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This is to certify that the

thesis entitled

The Osteology of the American Smelt (Osmerus mordax)

presented by

Jagat Pal Singh

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Fishery Biology


Major professor

Date March 5, 1959

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A STUDY OF

Submitted to
Michigan State
Science 17

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Approved

A STUDY OF THE OSTEOLOGY OF THE AMERICAN SMELT,
OSMERUS MORDAX (MITCHILL)

By
JAGAT PAL SINGH

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and Applied
Science in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Fisheries and Wildlife

1959

Approved Peter J. Tack

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AN ABSTRACT

The American smelt, Osmerus mordax (Mitchill) is classified under the family, Osmeridae by recent ichthyologists, Berg (1940); and Hubbs and Lagler (1947).

The skeleton of the smelt is typical of teleostean fishes of the suborder, Salmonoidea.

The olfactory region contains the paired proethmoids, prefrontals, vomers, nasals and the unpaired ethmoid.

The orbital region contains the paired circumorbital series of bones, frontals and sphenotics.

The otic region contains the paired pterotics, epiotics, parietals, post-temporals and the unpaired supraoccipital, the paired exoccipitals, prootics and supracleithrums.

The basicranial region contains the unpaired basioccipital and parasphenoid.

The oromandibular region contains the paired palatines, quadrates, articulares, metapterygoids, entopterygoids, pterygoids, premaxillaries, maxillaries, supramaxillaries, angulars and dentaries.

The hyoid region contains the paired hyomandibulars, symplectics, interhyals, epihyals, ceratohyals, hypohyals, operculars, preoperculars, suboperculars, interoperculars, branchiostegals and the unpaired basihyal and urohyal.

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The skeletons of the smelt and the salmon show differences sufficient for recent ichthyologists to classify them in the separate families, Osmeridae and Salmonidae, but retaining them in the same suborder, Salmonoidea.

The vertebral column, dorsal fin, pectoral fins, pelvic fins, anal fin and caudal fin are very similar to the typical teleostean fishes.

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ACKNOWLEDGMENTS

I am greatly indebted to Dr. Peter I. Tack, Head of Department of Fisheries and Wildlife for his guidance and supervision in my research work.

For all photographs of the various bones, the author is again indebted to the professor P. I. Tack.

I wish to express my gratitude to Dr. Eugene W. Roelofs for many suggestions and advice.

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LITERATURE CO

TABLE OF CONTENTS

	PAGE
INTRODUCTION.	1
GENERA AND SPECIES.	3
MATERIALS AND METHODS	12
DESCRIPTION OF OSTEOCRANIUM OF THE SMELT (<u>OSMERUS MORDAX</u>)	14
(a). Olfactory region	21
(b). Orbital region	22
(c). Otic region.	26
(d). Basicranial region	28
(e). Oromandibular region	29
(f). Hyoid region	32
(g). Branchial region	41
COMPARISON OF SMELT'S SKULL WITH SKULL OF SALMON.	43
DESCRIPTION OF VERTEBRAL COLUMN OF SMELT (<u>OSMERUS MORDAX</u>)	59
DESCRIPTION OF DORSAL FIN OF SMELT (<u>OSMERUS MORDAX</u>)	67
DESCRIPTION OF PECTORAL GIRDLE AND FIN OF SMELT (<u>OSMERUS</u> <u>MORDAX</u>)	71
DESCRIPTION OF PELVIC FIN OF SMELT (<u>OSMERUS MORDAX</u>)	76
DESCRIPTION OF ANAL FIN OF SMELT (<u>OSMERUS MORDAX</u>)	82
DESCRIPTION OF CAUDAL FIN OF SMELT (<u>OSMERUS MORDAX</u>)	86
PHYLOGENETIC RELATIONSHIP OF THE SMELT IN TELEOSTEAN FISHES.	92
SUMMARY	97
LITERATURE CONSULTED.	100

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SALON

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A TABLE

TABLE	PAGE
I. THE COMPARISON OF VARIOUS BONES OF SKULL OF THE SALMON AND THE SMELT.	57

1111

1. The American
2. Skull of the
3. Skull of the
4. Sagittal se
normal)
5. Skull of th
6. Skull of th
7. Hyobranchi
dorsal
8. Hyoid arch
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11. Skull of
12. Skull of
13. Skull of
14. Descript
A. F
B & C
D. C
15. Vertebra
(Cost)
16. Dorsal
17. Left co
the

LIST OF FIGURES

FIGURE	PAGE
1. The American Smelt, <u>Osmerus mordax</u> (Mitchill). . . .	8
2. Skull of the smelt (<u>Osmerus mordax</u>); lateral view. .	16
3. Skull of the smelt (<u>Osmerus mordax</u>); lateral view. .	18
4. Sagittal section of the skull of the smelt (<u>Osmerus mordax</u>)	20
5. Skull of the smelt (<u>Osmerus mordax</u>), dorsal view . .	24
6. Skull of the smelt (<u>Osmerus mordax</u>), dorsal view . .	25
7. Hyobranchial system of the smelt (<u>Osmerus mordax</u>), dorsal view	34
8. Hyoid arch, left half of the smelt (<u>Osmerus mordax</u>), mesial view	36
9. The preoperculars from skull of the smelt (<u>Osmerus mordax</u>), lateral view	39
10. Skull of Salmo sp., lateral view	45
11. Skull of Salmo sp., dorsal view.	47
12. Skull of the smelt (<u>Osmerus mordax</u>), lateral view. .	49
13. Skull of the smelt (<u>Osmerus mordax</u>), dorsal view . .	51
14. Description of vertebrae of the smelt (<u>Osmerus mordax</u>) 61 A. First vertebra (Atlas), posterior view B & C. A typical vertebra (3-41), posterior view D. Caudal vertebra, posterior view	
15. Vertebral column with the caudal fin of the smelt (<u>Osmerus mordax</u>).	63
16. Dorsal fin of the smelt (<u>Osmerus mordax</u>)	69
17. Left coracoid, scapula, cleithrum and pectoral fin of the smelt (<u>Osmerus mordax</u>), mesial view	73

1. Left re
view

2. Pelvic
view

3. Anal p

4. Caudal
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5. Caudal
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LIST OF FIGURES (Contd.)

