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Skull Osteology of *Osmerus eperlanus eperlanus* (L.) of the Miedwie
Lake

Osteologia czaszki *Osmerus eperlanus eperlanus* (L.) z jeziora
Miedwie

Строение черепа *Osmerus eperlanus eperlanus* (L.) из озера Медве

[With 11 Figures in the text]

Introduction

The salmonoid fishes have nowadays attracted the attention of many ichthyologists. Taking into account the fact that the osteology is the essential base of modern systematics, and that the osteological data concerning the smelt — *Osmerus eperlanus eperlanus* (L.) — is far from complete, this study was undertaken to advance our knowledge on this field. The subject of this paper is the skull osteology of *Osmerus eperlanus eperlanus* (L.) of the Miedwie Lake (Poland).

Until now only some fragments of the osteological structure of the genus *Osmerus* L. were dealt with: CHAPMAN (1941) published a key for determination of genera of the family *Osmeridae* in which he distinguished two main groups: one including *Osmerus* L., *Allosmerus* HUBBS, *Thaleichthys* GIRARD and the other with *Hypomesus* GILL and *Mallotus* CUVIER. He also reviewed the opinion of some other authors on the evolutionary trend of the family *Osmeridae*, regarding *Thaleichthys* GIRARD as the most primitive genus of this family. Recognizing the importance of the sensory canal (ALLIS, 1905 and others) for systematics, in the present study much attention was paid to the structure and localization of those canals, to make possible a correct location of the bones and establishing their homology.

Since the terminology of particular bones differs essentially in the publications of many authors, in the present study the terminology of NORDEN

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(1961) was applied, whereas the termes used by other authors are etained as synonyms.

The present paper constitutes for the subsequent monographic study concerning the genus *Osmerus* L. of the Polish waters. As the result of this study an existence of some osteological elements new for this genus was discovered, which might be essential for the correct systematic placing of the smelt.

For a more convenient description of particular bones, they were divided into three groups: 1. skeleton of the braincase, 2. skeleton of the visceral part of the skull, 3. the investing bones. Within those groups, minor units were distinguished and bones pertaining to them were described.

The study is based on the examination of nine adult specimens of the smelt from Miedwie Lake. Counts of meristic and measurments of plastic features have been performed previously. The osteological material was provided from fresh specimens as well as from those preserved in alcohol and formalin and stained with alizarin. This method enabled to recognize the correct localization of the bones and to detect their right interdependence. The Abbé apparatus was used for drawings.

The research was carried out in the Institute of Zoology of the Polish Academy of Sciences under the guidance of Dr M. Gąsowska to whom I wish to express my hearty thanks.

Skeleton of the braincase

It performs as a rule static and protective functions, sheltering brain and the principal sensory organs. It is composed mostly of bones of chondral origin in which three regions — the olfactory, the orbital and the otic — may be distinguished.

Bones of the olfactory region

The ethmoidal part is an elongated cartilage with a bluntly rounded rostral portion, and with two wing-like projections: the anterior and the posterior. The rostral part is covered by the vomer and by premaxillae bones. The anterior projection joins the maxilla and palatine. The anterior part of the posterior projection forms the posterior margin of the olfactory capsule, whereas the posterior one forms the anterior part of the orbital. The ventral part of the posterior projection forms the second articulation for the palatine (SWINERTON 1902; de BEER 1927). Moreover on this projection small bones are located, grown into the cartilage, these are *ossa praefrontalia* — (praeorbitale ALLIS, 1898; ethmoidale laterale BERG, 1940) which together with the cartilage on which they are formed, provide the upper anterior wall each orbit [Fig. 1]. Under the cartilage roof, in the posterior projection, lies the aperture — *foramen olfactorium advehens* (not illustrated) for the olfactory nerve — *nervus olfactorius* (I) and the orbito-nasal artery.

In front of the ethmoidal cartilage lies an unpaired, thin, ovoid osseous lamella — the *ethmoideum* — (mesethmoideum STARKS, 1926; GREGORY, 1933; de BEER, 1937; hypethmoideum BERG, 1940; NORDEN, 1961), the term applied by HARRINGTON (1955) and WEITZMAN (1962). This bone is covered by supraethmoid in its anterior — and by frontal, in its posterior part.

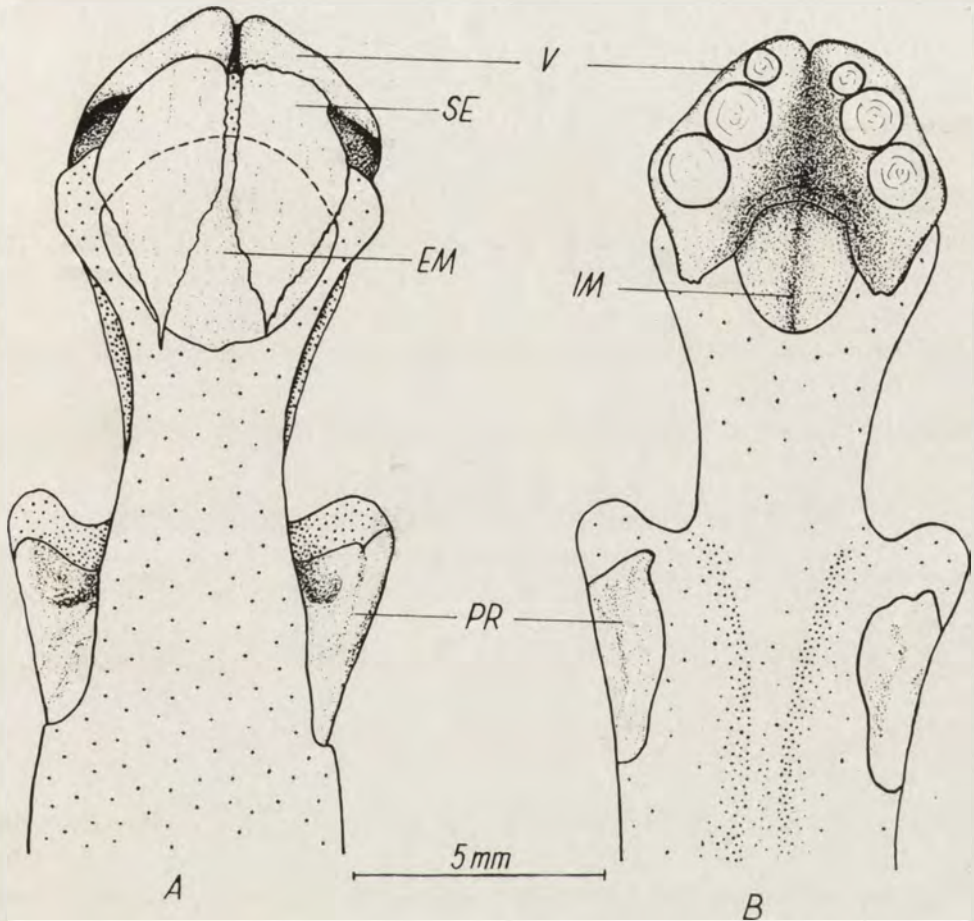


Fig. 1. Olfactory region of the skull of *Osmerus eperlanus eperlanus* (L.).
A — dorsal view (frontals are removed), B — ventral view (parasphenoid is removed),
EM — ethmoid, IM — infraethmoid, PR — prefrontal, SE — supraethmoid, V — vomer.

