron, the right ectethmoid and nasal bones had fused; however, the left ones had not. It could therefore be assumed that ossification and fusion of the left and the right side of the orbit is not coincident (possible artefact), however, more specimens would be needed to confirm this finding. Therefore our results on the young grey heron are discussed as preliminary data and further research is in progress. This study provides a detailed description with valuable new contributions to the knowledge of the grey heron's orbital region.

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Author contributions

S.B., Z.G. conceived the study, S.B, Z.G. and F.J. acquired and analyzed the data. S.B. wrote the manuscript. Z.G., F.J., V.K. and C.R. revised the manuscript.

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Legends to Figures

Fig. 1. Orbitonasal area of the adult grey heron (*Ardea cinerea*) from the right side. A: Photograph of a living grey heron (superficial projections). B: Skull skeleton. **Legend**: aj = *arcus jugale*; am = *angulus mandibulae*; ano = *apertura nasi ossea*; asc = *angulus supraorbitalis caud*alis; asr = *angulus supraorbitalis rostralis*; atm = *angulus tomialis maxillae*; cpo = *crista postocularis*; cso = *crista supraorbitalis*; ct = *crista tomialis*; fao = *fenestra antorbitalis*; fonti = *fonticulus interorbitalis*; fonts = *fonticulus supraorbitalis*; ill = *incisura lateralis lacrimalis*; nar = *naris*; oect = *os ectethmoidale*; ol = os lacrimale; olat = *os laterosphenoidale*; omes = *os mesethmoidale*; plect = *processus lateralis ectethmoidalis*; pol = *processus orbitalis lacrimalis*; psl = *processus supraorbitalis lacrimalis*; rm = *ramus mandibulae*; rfa = *rhamphoteca fenestrae antorbitalis*; rp = *rostrum parasphenoidale*; snl = *sulcus nasolabialis*; tl = *tumulus lacrimalis*; zf = *zona flexoria craniofacialis*.

Fig. 2. Skull of an adult (A) and young (B) grey heron (*Ardea cinerea*). Lacrimal bone (*os lacrimale*) in adult heron specimen has been removed. In the young heron the right frontal bone (B ofd) has been moved from its initial position and placed above the right nasal bone;

left frontal bone is in normal position (*in situ*). **Frame**: Skull of the adult great white heron (*Ardea alba*), which is more slender than that of the adult (A) and young (B) grey herons. **Legend**: asc = *angulus supraorbitalis caudalis*; asr = *angulus supraorbitalis rostralis*; cns = *crista nuchalis sagitalis*; cnt = *crista nuchalis transversa*; ctd = *crista temporalis dorsalis*; ctv = *crista temporalis ventralis*; df = *depressio frontalis*; ef = *eminentia frontalis*; fmt = *fossa musculi temporalis*; fontfn = *fonticulus frontonasalis*; fontfp = *fonticulus frontoparietalis*; fnf = *facies nasalis frontalis*; ofd = *os frontale dextrum*; ppo = *processus postorbitalis*; pz = *processus zygomaticus*; rhn = *rhamphoteca naris*; snl = *sulcus nasolabiale*; sutfn = *sutura frontonasalis (plana)*; sutif = *sutura interfrontalis*; sutip = *sutura interparietalis*; zf = *zona flexoria craniofacialis*.

Fig. 3. The orbital area of about three-month-old grey heron after cranium removal altogether with frontal bones; dorsal view. **Legend**: co = *capitulum oticum*; cs = *capitulum squamosum*; ons = *os nasale sinistrum*; pfn = *processus frontalis nasalis*; pfpr = *processus frontalis premaxillare*; pmn = *processus maxillaris nasalis*; poq = *processus oticus quadrati*; pprn = *processus premaxillaris nasalis*; sutin = *sutura internasalis*.