18.	Left pelvic fin of the smelt (<u>Osmerus mordax</u>), lateral view.	78
19.	Pelvic fins of the smelt (<u>Osmerus mordax</u>), lateral view.	80
20.	Anal fin of the smelt (<u>Osmerus mordax</u>)	84
21.	Caudal end and caudal fin rays of the smelt (<u>Osmerus mordax</u>). Diagrammatic.	88
22.	Caudal end and caudal fin rays of the smelt (<u>Osmerus mordax</u>)	90

INTRODUCTION

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INTRODUCTION

The common American smelt, *Osmerus mordax* (Mitchill) is classified under the family Osmeridae by Jordan (1929) and Berg (1940). The family Osmeridae is closely related to families Salmonidae, Coregonidae, Thymallidae and Argentinidae (Hubbs and Lagler, 1947), (Jordan, 1905), and (Berg, 1940). This is a small family with 7 genera and 13 species. Only three genera are listed by Berg (1940). These three genera are placed in the two subfamilies, Osmerini and Hypomesini. The genera *Osmerus* and *Mallotus* are placed under the subfamily Osmerini, while the genus *Hypomeus* is placed under the subfamily Hypomesini. The osteology of genus *Mallotus* is completely unknown. Berg gave the diagnostic subfamily characters of Osmerini as follows: (I) Olfactorius passing through the orbit. (II) Mesethmoid paired in young. (III) Vomers sometimes paired in young. The diagnostic characters of Hypomesini are (I) Olfactorius nerves not passing through the orbit. (II) Teeth feeble. (III) No canine on vomer. (IV) Mesethmoid and vomer unpaired.

No attempt has hitherto been made to describe the osteology of the smelt, *Osmerus mordax*, though Starks (1926) has described the ethmoid region of the smelt, *Osmerus dentex*. Excellent figures of *Salmo* sp., closely related to the smelt are described by Gregory (1933).

GENERA AND SPECIES

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GENERA AND SPECIES

There are 7 genera of smelt containing 13 species. For convenience, each genus is briefly characterized below. The species with their characters are listed under the corresponding genus.

I. Genus Mallotus Cuvier

External characters: (I) Scales very small, arranged in males in villous bands. (II) Pectoral fins broad, of 15 to 20 rays. (III) Teeth feeble. (IV) Pyloric caeca, six. (V) Branchiostegals 8 to 10. (VI) Dorsals inserted over ventrals. (VII) Gill rakers long and slender.

Mallotus villosus (Muller). Characters: (a) D.12; A.18, scales about 150. (b) Head long and pointed. (c) Base of anal in males compressed and prominent, its anterior rays simple and stiff. (d) Pectorals reaching more than halfway to ventrals and the latter reaching more than halfway to anal.

II. Genus Thaleichthys Girard

External characters: (I) Teeth feeble, those on tongue very weak. (II) Scales small, adherent and similar in both sexes. (III) All the teeth are very feeble, slender, and deciduous, although occasionally present on all the bones of the mouth; no permanent teeth on the tongue. (IV) Coloration dusky.

Thaleichthys pacificus (Richardson): Characters: (a)

D.11; A.21; P.11; scales 75. (b) Pyloric caeca 11. (c) Vertebrae 70. (d) Mouth large, the maxillary rather narrow and long, reaching beyond the middle of the rather small eye. (e) Lower jaw projecting. (f) Opercle with strong concentric striae. (g) Gill rakers are numerous, rather long and slender. (h) Ventrals large, inserted just in front of dorsal. (i) Pseudobranchiae small.

Thaleichthys albatrossis (Jordan and Gilbert)

Characters: (a) D.2, 10; A.1, 20; scales 75. (b) Mouth large, lower jaw heavy, strongly projecting. (c) Opercle with concentric striae. (d) Caudal moderate, well forked. (e) Dorsal high, anal fin low, long; ventrals long and pectorals moderate. (f) Ventrals inserted before dorsal. (g) Scales small, deciduous, those on the back are still smaller. (h) Lateral line distinct. (i) Tongue with moderate teeth, anterior 2 to 4 small hooked canines. (j) Upper jaw with small sharp teeth similar to those in lower jaw, none of them canine like. (k) Small teeth on palatine and pterygoid.

III. Genus *Spirinchus* Jordan and Everman

External characters: (I) Body comparatively deep and compressed. (II) Head rather short and deep. (III) The maxillary broad, short, its edge strongly curved, extending to opposite posterior margin of pupil. (IV) Mandible projecting. (V) Fins high.

Spirinchus thaleichthys (Ayers): characters: (a) D.9;

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A.14 to 16; scales 55 to 58. (b) Teeth weak, maxillary teeth scarcely visible. (c) Olivaceous, sides silvery and somewhat translucent. (d) A weak and feeble species, its flesh of excellent flavor. (e) Pacific coast from San Francisco northward to Bristol Bay in Alaska.

IV. Genus *Allosmerus*. Lockington

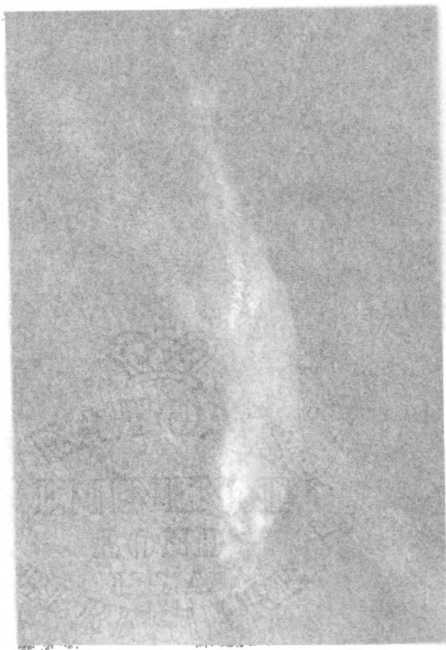
External characters: (I) Body elongate and compressed. (II) Head rather long, somewhat pointed, maxillary extending past pupil. (III) Lower jaw projecting. (IV) Maxillary narrow and somewhat convex. (V) Outline of both jaws nearly straight.