Os supraethmoideum — (proethmoideum STARKS, 1926; CHAPMAN, 1941; dermethmoideum GREGORY, 1933; mesethmoideum BERG, 1940) is a paired bone consisting of two separate flat bones resembling a scale in their shape. It remains a paired bone for life of the individual and not only in young specimens as reported by BERG (1955 p. 175). Supraethmoid touches the vomer in the anterior part and in the posterior — is in contact with frontal. When

observing the braincase from the ventral side we can state just in vertical axis to the supraethmoid and ethmoid, another bone [Fig. 1B]. It is partly covered by vomer and parasphenoid. This bone, very thin, ovoid, not flat but somewhat bent along its longitudinal axis. It is so thin and transparent that it becomes visible only after being stained with alizarin. Considering its position and its analogy to other bones, the most appropriate term for it seems to be *infraethmoideum*. In the place corresponding to the position of the just described bone, CHAPMAN, (1941, p. 284, Fig. 4) figured in *Thaleichthys pacificus* (RICHARDSON) a small unpaired bone lying between vomer and parasphenoid, which he named "ventral ethmoid", not describing it in the text.

Bones of the orbital region

This region consists mostly of cartilage forming the orbits on both side of the braincase, separated from each other by septum interorbitale. To this region three bones of chondral origin belong: the unpaired orbitosphenoid and basisphenoid, which fails to occur in the smelt, and the paired pterosphenoid. In this region the paired sclerotic cartilage of the cutaneous origin are present too.

Cartilaginee scleroticae — occur — one pair in each orbit, as chondrous only slightly ossificated lamellae. They are thin, ovoid, slightly concave plates embracing the otic ball from the anterior and posterior side [Fig. 10].

Os pterosphenoidum — (term used by NORDEN after GOODRICH, 1930 discussed by HARRINGTON, 1955 p. 287 = pleurosphenoid de BEER, 1937; WEITZMAN, 1962; alisphenoid GREGORY, 1933; BERG, 1940; CHAPMAN, 1941) — is a bone of a very irregular shape, being a horse-shoe-like lamella on the rear side of the orbit, and posteriorly elongated into an irregularly twisted wall. Each of those bones is connected posteriorly with the sphenotic and, somewhat lower, with prootic [Fig. 2]. The upper posterior margin of pterosphenoid together with the surrounding cartilage forms the edge of the dorsal fontanelle. Ventrally and towards the centre it forms the anterior part of the otic region. Ventrally pterosphenoids are joined together by a chondrous membrane, perforated by the foramen for the *nervus opticus* (II) and *nervus oculomotorius* (III).

Bones of the otic region

This is the most ossified part of the braincase, composed of the following bones: paired — sphenotic (autosphenoticum HOLMGREN and STENSIÖ, 1936; HARRINGTON, 1955), pterotic (squamosal RIDWOOD, 1904a; autopteroticum HARRINGTON, 1955), prootic, epiotic, exoccipital (occipitale laterale BERG, 1940), opisthotic (intercalare BERG, 1940), and unpaired supraoccipital and basioccipital. To the components of this region belong also the otoliths (three pairs).

Os sphenoticum — is the most anterior bone of the otic region. It is a roof-shaped bone, one of its side lying on the dorsal, another on the lateral side of the braincase. The peak of this bone forms an arched twisted comb, which, with its anterior margin nearly touches the dermosphenotic. Anteriorly sphenotic joins the pterosphenoid, ventrally — the prootic, and posteriorly — the pte-

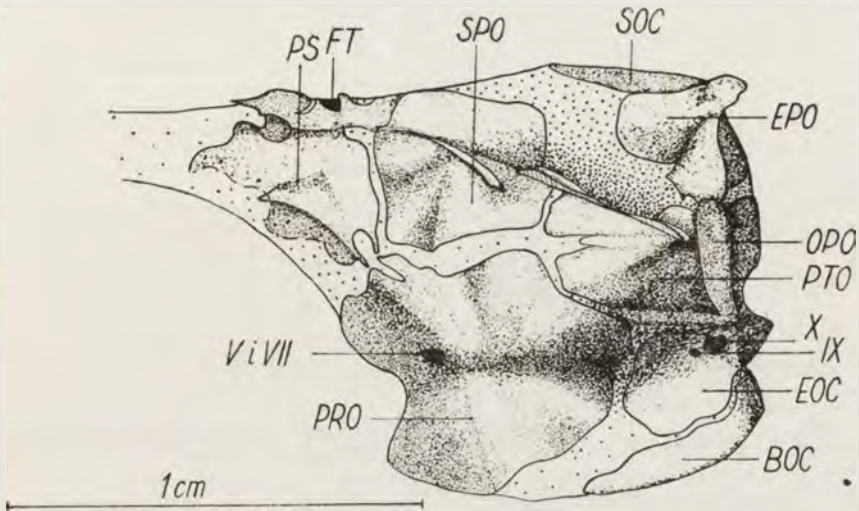


Fig. 2. Otic region of the skull of *Osmerus eperlanus eperlanus* (L.), lateral view. BOC — basioccipital, EOC — exoccipital, EPO — epiotic, FT — dorsal fontanelle, OPO — opisthotic, PRO — prootic, PS — pterosphenoid, PTO — pterotic, SOC — supraoccipital, SPO — sphenotic.

rotic [Fig. 2,3]. The sutures between those bones are filled with the cartilaginous tissue. The posterior part forms the anterior wall of the lateral temporal fossa. Together with pterosphenoid it forms the posterior wall of the orbit. Dorsally the sphenotic is covered by the frontal in the anterior, and partly by parietal and pterotic in the posterior part. The inner surface bears a duct for a part of the anterior semicircular canal.

Os pteroticum — is a large bone lying externally on the latero-dorsal part of braincase. It is as well chondral as dermal origin. Anteriorly it joins, by means of a chondral suture, the sphenotic, ventrally — the prootic and exoccipital. An incision in the pterotic forms a part of junction with hyomandibular. Posteriorly the pterotic joins the epiotic and exoccipital. The place of junction is covered by a rather small bone — the opisthotic. In its inner surface there is a vertical canal protruding externally and enlarging downwards, closing the perpendicular semicircular canal with an ampulla. The dorsal part of pterotic, called supratemporal-intertemporal (HOLMGREN and STENSJÖ, 1936), intertemporal (de BEER, 1937), membranopterotic (HARRINGTON, 1955) forms the edge of the lateral temporal fossa, covering partly the sphenotic with its anterior — and meeting the lateral and superior extrascapular with its poste-

rior end. It carries also the open (like all the sensory canal in the smelt — vide the description of the investing bones) lateral suborbital canal. In the posterior part, this canal joins the other one running in the lateral and superior extra-scapular. In the anterior part, it runs above the sphenotic and subsequently joins the canal running in dermosphenotic and in frontal, whereas downwards it joins the preopercular canal across the skin region.