Fig. 4. The orbital area of young grey heron after following cranium removal. The large arrows show the rostral direction. **Above**: right view. The right ectethmoid is fused with right nasal bone (arrowheads); arrow = entrance into the ectethmoid sinus covered by a soft tissue. **Below**: left view. The left ectethmoid is not fused with right nasal bone (arrowheads). The ventral margin of mesethmoid bone is free, since parasphenoidal rostrum (*rostrum parasphenoidale*) has been removed together with the cranium. **Legend**: aj = *arcus jugalis*; lchp = *lamella choanalis palatini*; oect = *os ectethmoidale*; oectla = os ectethmoidale, lamina antorbitalis; oectlo = os ectethmoidale, lamina orbitalis; omes = *os mesethmoidale*; on = *os nasale*; pfn = *processus frontalis nasalis*; pmn = *processus maxillaris nasalis*; v = *vome*r; arrow with dotted line = the instalment direction of frontal bone between the nasal bone and the dorsal edge of ectethmoid.

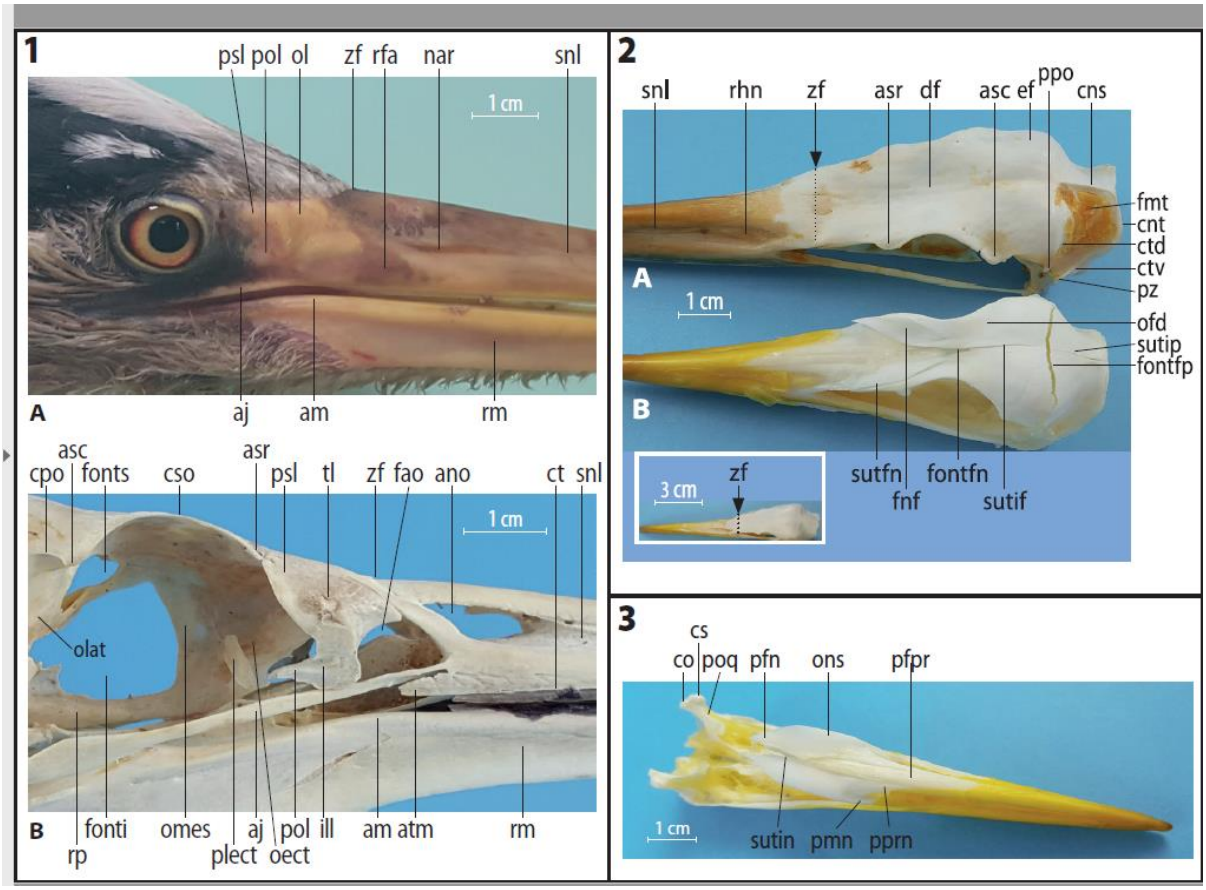
Fig. 5. Left frontal bone (*os frontale sinistrum*) of the young grey heron from ventral view. **Legend**: cso = *crista supraorbitalis*; fc = *facies cerebralis*; fo = *facies orbitalis*; mif = *margo interfrontalis*; mlat = *margo laterosphenoidalis*; mp = *margo parietalis*; mt = *margo temporalis*; pl = *processus lacrimalis*; ppo = *processus postorbitalis*.