Allosmerus annenuatus (Lockington): Characters (a) Eyes large. (b) D.10; A.15-17; P.11; Scales 65. (c) Teeth on tongue strong, but small; teeth on maxillary conspicuous. (d) Front of both jaws with rather strong teeth; palatine teeth variable, usually strong. (e) Fins low. (f) Pectorals not reaching ventrals, ventrals not reaching anal. (g) Greenish dorsally sides silvery.

V. Genus *Osmerus* (Artedi) Linnaeus

External Characters: (I) Body elongate and compressed. (II) Head long and pointed. (III) Mouth wide, the slender maxillary extending to past the middle of the eye. (IV) Lower jaw projecting. (V) Preorbital and suborbital bones narrow. (VI) Maxillary and premaxillary with fine teeth, lower jaw with small

FIGURE 1. THE AMERICAN SMELT, OSMERUS MORDAX (MITCHILL)
LATERAL VIEW, X





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teeth, which are larger posteriorly. (vii) Tongue with a few strong, fang-like teeth, largest at the tip. (viii) Hyoid bone, vomer, palatines, and pterygoids with wide set teeth. (ix) Gill rakers are long and slender. (x) Branchiostegal rays 8. (xi) Scales large, loose, 60 to 70 in the lateral line. (xii) Dorsal small, about midway of the body, over the ventrals; anal rather long. (xiii) Pyloric caeca small, few.

Osmerus dentex, Steindachner; Characters: (a) D.10; A.13; V.8; scales 66. (b) Eyes large, two-thirds length of snout. (c) Maxillary reaching posterior margin of eye, its length 5 times in distance from tip of lower jaw to dorsal. (d) Height of dorsal one-half the length of head; height of anal two-sevenths; pectoral shortish, reaching halfway to ventrals. (e) Back pale olive, scales edged with darker. (f) Sides above lateral line purple, changing below to blue, and then to violet and gold.

Osmerus mordax (Mitchill), American smelt (Fig. 1): Characters: (a) D.10; A.15; P.13; scales 68. (b) Body rather long and slender. (c) Head large, with large mouth, and stronger teeth than in the other species of the genus. (d) Small teeth along the edge of the maxillary; strong fang-like teeth on tongue and front of vomer; cardiform teeth on palatines, pterygoids, and hyoid bone; mandible with moderate teeth, its tip projecting. (e) Maxillary extending to a little beyond middle of eye. (f) Scales deciduous. (g) Dorsal fin rather posterior, in position and the ventrals under its origin; lower fins moderate, none

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reaching the next behind it. (h) Transparent greenish above, silvery on sides. (i) Body and fins with some dark punctulations.

Osmerus sergeanti Norris; Characters: (a) Form elliptical, elongated and section oval; (b) Lower jaw projecting, with an upward curve; (c) Scales on all the gill covers largest on preopercle; (d) Five large recurved teeth on the tongue, the largest on the extreme point, two of the same kind on the front of the upper jaw; (e) No teeth on the vomer, a patch of small ones on the palatine bones and maxillaries. (f) Silvery steel color above, with light greenish reflections. (g) Branchial rays 8-11, C 20; P 11; V 8, A 15; (h) Tail forked, upper lobe slightly longer..

Osmerus eperlanus: European species.

VI. Genus Hypomesus Gill

External Characters: (I) Body rather elongate, moderately compressed, covered with scales of moderate size; (II) Head rather pointed, and the mouth moderate; (III) Lower jaw projecting; (IV) Teeth minute, on jaws, vomer, palatines, pterygoids and tongue. (V) Ventrals inserted directly under middle of dorsal, and they are midway between eye and base of caudal; (VI) Branchiostegals 6 to 7.

Hypomesus pretiosus (Girard): Characters: (a) D.10; A.15; P.14; V.8; Scales 70. (b) Fins low, the longest dorsal ray 8 in length without caudal; (c) Pectorals scarcely reaching

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halfway to ventrals, and the ventrals not reaching vent; (d) Light olivaceous above; (e) A silvery band along the lateral line.

Hypomesus olidus (Pallas): Characters: Scales 56 to 60. (b) The dorsal fin higher than in Hypomesus pretiosus, the longest dorsal ray 6 in length of body; (c) Pectorals reaching $2/3$ the distance to base of ventrals. (d) Coloration dusky, slightly translucent.

Hypomesus japonicus: found in Japan.

VII. Genus Therobromus Lucas

to

External characters: (I) Similar ^{to} the genus, Mesopus.

(II) Vertebral formula 26 precaudals, 22 caudals, plus 1 hypural.

Therobromus callorhini Lucas: Characters: (a) Chondrocranium well developed: (b) Superior maxillary edentulous, pointed teeth on vomer and anterior part of palatine. (c) Lower jaw very deep. (d) Pointed teeth on dentary. (e) Articular well developed. (f) Vertebrae simple, anterior but very little shorter than the posterior; centra not sculptured, but bearing many fine longitudinal ridges.

N.B. Therobromus callorhini is known only from skeletons and bones found in the stomachs of fur seals.

MATERIALS AND METHODS

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MATERIALS AND METHODS

A number of adult smelt for this study were taken from the commercial catch at Little Bay de Noc (February, 1958), Michigan, and they were shipped to the Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan. Specimens for this study were taken from this collection.