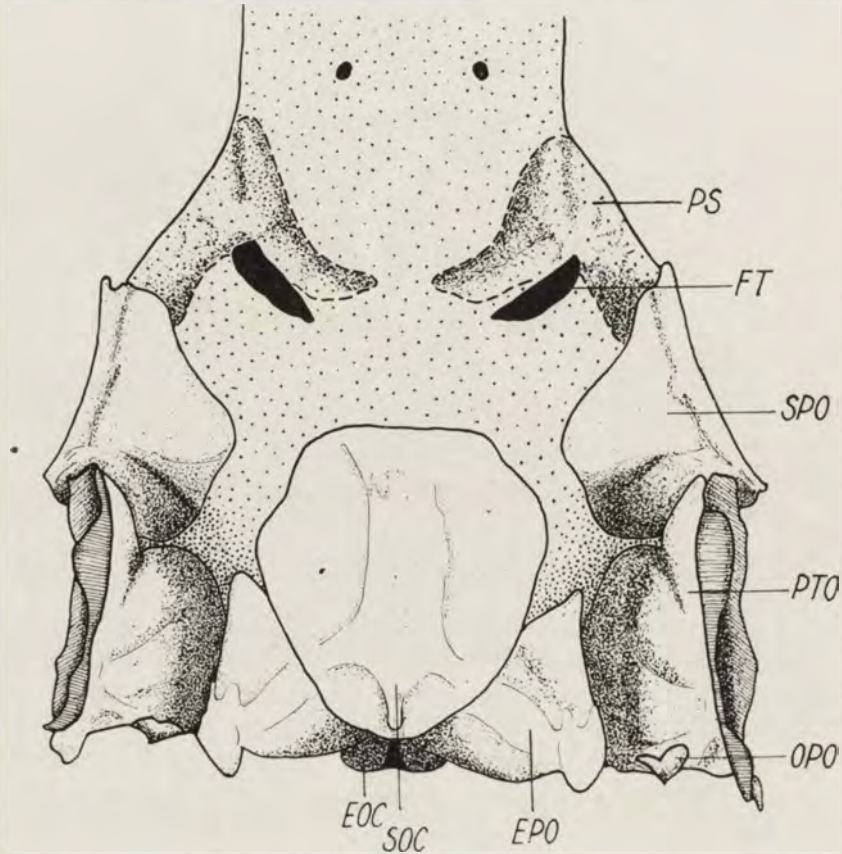


Fig. 3. Otic region of the skull of *Osmerus eperlanus eperlanus* (L.) — dorsal view (frontals and parietals are removed). EOC — exoccipital, EPO — epiotic, FT — dorsal fontanelle, OPO — opisthotic, PS — pterosphenoid, PTO — pterotic, SOC — supraoccipital, SPO — sphenotic.

Os prooticum — touches centripetally the prootic of the opposite side. This union results in formation of the cerebral capsule and of the osseous vault for the posterior and anterior miodom. Anteriorly the miodom finds place in the parasphenoid. Externally prootic has a shape of hexagonal, not very regular, and slightly twisted plate with a large foramen somewhat forwards of it. This foramen is the exit for the nerves *trigeminus* (V) and *facialis* (VII). Antero-dorsally prootic touches the pterosphenoid. There is an incision in

the prootic situated in front of an analogical incision in pterosphenoid. Dorsally the prootic touches sphenotic and pterotic, posteriorly — the exoccipital and basioccipital and ventrally — the parasphenoid. The posterior median part of prootic is bent inside, forming the anterior part of the subtemporal fossa (RIDEWOOD, 1904a, p. 62). The inner surface of prootic is very irregular, with three distinctly expressed concavities. The most superior of them serves as location for the posterior semicircular canal, the anterior — for the anterior semicircular canal and the posterior for the otolith (sagitta).

On the boundary of the three bones just described, a cartilage area — slightly depressed — produces the junction for the hyomandibular.

Os epioticum [Fig. 2] — is a conus-shaped bone with a strongly ossified process on its apex. The ligament inserted to this process joins epiotic with posttemporal. The epiotic touches on one side the supraoccipital, on the other, the pterotic, exoccipital and opisthotic. The lateral wall of the epiotic forms the edge of the lateral temporal fossa, the posterior one — of the posterior temporal fossa. The inner surface of the epiotic closes the posterior vertical semicircular canal.

Os exoccipitale — occipitale laterale (BERG 1940), ventrally joins the same bone of the other side by means of a protruding crest, forming the bottom of the otic capsule and also the wall of the posterior semicircular canal. From behind, exoccipitals embrace thoroughly the foramen magnum, except its small dorsal sector which is surrounding by cartilage. This cartilage serves as junction for the bones under discussion. Posteriorly, inside the posterior temporal fossa and on its margin, the exoccipital touches the epiotic, dorso-laterally — the pterotic, anteriorly meets prootic, ventrally and from behind the basioccipital. On the lateral side of the exoccipital there are two foramina [Fig. 2], the small one for the *nervus glosso-pharyngeus* (IX), the other, comparatively large and shifted backwards, for the *nervus vagus* (X). Both foramina are located near the bottom of the subtemporal fossa. Posteriorly and ventrally both exoccipitals meet together touching each other with their projections (occipitale condylus), which have smooth surfaces for articulation with vertebral column.

Os opisthoticum — intercalare (BERG, 1940) is a small paired V-shaped bone with its ventral arm slightly longer than the posterior one. This bone covers the chondral junction between the pterotic, epiotic and exoccipital, and is only feebly connected to the braincase. It is the only not endochondral bone in the otic region, ossified within the membranous ligament, initiating from the inward process of posttemporal (NORDEN, 1961, p. 694).

Os supraoccipitale — is a flat, nearly rectangular osseous plate, covering the braincase on the dorsal side. Like the prootic it is of double origin: chondrous and dermal. Its dorsal part (of dermal origin) carries a big occipital crest. In its anterior and antero-lateral part supraoccipital is embraced by cartilage, laterally it touches the epiotic on each side, from behind its anterior part

touches the exoccipital. Dorsally, the lateral parts of supraoccipital are covered by the parietals.

Os basioccipitale — constitute the inferior part of the cerebral capsule. Its posterior part joins the first vertebra. Its inferior wing-shaped part contains the otolith sagitta, its anterior part is covered from outside by parasphenoid. The basioccipital joins prootic anteriorly and exoccipital from the dorsal side [Figs 2,4]. It constitutes also the roof and the walls of the miodom, whereas the bottom of the miodom is formed by the parasphenoid.

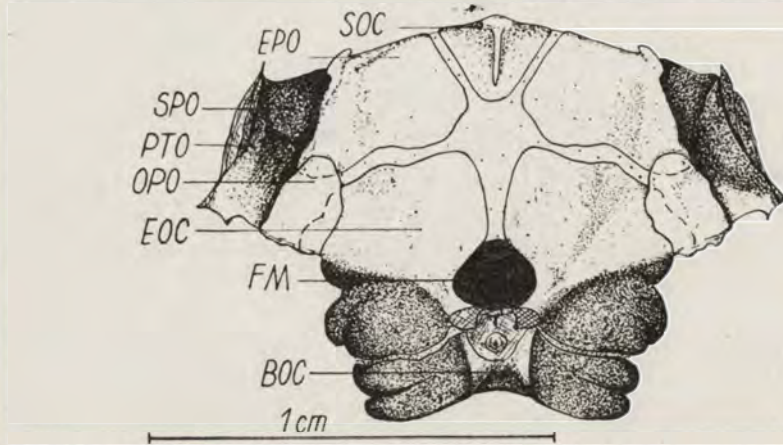


Fig. 4. Otic region of the skull of *Osmerus eperlanus eperlanus* (L.) from behind. BOC — basioccipital, EOC — exoccipital, EPO — epiotic, FM — foramen magnum — OPO — opisthotic, PTO — pterotic, SOC — supraoccipital.