Fig. 6. Ventromedially turned process of the frontal bone (*processus lacrimalis frontalis*, plf) and its articular surface with lacrimal bone (*facies articularis lacrimalis*, fal) in an adult grey heron. **Legend**: aj = *arcus jugale*; asr = *angulus supraorbitalis rostralis*; cso = *crista supraorbitalis*; fal = *facies articularis lacrimalis*; oectla = *os ectethmoidale, lamina antorbitalis*; oectlo = *os ectethmoidale, lamina orbitalis*; omes = *os mesethmoidale*; plect = *processus lateralis ectethmoidalis*; plf = *processus lacrimalis frontalis*.

Fig. 7. The ectethmoid and lacrimal bones in an adult grey heron (ventral view). The skull is artificially interrupted at the level of craniofacial hinge (vertical arrow). The top of the ventral process of ectethmoid extends in the close proximity to the medial orbital process of the lacrimal bone (the ectethmoid-lacrimal complex). **Legend**: cect = *crista ectethmoidalis*; cpl =

crista processus lacrimalis frontalis; faect = *facies antorbitalis ectethmoidalis*; fon = *foramen orbitonasalis*; ol = *os lacrimale* (distal part); plect = *processus lateralis ectethmoidalis*; pol = *processus orbitalis lateralis*; pom = *processus orbitalis medialis*; rp = *rostrum parasphenoidale*; tect = *tuberculum ectethmoidalis*. Dotted semicircle = rostral margin of the ectethmoid bone.