The smelt's skeleton was prepared in the following ways: (1) Boiling the fish in the water, (2) Use of trypsin and ammonia, (3) Staining the skeleton with alizarin red, and (4) Use of dermestid beetles.

The following three methods were inadequate for this study: (1) Boiling the fish in water, (2) Use of trypsin and ammonia, (3) Staining with alizarin red.

In the preparation of a skeleton, the use of carpet beetles proved to be the most useful method even if the skeleton is delicate and bones are of membranous nature. The fishes with a label are left in the "Insect colony" for a period of 7 to 10 days, and the beetles eat all the fleshy part of body and clean almost every piece of bone. The main advantage of this method is that the bones remain articulated. This method was very successful in the preparing of the skeleton for this study.

DESCRIPTI

DESCRIPTION OF OSTEOCRANIUM OF THE SMELT (OSMERUS MORDAX)

FIGURE 2. SKULL OF THE SMELT, (OSMERUS MORDAX)

LATERAL VIEW.

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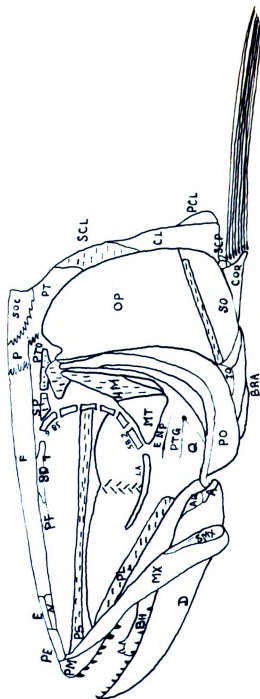


FIGURE 3. SKULL OF THE SMELT (OSMERUS MORDAX),
LATERAL VIEW?
2 X





FIGURE 4. MEDIAL ASPECT OF LEFT HALF OF SKULL, OSMERUS MORDAX
OF THE SMELT, (OSMERUS MORDAX)
2 X





DESCRIPTION OF OSTEOCRANIUM OF THE SMELT (OSMERUS MORDAX)

Olfactory Region

Cartilage bones: Paired proethmoids (Fig. 2. PE), and unpaired ethmoid (E).

Dermal bones: Paired prefrontals (PF), vomers (V), and nasals (N).

The proethmoids (Fig. 5. PE): They are composed of fragile, cancellous endochondral bones. They are situated on the dorsal side of the vomers and are very obvious from the dorsal view. The fused proethmoids and the vomers are encased dorsally, anteriorly and laterally by cartilage continuous with the platnum ethmoidale. The proethmoids are exclusively supported by the vomers and posteriorly are attached to the median ethmoid bone.

The ethmoid (Fig. 5. E): It is a square shaped bone which lies medially with the vertical posterior edge perpendicular to its ventral edge. It is thin and sometimes overlooked. Ventrally it flares anterolaterally on either side of its median notch, which conforms with the underlying vomers.

The prefrontals (Fig. 2. PF): They are posteriorly placed, remote from the ethmoid and vomers, leaving a long nasal fossa anteriorly. They have the same appearance as other membrane bones. Each is fused to the lateral border of the frontals.

The vomers (Fig. 5. V): They cannot be seen from the dorsal side, although their position is quite obvious from the ventral side, if the lower jaw is removed. They are thin, flat, paddle-shaped bones underlying the proethmoid, and overlapping the anterior end of parasphenoid ventrally. A pair of strong canine teeth is present on each vomer. Vomerine teeth are important in the systematics of the family, Osmeridae.

The nasals (Fig. 5. N): They are long, slender inconspicuous bones attached to the corresponding frontals. They are very similar in appearance to the frontals, are situated laterally to the ethmoid, and are connected anteriorly with the proethmoids and posteriorly with the frontals.

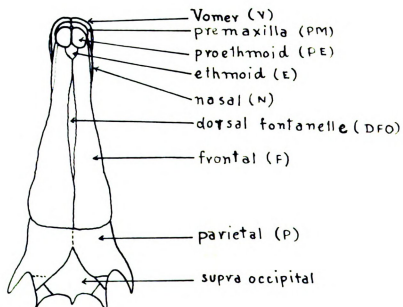
Orbital Region

Dermal bones: Paired lacrymals (Fig. 2. LA), suborbitals (SB 2-4), suborbitals (SB 5-6), supraorbital (SO 7), frontals (F), and sphenotics (SP).

The circumorbital bones (Fig. 2. LA, SB 2-6, SO 7):

All the bones of the circumorbital series are arranged more or less ring-like around the eye. They are all flat, surmounted by a bony tube. Suborbitals 4 and 5 (SB 4-5) show a little evidence of fusion. Suborbital 6 (SB 6) is reduced to a bony piece, which is often white. Supraorbital 7 (SO 7) is attached to the edge of the corresponding frontal and ^{is} laid horizontally parallel with the prefrontals.

FIGURE 5. SKULL OF THE SNELT (OSMERUS MORDAX),
DORSAL VIEW.

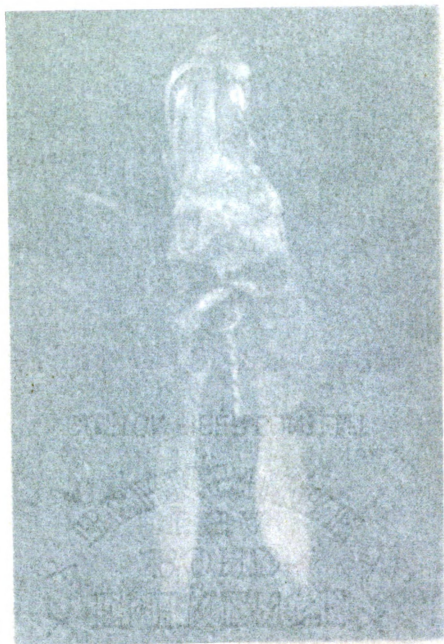


3X

FIGURE 6. SKULL OF THE SMELT, (OSMERUS MORDAX)

DORSAL VIEW

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The frontals (Fig. 5, F): They make the roof of the brain cavity and are joined anteriorly with the ethmoid and the proethmoids. Posteriorly they are attached to the parietals. A fontanelle is found between the frontals, although they show a suture at the anterior and posterior ends.