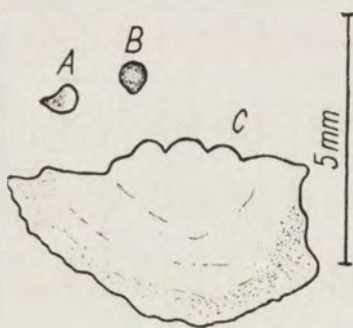


Fig. 5. Otoliths. A — asteriscus, B — lapillus, C — sagitta.

Otoliths — occur in the smelt in three pairs [Fig. 5]. They lie inside the labyrinth composed of the sac and utricle, from which the above mentioned semicircular canals initiate. The biggest of the otoliths — sagitta, is in the sacculus, located in the boundary of bones: prootic, exoccipital and basioccipital. The two smaller otoliths — lapillus and asteriscus are located in the utricle and in the lagena, which is a diverticle of sacculus. Both are located inside the prootic. When the skull is dyed and cleared, they are well seen through the lateral temporal fossa.

Skeleton of the visceral part of skull

The skeleton of the visceral part of skull supports the anterior part of the digestive tube. This bones composing it will be discussed as three groups:

I. Maxillo-mandibular region, in which the following elements may be distinguished: the area of the maxilla, that of the mandibular and the palatoquadrate arch (NORDEN, 1961) or palatine arch (WEITZMAN, 1962);

II. Hyoid arch;

III. Branchial arches.

The first of these groups of bones is developed as a food providing organ, the second forms the union of the palatoquadrate arch with otic skull region and with the branchial arches. In the third group consisting of five arches, the first four arches are well developed, whereas the fifth is reduced and by contrast to other arches it is called the inferior pharyngeal bone (*os pharyngeum inferius*).

Maxillo-mandibular region

This region consists of twelve paired bones of chondral as well as dermal origin. The chondral bones are: metapterygoid and quadrate, those of cutaneous origin: mesopterygoid, ectopterygoid, premaxilla, supramaxilla and coronomeckelian, those of mixed origin: palatine, angular, retroarticular and dentary.

The upper jaw bones

Os praemaxillare — is a narrow bone, broadening in front and slightly bent mesially. It ossifies in skin and joins the analogous bone of the opposite side by a median suture. They both embrace rostrum and reach anterior part of maxilla. Each bone carries 15–19 tiny, sharp, conical denticles slightly bent backwards.

Os maxillare — is a long narrow bone, partly surrounding the mouth opening; its anterior end is bent mesially at nearly right angle. It carries 50–80 tiny, sharp teeth [Fig. 10] on its two-third of length. Anteriorly and ventrally it articulates with premaxilla, dorsally and mesially with palatine.

Os supramaxillare — surmaxilla Ridewood 1904a; jugal de BEER, 1937 is a spoon-shaped bone bent very slightly, approximately by half shorter than maxilla. It lies behind maxilla and covers it partly [Fig. 10].

Lower jaw bones

Os dentale — as mentioned above, is a bone of a mixed origin, arisen by fusion of several bones together. For explanation of sometimes complicated names of bones and of the origin of single bones composing dentary, the papers of HOLMGREN and STENSIÖ (1936), de BEER (1937), LEKANDER (1949), HARRINGTON (1955), and WEITZMAN (1962) should be consulted. Dentary is the biggest bone of the whole region. The paired one joins anteriorly, forming U-shaped semicircle. The lateral, external surface of dentary, approximately on half of its height, carries a bony fold bent downwards and covering the sensory canal. The superior margin of dentary carries a row of big sharp teeth

(12–15) crooked inwards. In the anterior part of this margin, on the bony fold protruding upwards, situated more externally — there is another row (16–18) of much smaller teeth. The posterior part of the upper margin is connected by the cutaneous fold with maxilla. The internal surface of dentary is the place for the anterior part of the Meckel cartilage. Posteriorly dentary is connected with angular [Fig. 6].

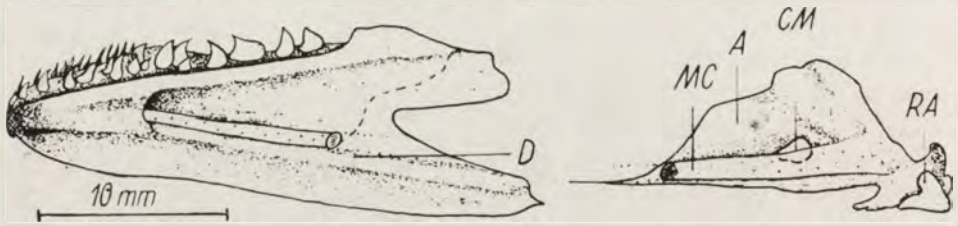


Fig. 6. Lower jaw of *Osmerus eperlanus eperlanus* (L.). A — angular, CM — coronomeckelian, D — dentary, MC — Meckel's cartilage, RA — retroarticular.

Os angulare — dermarticular GOODRICH, 1930; articular GREGORY, 1933; de BEER, 1937; BERG, 1940 — is perhaps the most disputable of all bones on account of its uncertain origin and development (see NORDEN, 1961, p. 700). In Teleosts it is composed of two parts: the external (ectosteal) and the internal (endosteal). They are fused together and only in some *Clupeiformes* (*Elops* L., *Megalops* LACÉPÈDE, *Albula* GRONOW and others, RIDEWOOD, 1904a, b) both parts occur. In *Osmerus* L. it is a single, rather big, flat bone, thickened in its posterior part. Its anterior part is connected to dentary and by means of a der-

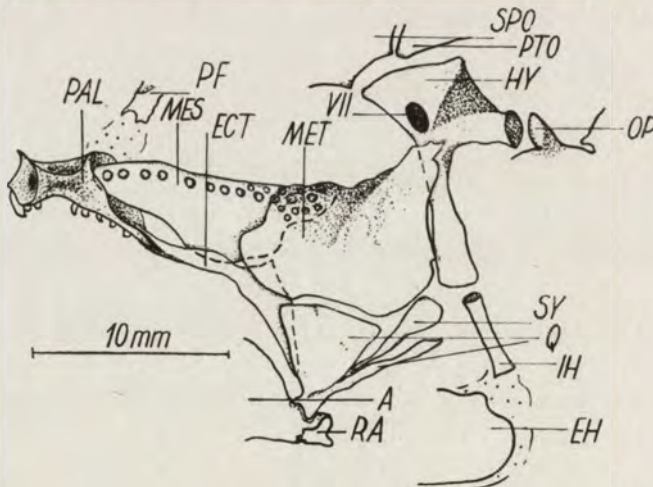


Fig. 7. Hyoid arch of *Osmerus eperlanus eperlanus* (L.). A — angular, ECT — ectopterygoid, HY — hyomandibular, IH — interhyal, MES — mesopterygoid, MET — metapterygoid, PAL — palatine, Q — quadrate, PF — prefrontal, PTO — pterotic, OP — opercle, RA — retroarticular, SPO — sphenotic, SY — symplectic.

mal fold to maxilla. The posterior part touches ventrally the retroarticular. In this part it carries a sensory canal which intermediates between that of preopercle and of dentary one. Dorsally, the posterior part of angular articulates with the ventral protrusion of quadrate. The internal side of angular, comprises the posterior part of Meckel cartilage.