Fig. 8. Artificial transverse section of an adult grey heron orbit at the level of rostral supraorbital angle of frontal bone (asr); photography (A) and illustration (B). The ectethmoid tubercle (tect) is obvious, as well as the ectethmoid sinus (sinect). **Legend**: asc = *angulus supraorbitalis caudalis*; asr = *angulus supraorbitalis rostralis*; df = *depressio frontalis*; fo = *foramen opticus*; ipl = *incisura processus lateralis*; laect = *lamina antorbitalis ectethmoidalis*; ld(m) = *lamina dorsalis (mesethmoidalis?)*; lf = *lamina frontalis*; ln = *lamina nasalis*; loect = *lamina orbitalis ectethmoidalis*; ofn = *os frontonasale*; plect = *processus lateralis ectethmoidalis*; ppo = *processus postorbitalis*; rp = *rostrum parasphenoidale*; sfn = *synostosis frontonasalis* (pneumatized layer of the fronto-nasal bone); sinect = *sinus ectethmoidalis*; tect = *tuberculum ectethmoidalis*.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rp plect oect
2
snl rhn zf asr df asc ef ppo cns
fmt
cnt
ctd
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pz
A
1 cm
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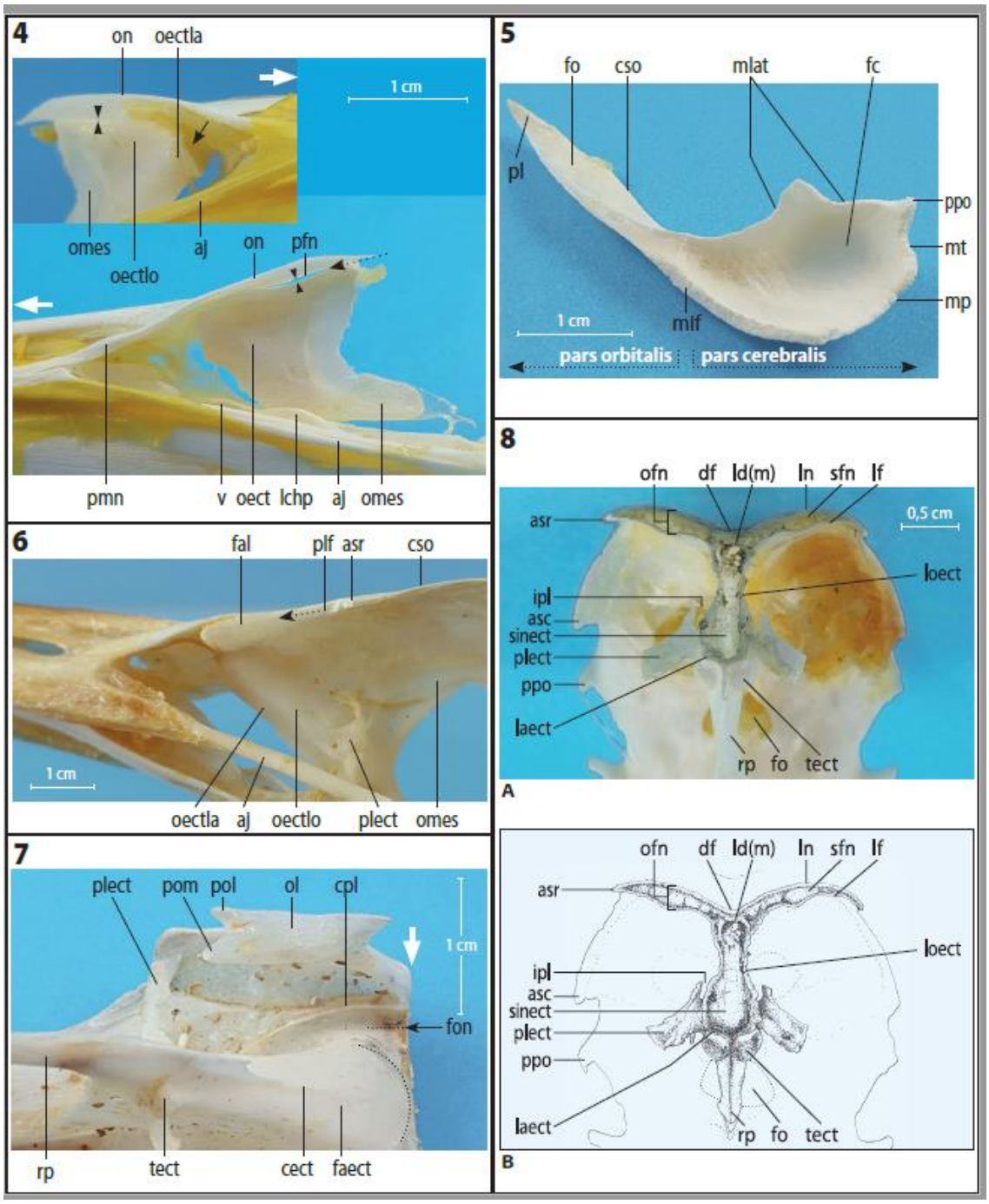
sutip
fontfp
B
3 cm zf
sutfn fontfn
fnf sutif
3
cs
co poq pfn ons pfpr
1 cm
sutin pmn pprn

1
2


4
on
oectla
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5
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plf
asr
cso
1 cm
oectla
aj
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plect
omes
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plect
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ol
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1 cm
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8
ofn
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B

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