The sphenotics (Fig. 2. SP): They form the side walls of the cranial cavity, join pterotics posteriorly and the orbital region anteriorly.

Otic Region

Cartilage bones: Paired pterotics (Fig. 2. PTO), epiotics (EPT), exoccipitals (EO), prootics (PRO), and unpaired supraoccipital (SOC).

Dermal bones: Paired parietals (P), post-temporals (PT), and supracleithrum (SCL).

The pterotics (Fig. 2. PTO): Anteriorly they attach to the sphenotics and ventrally with the hyomandibulars. Their upper portion contributes to the surface of the skull externally and to the vault of subtemporal fossae internally, within which they fuse with the lamellae of the epiotics. Ventrolaterally, they curve around the horizontal semicircular canals, rejoining their upper portion within the fossae, thus completely enclosing the canals, and forming the other margin of the fossae.

The epiotics (Fig. 4.): They enclose the posterior

semicircular canals. They are just below the pterotics and posteriorly attach to the opercular bones. It is assumed that the epiotics fuse with the supraoccipital dorso-mesially, with the exoccipitals ventroposteriorly and also ventro-mesially within the subtemporal fossae.

The exoccipitals (Fig. 4): They are not shown in the diagram. It appears that they fuse with the pterotics antero-laterally, with the epiotics dorsally outside, and laterally inside the subtemporal fossae. The exoccipitals join mesially with the basioccipital.

The prootics (Fig. 4.): They are situated on the ventral side of the braincase, completely invisible from the dorsal side. They are joined by the parasphenoid, which is club-shaped posteriorly. Their posterolateral extensions form the antero-mesial curvature of the subtemporal fossa roof, and are joined with pterotics and exoccipitals.

The supraoccipital (Fig. 2. SOS): It is shield-shaped. There is a small median convexity. It seems that it has concave anterior border which conforms to the posteromedial margin of the posterior chondrocranium fontanelle. The supraoccipital forms sutures laterally with the epiotics and parietals. Posterior to the sutures, it joins the cartilage roofing of foramen magnum. The intermembranous spine of supraoccipital is present at the posterior end of this bone.

The parietals (Fig. 2. P): They overlies the posterior

part of the chondrocranial fontanelle, the upper portion of sphenoids, epiotics, and the supraoccipital. The right and left parietal joins at the middle and both are joined anteriorly by the frontals. They are similar in appearance with frontals, smooth, slightly concave dorsally and more or less triangular.

The post-temporals (Fig. 2. PT): They are lancet-shaped and the upper ends of these bones join the epiotics. Both fuse at the dorsal side of the skull. The sub-temporals and supracleithrums are the intermediate bones between the skull and the pectoral girdle.

The supracleithrums (Fig. 2. SOL): They are flat, paddle-shaped, with the anterior ends articulating with the under surface of the post-temporals, and the knife blade like posterior ends articulate with the lateral surface of the cleithrums below.

Basicranial Region

Cartilage bones: Unpaired basioccipital (Fig. 4.).

Dermal bones: Unpaired parasphenoid (Fig. 2. PS).

The basioccipital (Fig. 4.): It forms the roof and posterior wall of the myodome. The ventral wall is continuous behind with the conical, posteriorly concave centrum of the subsumed proatlas vertebra. Dorsoventrally, on each side, the basioccipital forms a suture with the ventromedial edge of the adjacent exoccipital.

The parasphenoid (Fig. 2. PS): This is the longest bone in the skull of the smelt, and extends in the midline along the greater part of the ventral length of the neurocranium. At its anterior end, it is overlapped by the proethmoids and vomers. It constitutes a thick narrow strut of bone which skirts the lower edge of the vertical plate of the orbitosphenoid. At the posterior end of this bone, it widens abruptly to its maximum width and forms a club-like structure. The club-shaped posterior end joins with the prootics. A narrow groove is formed from the ventroanterior end of this bone which increases in its width from the middle part to the posterior end.

Oromandibular Region

Cartilage bones: Paired palatines (Fig. 2. PL), quadrates (Q), articulares (AR).

Dermal bones: Paired metapterygoids (Fig. 2. MPT), entopterygoids (ENP), pterygoids (PT), premaxillaries (PM), maxillaries (MX), supramaxillaries (S.MX), angulars (A), and dentaries (D).

The palatines (Fig. 2. PL): They are dentigerous, rod-like and lie underneath against the ventral side of the entopterygoids. The anterior half of these bones have canines of variable number and size.

The quadrates (Fig. 2. Q): They are more or less triangular bones. Anteriorly they are flat and fan shaped, posteriorly they are produced in a long, thick, handle-like knob.

At their anteroventral angles, they bear the condyles which articulate with the notch in the angulars. Dorsally, the mesial surfaces of the quadrates are applied to the lower lateral surfaces of the posterior ends of pterygoids.

The articulares (Fig. 2. AR): They are small, slender bones, almost united with the dentaries, and posteriorly fused with the angulars.

The metapterygoids (Fig. 2. MT): They are broad, flat bones, and are almost rectangular in shape. The dorsoposterior and dorsoanterior angles of these bones form the chief point of articulation with the hyomandibulars. The symplectics join the hyomandibulars and the metapterygoids posteriorly. Dorsoanteriorly, the mesial surfaces of the metapterygoids are applied to the posterior lateral surface of the entopterygoids. The right half of the metapterygoids borders on the dorsal edge of the symplectics.

The entopterygoids (Fig. 2. ENT): They are similar in appearance to the metapterygoids. Their mesial surfaces are attached above the lateral surface of the anteroventral corners of the pterygoids. Their lateral surfaces are applied to the mesial surfaces of the anterior parts of the quadrates. The entopterygoid and the pterygoid are almost fused together, their respective areas being only partially distinguishable. On their ventral sides, mesially, there is a series of teeth present.