Os retroarticulare — angular RIDEWOOD 1904a, b; GREGORY, 1933; BERG, 1940 — is seen from outside only as a small triangular bone touching angular. From inside however it partly overlaps angular [Figs 6, 10]. In *Osmerus eperlanus eperlanus* (L.) it is inseparably fused with angular and only after a treatment with KOH may be separated from it.

Os coronomeckelium — sesamoid articular RIDEWOOD, 1904a; os Meckeli BERG, 1940; sesamoid angular RAMASWAMI, 1952a, b — is a small, ovoid bone located between angular and the Meckel cartilage. It was first described by COPE (1878) as „coronoid bone” in the mandible of *Belone* CUVIER. This bone probably corresponds to the bone b (BERG, 1940, p. 198, fig. 86) in *Amia calva* L. According to RIDEWOOD (1904a) it is an ossified ligament.

Palato-quadrate arch

Os palatinum — autopalatine, dermopalatine ALLIS, 1897; autopalatine GOODRICH, 1930; GREGORY, 1933; de BEER, 1937; HARRINGTON, 1955 — is the most anterior bone of the palatoquadrate arch. It is of double origin: the superior part — autopalatine, ALLIS, 1897 — being of chondrous derivation, and inferior part — dermopalatine ALLIS, 1897, de BEER 1937 — of dermal one. This last bears a row of big, sharp teeth 7–9 in number. Palatine is attached to braincase in two places. Its anterior part joins the anterior projection of the ethmoid cartilage (see the description of the olfactory region). This junction is known as rostro-palatine articulation (de BEER, 1937). In its posterior, palatine is fixed by means of a chondrous projection to the ethmoid cartilage (ethmopalatine articulation de BEER, 1937) on the posterior projection. The external part of the palatine is attached to the maxilla by a ligament, the median is covered by the anterior part of mesopterygoid and the posterior part touches the ectopterygoid.

Os mesopterygoideum — endopterygoid GOODRICH, 1930; de BEER 1937; HARRINGTON, 1955; entopterygoid BERG, 1940 — lies, like remaining bones of this arch, in the median part of the palatoquadrate cartilage (TCHERNAVIN, 1938). The external part of mesopterygoid partly forms the inferior wall of the orbit. Mesopterygoid is a very thin bone, slightly elongated. On its superior edge from inside runs an irregular row of teeth which are ranged in three or four rows on the posterior part. They are of about 35 in number on each bone. The anterior part of mesopterygoid covers from inside a part of the palatine, touching the ethmoidal cartilage beneath prefrontal. The inferior edge is covered partly by the ectopterygoid.

Os metapterygoideum — derives from the posterior part of the palato-quadrate cartilage. It is a thin, toothless bone, of the shape similar to rectangle [Fig. 7]. Anteriorly it partly overlaps the mesopterygoid and ectopterygoid. Ventrally it is separated from the quadrate and the dorsal part of symplectic by a narrow stripe of cartilage.

Os ectopterygoideum — pterygoid TCHERNAVIN, 1938; CHAPMAN, 1941 — is a thin, elongated bone, slightly bent, anteriorly somewhat broadened and forming a sort of depression in which the inferior ridge of mesopterygoid is located. The posterior dorsal edge is covered by metapterygoideum whereas the posterior ventral — by quadrate. The free ventral edge is loosely connected with maxilla by a fold of skin.

Os quadratum — originates as the result of ossification of the inferior part of the palato-quadrate cartilage. It is a fan-shaped bone with a lateral projection which, according to de BEER (1937), is an ossified ligament. This projection joins the quadrate with the preopercle. Between the projection and the fan-shaped part of quadrate lies the symplectic, joining the quadrate bone with hyomandibular. The anterior edge of quadrate overlaps a part of ectopterygoid. The inferior part of the quadrate terminates in an articular condyle which meets the depression in the angular producing a mobile junction.

Hyoid arch

To this arch belong seven paired bones of the chondral origin: hyomandibular, symplectic, interhyal, epihyal, ceratohyal, hypohyal superior and inferior. Here the unpaired cartilage forming the base of the „tongue” should be included. It is usually called basihyal cartilage.

Os hyomandibulare — is a link between the palatine arch, branchial arches, opercle and the cerebral part of skull. Its shape is irregular [Fig. 7], with two distinctly marked projections: the posterior with an articulation surface for the opercle, and the inferior one, which joins the metapterygoideum and through a narrow chondral area with the symplectic and interhyal. The broad dorsal edge of hyomandibular joins the pterotic and sphenotic. In its superior part there is a foramen for the *nervus facialis* (VII). The whole bone is covered by the great muscle — *adductor mandibularis*.

Os symplecticum — is connected in its superior broader edge with hyomandibular by a stripe of cartilage. The inferior part of symplectic is located between the fan-shaped part of quadrate and its lateral projection. The upper edge of symplectic communicates with metapterygoideum.

Os interhyale — a small, thin, elongated bone. Its one end is attached through the cartilage to the inferior arm of the hyomandibular, the second end is attached to the cartilage surrounding the upper posterior part of epihyal. This way, the inferior hyoid elements are united with the hyomandibular.

Os epihyale — a rather thick bone, of a somewhat triangular shape [Fig. 8]. Its broad, anterior edge joins by a cartilaginous suture the ceratohyal on its whole width. Its posterior dorsal end is connected to the interhyal. Three branchiostegal bones (*radii branchiostegi*) are attached to its anterior edge.

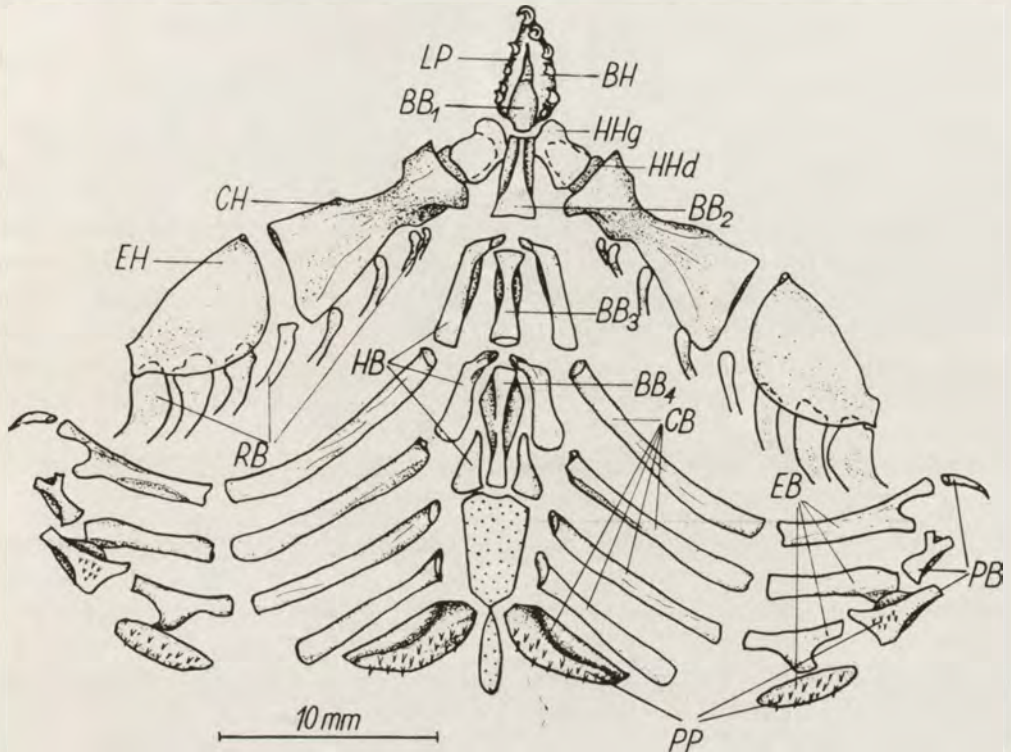


Fig. 8. Branchial skeleton of *Osmerus eperlanus eperlanus* (L.). BB — basibranchial, BH — basihyal cartilage, CB — ceratobranchial, CH — ceratohyal, EB — epibranchial, EH — epihyal, HB — hypobranchial, HHd — hypohyal inferior, HHg — hypohyal superior, PB — pharyngobranchial, LP — lingual plate, PP — pharyngeal plate, RB — radii branchiostegi.

Os ceratohyale — a large flat bone, slightly narrowed in the middle of its length [Fig. 8]. Its broader posterior edge communicates with epihyal, whereas the anterior one touches the thick cartilage, which bears the superior and inferior hypohyals. Four rays of the branchiostegal bones are attached to the inferior edge of ceratohyal.

Ossa hypohyalia — ossified in a thick cartilage from its superior and inferior surface, in form of semi-cylindric osseous plates. From behind they touch the ceratohyal, anteriorly they communicate with the first and second basibranchials [Fig. 8]. Inferior (smaller) hypohyal is connected to the urohyal by a ligament.

Cartilago basihyalis — lingual plate ROSENTHAL, 1832; glossohyal OWEN, 1853; basi- or glosso-hyal PARKER, 1873; symbranchial I GAUPP, 1905. The last name (symbranchial I) according to GAUPP is only the posterior part of basihyal cartilage. Basihyal cartilage is a big, thick cartilage, on which two bones are located: basibranchial I and lingual plate. Basihyal cartilage joins the basibranchial II from behind and hypohyals bones laterally.

Urohyal

Os urohyale — (not illustrated) can hardly be included into one of arches. It is described here because it lies near the hyoid arch and is attached to it by ligament. The urohyal is a flat horizontally situated plate, in form of a isosceles triangle with its apex being headed forward. A vertical crest runs along its median line on the dorsal surface. The urohyal lies freely in muscles below basibranchials. Its anterior part is attached by ligaments to the inferior hypohyals. De BEER (1937) cited several synonyms of this bone, presuming its homology with parahyoideum in the genus *Polypterus* LACÉPÈDE and that of *Amphibia*.

Branchial arches

The branchial arches comprise bones mostly of chondral origin: paired pharyngobranchials, epibranchials, ceratobranchials, hypobranchials and the unpaired basibranchials. There are also bones of dermal origin: paired pharyngeal plates and a single lingual plate as well as the basibranchial plate. In the branchial arches many chondrous elements remain present, especially as articular surfaces; the posterior part of *copula communis* (TCHERNAVIN, 1938) is also endochondral.

Ossa basibranchialia — copulae RAMASWAMI, 1952 — occur in *Osmerus eperlanus eperlanus* (L.) in the number of four [Fig. 8]. The first basibranchial bone is a flat and broad one lying on the dorsal surface of the basihyal cartilage. The three next arranged backward one after another. The basibranchial I and II (symbranchium I and II GAUPP, 1905) touche the hypohyals. These bones are separated from one another by chondrous bridges. The hypobranchials I and II are attached between the basibranchials II and III and between basibranchials III and IV. The hypobranchials III cling to the side of basibranchial IV, by means of a chondral area. Posteriorly the basibranchial IV is joined to the broad and flat cartilage plate lying between the ceratobranchials. The cartilage plate terminates in a tail shaped process (TCHERNAVIN, 1938) lying between the ceratobranchials V.

The basibranchials together with the basihyal cartilage form — according to TCHERNAVIN (1938) — the anterior copula. Its prolongation, the cartilaginous plate with a tail projection, is the posterior copula. Together they are called Copula Communis.

Ossa hypobranchialia — are present in only three first branchial arches. The two first resemble each other. They are bent on their anterior end which joins the cartilage bridge between the basibranchials. The hypobranchial III, a triangular bone, is attached by one edge to the basibranchial IV, its posterior end joins the ceratobranchial III.

Ossa ceratobranchialia — occur as five pairs. They are the longest bones of the branchial skeleton. The first three join the hypobranchials with their posterior ends, the two terminal are attached to the posterior copula. The posterior ends of ceratobranchials are attached to the respective epibranchials by means of a chondrous suture. On the ventral side, the first four have grooves in which branchial arteries are embedded. The fifth ceratobranchial carries a large plate with teeth (pharyngeal plate). According to CHAPMAN (1941, p. 280) those ceratobranchials are toothless.

Ossa epibranchialia — four pairs of long bones [Fig. 8]. The first and third pair are bifurcated. Epibranchials join the pharyngobranchials by their posterior ends. The last pair of epibranchials carry pharyngeal plate armed with teeth. The first three epibranchials have grooves on their dorsal side to receive branchial arteries.

Ossa pharyngobranchialia — occur only in the three first branchial arches. The first, spine-shaped pair, join its epibranchial. The second, bifurcated, with three articular surfaces joins the epibranchial and pharyngobranchial of the first arch. The third pair, with three articular surfaces as well, are the longest and broadest. They join their epibranchials, and the pharyngobranchials and epibranchials of the second arch. On their inferior surface occur small pharyngeal plates armed with teeth. [Fig. 8].

Spinnae branchiales, (gill rakers — not illustrated), occur on hypobranchials, ceratobranchials and epibranchials. Pharyngobranchials are lacking of the gill rakers. On the first branchial arch there are (31, 32) 33–36 (37) gill rakers.

Os linguale plattum — supralingual plate BRUCH, 1861; dermentoglossum GAUPP, 1905; supralingual bone TCHERNAVIN, 1938 — embraces the basihyal cartilage and the basibranchial I which lies over it. It carries on its surface 9–11 big, strong teeth (tongue teeth NORDEN, 1961), with slightly crooked ends.

Os basibranchiale plattum — supracopulare TCHERNAVIN, 1938; suprabasal CHAPMAN, 1941 — is an unpaired bone plate carrying on its surface many

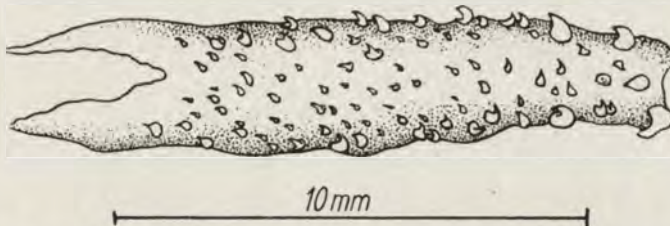


Fig. 9. Basibranchial plate of *Osmerus eperlanus eperlanus* (L.).

teeth of different size [Fig. 9]. It covers basibranchials II and III and partly also IV together. According to TCHERNAVIN, (1938) and BERG (1955), two bones placed one behind the other were found in *Osmeridae*.