The pterygoids (Fig. 2. PTG): They are almost fused with the entopterygoids. They narrow gradually towards their anterior ends. The homology of the pterygoid is confused. The pterygoid and the entopterygoid of the fishes represents only the pterygoid in the mammalian skull.

The premaxillaries (Fig. 5. PM): They are short, slender and dentigerous bones, most anteriorly situated on the upper jaw. They meet in the middle of the anteriormost part of snout. Teeth are variable in number and size. The dorsal edge of premaxillary is attached to the ventral edge of maxillary and overlaps the vomers.

The maxillaries (Fig. 2. MX): They are the main bones of upper jaws, and are strongly toothed. They have large knobs at the anterior ends which fit into distal concavities of the submaxillary cartilages. This knob-like condyle is the anchor and pivot of the maxillaries. Below the knob, each maxillary sends mesially a slender rod, which approaches a corresponding rod from the other maxillary. Except at their anterior ends, the maxillaries are thin and flat and have a broad ascending crest much like that of the dentary.

The supramaxillaries (Fig. 2. SMX): They are situated dorsolateral of the posterior half of the maxillaries. They are more or less hammer-shaped and some fusion has occurred with the maxillaries. They are glassy in appearance and almost transparent. The ventral side of ^{the} supramaxillaries attaches to

the dorsal side of the posterior half of ^{the} maxillaries.

The angulars (Fig. 2. A): They are the small bones situated at the knobs on the posterior parts of dentaries. They have a dorsal notch here for the articulation with the quadrates, and opposite to these, the ventral notches into which the dorsal edges of articulars fit. They almost fuse with the dentaries.

The dentaries (Fig. 2. D): They are the largest bones in the mandibles. Each curves mesially and anteriorly, to form the symphysis with its fellow of the opposite side. The dentaries send dorsally the flat, broad, ascending ridges which possess the strong teeth. The teeth bearing borders of dentaries and the posterior knobs are opaque, while the remainder of these bones are translucent.

Hyoid Region

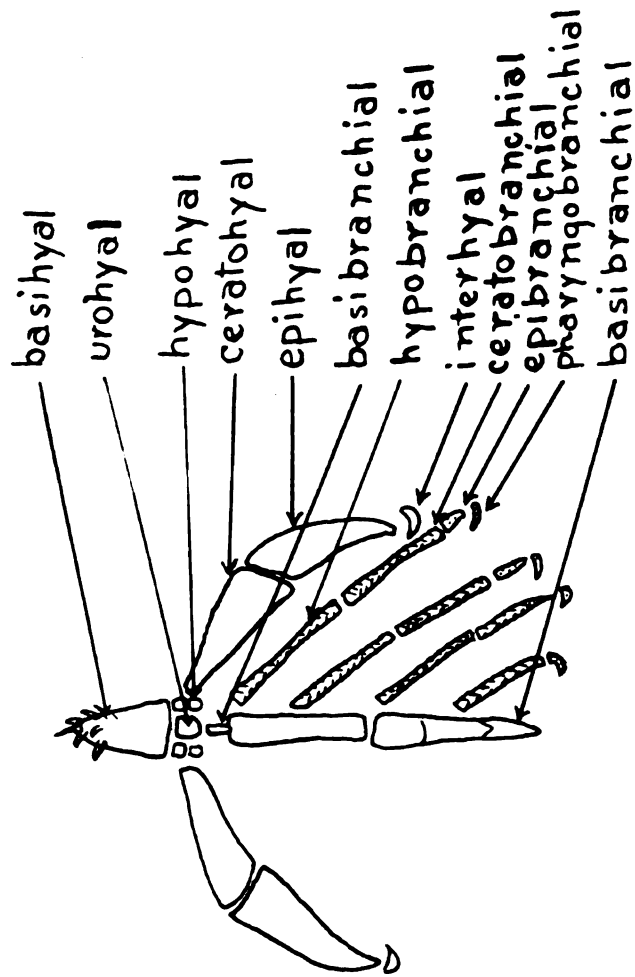
Cartilage bones: Paired hyomandibulars (Fig. 2. HM), symplectics (SY), interhyals (Fig. 7. IH), epiphyals (EH), ceratohyals (CH), hypohyals (HH), and unpaired basihyal (BH).

Dermal bones: Paired operculars (OP), preoperculars (POP), suboperculars (SOP), interoperculars (IOP), branchiostegals (BS), and unpaired urohyal (UH).

The hyomandibulars (Fig. 2. HM): They are very irregular bones in both structure and shape. They articulate anteriorly with metapterygoids and are attached below to the symplectics through cartilage. They consist of the thick swellings