Ossa pharyngealia platta — occur in three pairs as small plates with teeth on the third of the pharyngobranchials, on the fourth of epibranchials and on the fifth of ceratobranchials [Fig. 8].

Investing bones

The majority of investing bones are associated with the lateral sensory canals located on the skull surface. A detailed descriptions of the sensory canals, their formation and the bones connected with them, are given by ALLIS (1904) and LECANDER (1949). In the present study, the sensory canals were discussed as much as it was necessary for description of particular bones. The fact which deserves being mentioned, is that in *Osmerus* L. all sensory canals are open and never enclosed in complete osseous tubes as it occurs in majority of Teleosts.

Dorsal investing bones

Ossa supraethmoideum — see the description of the olfactory region.

Ossa nasale — a paired dermal bone, of a tubular shape, with one open side (external). Nasal is located loosely in skin, closely to the lateral edge of the anterior part of frontal. It enclose the anterior part of the supraorbital sensory canal.

Ossa frontale — a paired dermal bone that covers the major part of braincase from the dorsal side. In the middle line it joins the corresponding bone from the other side. Only in the anterior part, both frontals are separated from each other by a cartilage. Posteriorly the frontal touches the parietal, while anteriorly it is in contact with supraethmoid and ethmoid. The exterior, lateral edge of the frontal forms the superior edge of the orbit. A sensory canal run along the frontal. Anterior end passes into the nasal while posteriorly ramifies, and its ventral branch joins laterally the suborbital canal, running in dermosphenotic and in the outer part of prootic [Fig. 10].

Ossa parietale — is a paired bone of irregular shape. Both parietals are completely separated from each other by the supraoccipital which is partly covered by them. The anterior part of each parietal joins the posterior edge of the frontal. The postero-lateral wall of the parietal forms a part of the lateral wall of the temporal fossa.

Ossa extrascapularia — tabulare, scale bone GREGORY, 1933; supratemporal STARKS, 1926; lateral line bone CHAPMAN, 1941 — occur as four bone on each side of the skull. Two of them have the transversal position, while two other lie horizontally at the right angle to the former [Fig. 10]. The transversal bear the supratemporal sensory canal (ALLIS, 1904), the two horizontal close

the main subtemporal sensory canal which runs from the circumorbital bones and subsequently across the external part of the pterotic, along the both horizontal extrascapulars and the paired *ossa posttemporalia*. (Posttemporals are well seen in side view and from the dorsal surface of skull; they are often included into the pectoral girdle). From the posttemporal, the suborbital canal passes across the paired *os supracleithrum*, then over the scales producing

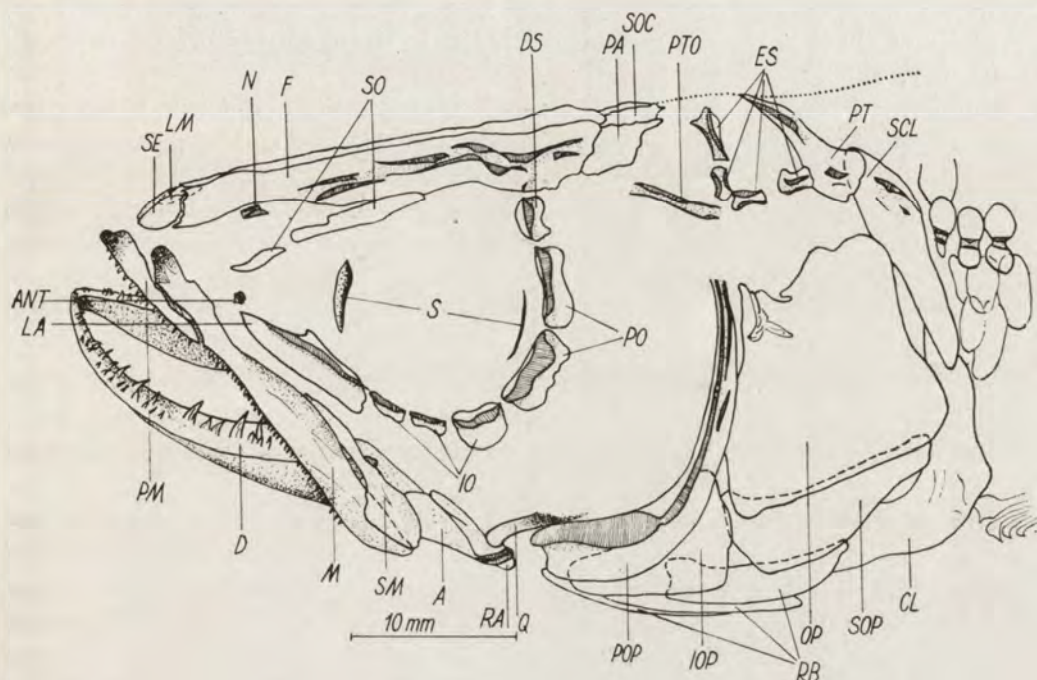


Fig. 10. Investing bones of *Osmerus eperlanus eperlanus* (L.). A - angular, ANT - antorbital, CL - cleithrum, D - dentary, DS - dermosphenotic, ES - extrascapular, F - frontal, IO - infraorbital, IOP - interopercle, LA - lachrymal, M - maxilla, N - nasal, OP - opercle, PA - parietal, PM - premaxilla, PO - post-orbital, POP - preopercle, PT - posttemporal, PTO - pterotic, Q - quadrate, RA - retro-articular, RB - radii branchiostegi, S - sclerotic, SCL - supracleithrum, SE - supratethmoid, SM - supramaxilla, SO - supraorbital, SOC - supraoccipital, SOP - subopercle.

the lateral line of the body - *linea lateralis*. In *Osmerus eperlanus eperlanus* (L.) of the Miedwie Lake this canal occurs however only on the first 3-11 scales. At the junction of the transvers and horizontal extrascapulars with the external pterotic - three sensory canals are meeting: the main suborbital (having a horizontal course in this place), the supratemporal (running up transversally) and the preopercular one which runs downwards and then along the preopercular bone.

Lateral investing bones

Ossa circumorbitalia — are paired bones, 10 on each side of the skull; they surround nearly all the orbit except for its dorsal part which is covered by frontal. Some authors (RIDEWOOD, 1904b; BERG, 1940; VLADYKOV, 1954) name these bones by different terms. In the present paper terms used by NORDEN (1961) are applied: Two supraorbitals — the only bones of this series with no sensory canals, three infraorbitals, three postorbitals — (the most superior of them is the dermosphenotic), the lacrimal and antorbital (adnasal) GREGORY, 1933.

Os supraorbitale anterior — is narrow, slightly bent, and forms the ventral edge of the olfactory capsule. It lies above the anterior end of palatine bone. Posteriorly it borders on the posterior supraorbital.

Os supraorbitale posterior — forms the posterior wall of the olfactory capsule. On the dorsal side it borders on the frontal. All together the supraorbitals produce the anterior upper edge of orbit.