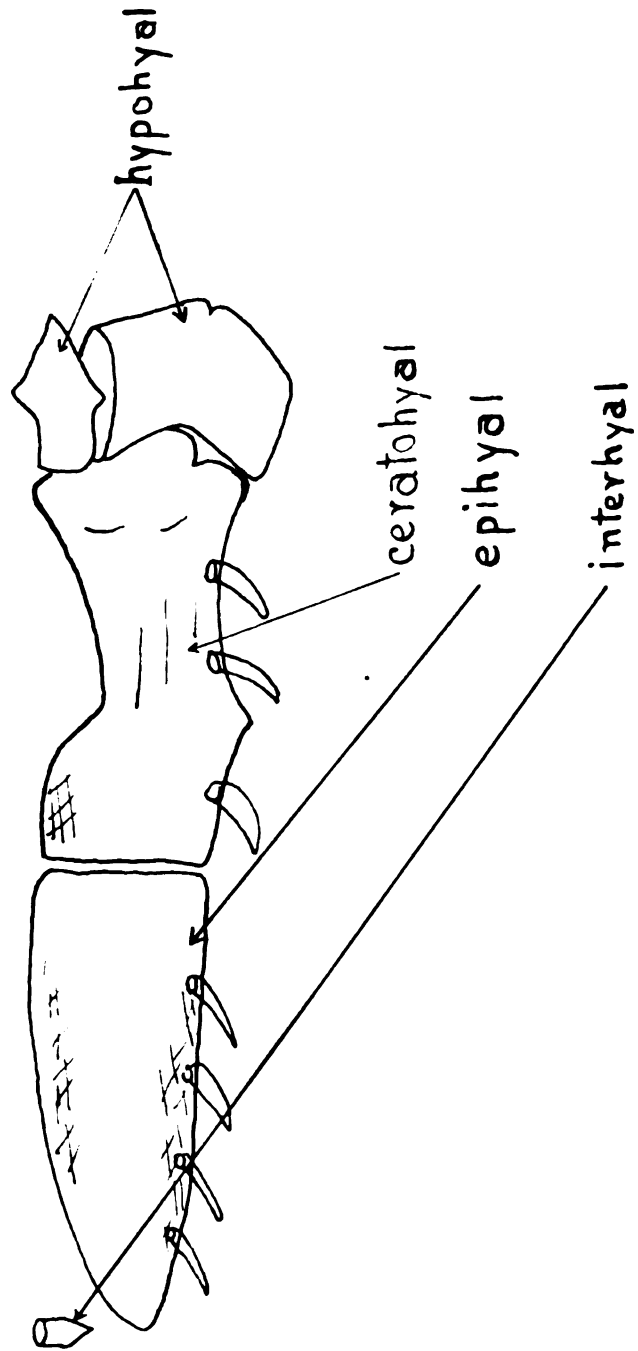
FIGURE 7. HYOBANCHIAL SYSTEM OF THE SMELT (OSMERUS MORDAX),
DORSAL VIEW.



Dorsal view, 3X

FIGURE 8. HYOID ARCH, LEFT HALF OF THE SMELT (OSMERUS MORDAX),
MESIAL VIEW.

10 X



of bones with thin flanges extending on either side, anteriorly and posteriorly, respectively. The anteriormost strut attaches to the sphenotic and forms a triangular piece of bone. From its anterior angle another triangular bone hangs down laterally which attaches to the metapterygoid and symplectic. There is a distinct gap between hyomandibular and preopercular.

The symplectics (Fig. 2. SY): They fit in the grooves on the dorsal surface of the posterior extension of the quadrates. The anterior ends are inserted between these extensions and fan-shaped part of quadrate.

The interhyals (Fig. 8. IH): They are small, somewhat cylindrical, connected at one end with the cartilage between the hyomandibulars, symplectics and metapterygoids, and at the other end with the upper end of the epihyals.

The epihyals (Fig. 8. EP): They are thick, massive, somewhat triangular and their apices are directed dorsolaterally towards the interhyals. Their bases are broadly articulated with the posterior ends of the ceratohyals.

The ceratohyals (Fig. 8. CH): They are broad, and lateroposteriorly join the epihyals. The dorsal head articulates with the upper hypohyal, the ventral head with the lower hypohyal.

The hypohyals (Fig. 8. HH): They have two parts, upper hypohyal and lower hypohyal. The upper articulates at one end with the ceratohyal and other end with lower hypohyal. The lower hypohyal is more or less V-shaped bone.

FIGURE 9. THE PREOPERCULARS FROM SKULL OF THE SMELT (OSMERUS MORDAX),
LATERAL VIEW,
2 X



U



The basihyal (Fig. 7. BH): It is a massive, thick and dentigerous bone. It takes the position of the tongue in the mouth. Teeth are strong and curved.

The urohyal (Fig. 7. UH): It is a flat, broad, horizontal plate surrounded by the hypohyals laterally, basihyal anteriorly, and basibranchial posteriorly.

The branchiostegals (Fig. 2. BST): They consist of five pairs of flat, curved bones, which are arranged like the leaves of a book in an ascending manner from the anterior to the posterior, on the ventral side of the skull. Most of them are slightly produced anterodorsally and articulate with the hyoid apparatus.

The preoperculars (Fig. 2. and 9. PO): They are sickle-shaped and overlap the anterodorsal surface of hyomandibulars, the posterior end of quadrates, symplectics, the interhyals, the upper lateral surface of the interoperculars and anterior edge of operculars.

The interoperculars (Fig. 2. IO): They are more or less triangular, with slightly incurved upper edges. They overlap the anterior ends of suboperculars and are overlapped anterolaterally by the preoperculars.

The suboperculars (Fig. 2. SO): They have the characteristic semilunar shape and the anterior ends are overlapped by the posterior end of operculars. The anterior margin of suboperculars overlap the posterior end of interoperculars.

The operculars (Fig. 2. OP): They are very thin, almost glassy in appearance and transparent. The posterolateral ends overlap the supracleithrums, cleithrums and postcleithrums of pectoral girdle. The lower edges overlap the suboperculars.

Branchial Region

Cartilage bones: Paired pharyngobranchials (Fig. 7. PB), epibranchials (EB), ceratobranchials (CB), hypobranchials (HB), and unpaired basibranchial (BB).

The pharyngobranchials (Fig. 7. PB): There are two pairs of pharyngobranchials.

The ceratobranchials (Fig. 7. CB), and the epibranchials (Fig. 7. EB): They are thin, long, cylindrical bones. The upper end of epibranchial and lower end of the ceratobranchial are joined with articular heads. The articular heads are thick while the opposite ends are thin. The fifth epibranchial is not evident.

The hypobranchials (Fig. 7. HB): These consist of three pairs of osseous, comma-shaped bones, quite adjacent to the basibranchials. The fourth hypobranchial is found in some species, but is absent in the smelt.