Os lacrimale — praeorbital RIDEWOOD, 1904; BERG, 1940; suborbital VLADYKOV, 1954 — is the biggest bone of all those surrounding the orbit. It carries on its surface a part of the suborbital canal. The inferior part of the lachrymal borders on the maxilla and supramaxilla across the skin, posteriorly it touches the infrorbital I. Its superior edge forms a part of the anterior margin of the orbit.

Os antorbitale (adnasale) — seems to be homological to the bone of the same name in fishes of a lower systematic range e. g. *Crossopterygii*, *Polypteryni* or *Amioidei*, and the same term should probably be applied to it. According to GREGORY (1933, p. 93) this bone is "absent in teleosts". The antorbital is placed somewhat more anteriorly and higher than lachrymal [Fig. 10] and encloses the anterior part of the suborbital canal. According to WEITZMAN it occurs in some teleosts but is not connected with the sensory canals.

Ossa infraorbitalia I, II, III — from the ventral margin of the orbit. They are thin osseous plates carrying the suborbital canal on their surface. The first infraorbital borders on the lachrymal by its anterior edge, the third one — on the postorbital by its posterior edge.

Ossa postorbitalia I, II, III — form the posterior margin of the orbit. They partly cover the *adductor mandibularis* which joins them with preopercle. They all carry the suborbital canal which, in the dermosphenotic, the most superior of those bones, fuses with the supraorbital canal running inside the nasal and frontal bones.

Os praeoperculum — is a semilunar bone. Its position is indicated by its name. This one carries the preopercular sensory canal which dorsally joins the suborbital and the supratemporal canals across the skin. On the lateral side, the preorbital canal runs across the angular and subsequently — along the dentary as the mandibular canal. The anterior edge of preopercle is the

attachment point for the *musculus adductor mandibularis*. The inferior part of this edge joins the exterior part of the quadrate [Fig. 10]. The posterior edge partly covers the opercle and interopercle.

Os operculum — is the biggest bone in the skull of *Osmerus* L. It is thin, flat bone plate of a trapezoid shape. Its superior thickened part has an articulating surface on its internal side, to join the right (posterior) process of the hyomandibular. The anterior edge of the opercle is partly covered by the preopercle, the inferior one — overlaps the superior edge of subopercle. Posteriorly it touches the supracleithrum, inferiorly covers a part of *os cleithrum*. The dorsal edge of opercle covers partly three muscles: *musculus opercularis dilatator*, *levator* and *adductor*.

Os suboperculum — is a flat bone plate. Its anterior edge is covered by interopercle, the dorsal — by opercle. Posteriorly subopercle overlaps a part of cleithrum, and ventrally overlaps the seventh and eighth branchiostegal rays.

Os interoperculum — a flat triangular bone. Its antero-dorsal edge is covered by preopercle. The posterior edge overlaps partly the subopercle, the ventral — the anterior part of the last branchiostegal ray, and inwards — a part of the epihyal.

Radii branchiostegi — occur in *Osmerus* L. in number 7 or 8. CHAPMAN (1941) reported 6 or 7 of them. The first branchiostegal ray is the smallest, situated the most anteriorly. The next are gradually larger. The first three or four rays are attached to the ceratohyal, the fourth or the fifth lie between the ceratohyal and epihyal, the last three are attached to the epihyal.

The ventral investing bones

Os parasphenoideum — is a long narrow bone enlarged on both ends [Fig. 11]. In its anterior part, on the dorsal surface it carries a crest which is embedded

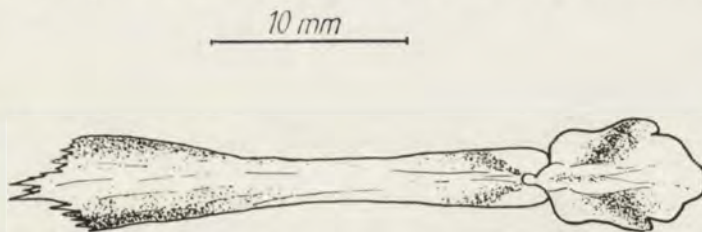


Fig. 11. Parasphenooid of *Osmerus eperlanus eperlanus* (L.) — dorsal view.

in the infraethmoid, and this one in turn — fit into a groove in ethmoid cartilage. The extension of the posterior part, somewhat concave, forms the bottom and partly the lateral walls of the posterior midom. In its anterior part it borders on vomer, in the posterior — dorsally on the left and right prootic and basioccipital. Together with metapterygoid, mesopterygoid and palatine it produces the superior vault of the mouth.

Vomer — prevomere HARRINGTON, 1955 — is mounted upon rostrum, like a cap, covering it from above, anteriorly and from the ventral side. It is unpaired in mature *Osmerus* L., and carries rarely two, more often to six big, strong, canine like teeth. STARKS, 1926 and CHAPMAN, 1941 reported only two teeth on the vomer in the genus *Osmerus* L. Anteriorly vomer is surrounded by the premaxillas, dorsally it touches the supraethmoid, ventrally it borders on the infraethmoid and the on parasphenoid. According to GREGORY (1933) and de BEER (1937) this bone is homologous to praevomer in tetrapods, according to HARRINGTON (1955) its homologous bone in mammals would be the parasphenoid.

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STRESZCZENIE

Autor daje dokładne opracowanie osteologiczne czaszki stynki *Osmerus eperlanus eperlanus* (L.) z jeziora Miedwie (Polska). Materiał osteologiczny do tej pracy uzyskiwany był przez preparowanie szkieletów oraz dzięki barwieniu czaszek alizaryną i następnie prześwietlaniu ich w KOH. Metoda ta pozwoliła stwierdzić właściwe położenie poszczególnych kości względem siebie. Rysunki do pracy wykonane były z barwionych i prześwietlonych preparatów przy pomocy aparatu ABBEGO.

W wyniku pracy znaleziono dwie nowe kości dla rodzaju *Osmerus* L. Są to: *os infraethmoideum*, leżąca w obszarze chrzęści ethmoidalnej i *os antorbitale* wchodząca w skład kości wokółocznych. Szczególnie charakterystyczne jest wykrycie *os antorbitale*, kości bardzo dyskutowanej przez wielu autorów i mogącej mieć duże znaczenie systematyczne dla stynki. Praca ta ma także stanowić oparcie dla następnej pracy, monograficznej, dotyczącej stynki Polski.

РЕЗЮМЕ

Автор подробно описывает строение черепа корюшки, *Osmerus eperlanus eperlanus* (L.) из озера Медве (Западное поозерье, Польша). Остеологические препараты были получены путем окрашивания ализарином и просветления в КОН. Этот метод позволил установить истинную форму и положение отдельных костей по отношению одна к другой. Рисунки были выполнены с препаратов при помощи рисовального аппарата типа Аввё.

В результате исследований были найдены две новые для рода *Osmerus* L. кости: *os infraethmoideum*, находящаяся в области этмоидального хряща, и *os antorbitale*, входящая в состав глазничных костей. Особый интерес представляет открытие *os antorbitale* — кости, не признаваемой многими авторами, что может иметь большое систематическое значение для корюшки.

Настоящая работа послужит основанием для следующей работы, посвященной обработке корюшки Польши.

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