The basibranchials (Fig. 7. BB): These are three strong, cylindrical bones, which articulate end to end and arrange in a linear fashion. They are unpaired, and lie in the midventral line of the pharynx. The first basibranchial is a curved rod

of bone lying between the hypohyals and extending anteriorly beneath the basihyal. The second basibranchial is strong, long & cylindrical with the several teeth of almost equal length. The third basibranchial is shorter than the second, and has a broad articulating surface at the posterior end and is pointed at the anterior end.

COMPARISON OF THE SMELT'S SKULL WITH THE SKULL OF THE SALMON

FIGURE 10. SKULL OF SALMO SP., LATERAL VIEW.
AFTER GREGORY.

FIGURE 11. SKULL OF SALMO SP., DORSAL VIEW.
AFTER GREGORY.

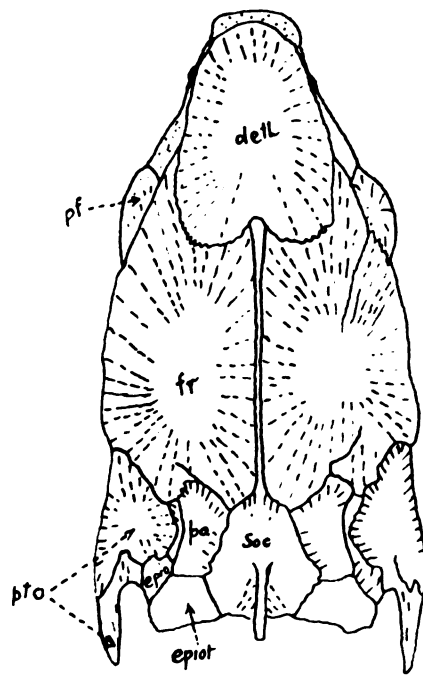


FIGURE 12. SKULL OF THE SMELT (OSMERUS MORDAX); LATERAL VIEW

2 X

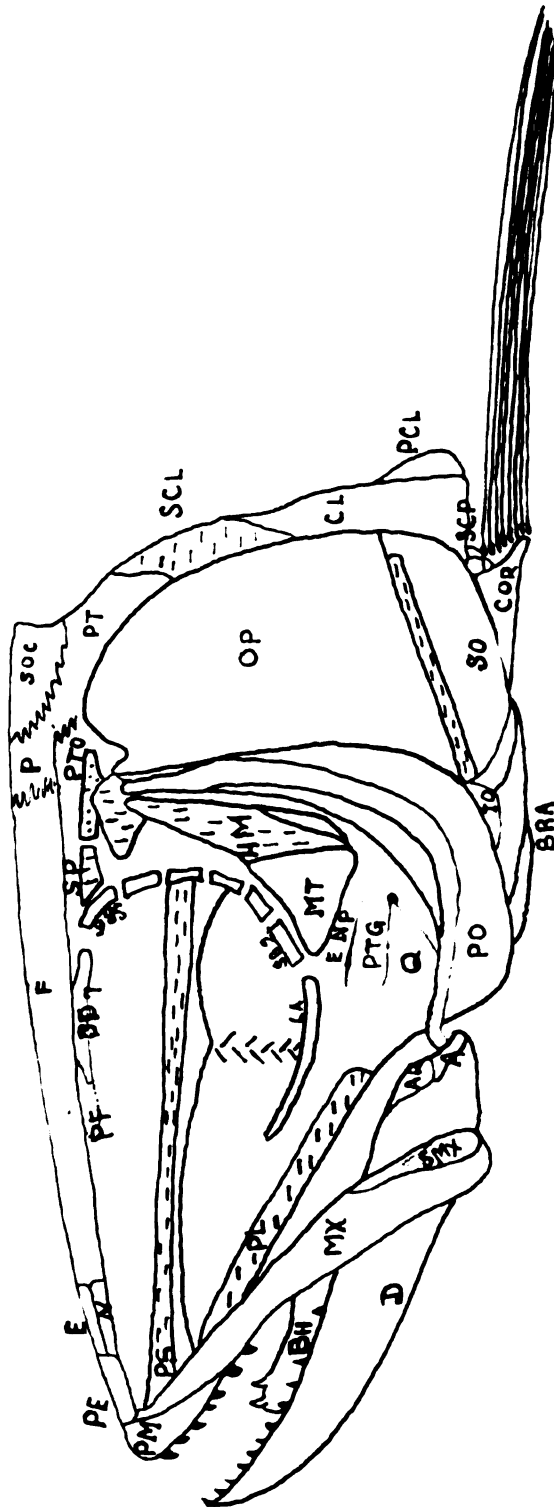
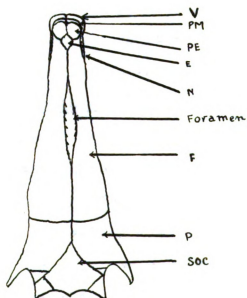


FIGURE 13. SKULL OF THE SMELT (OSMERUS MORDAX), DORSAL VIEW.

2 X



2 X

COMPARISON OF SMELT'S SKULL WITH THE SKULL OF SALMON

The parietals (Fig. 10. Pa) of the salmon (Salmo salar) are small, ridged and subarcuate, separated by the whole width of the broad supraoccipital. They articulate with it and also with the corresponding frontal and epiotic. The parietals (Fig. 12. P) of the smelt (Osmerus mordax) unite in the mid-dorsal line. Anteriorly each is attached to the frontal and posteriorly with the supraoccipital.

The frontals (Fig. 10. fr) of the salmon are large and strong. They meet to form the sagittal suture in their posterior half, but further forwards a smooth ridge of cartilaginous skull separates them. The frontals (Fig. 12. F) of the smelt are flat, and form a sagittal suture posteriorly. Anteriorly they meet with the proethmoids and ethmoid as well as slightly touching each other. There is a long fontanelle in the center portion.

The vomers of the salmon are oblong and thick in front, with a sharp keel on the anterior portion, between the paired ethmoids. They bear the sharp recurved teeth. These bones underlie the proethmoids for a considerable distance. The vomers (Fig. 13. V) of the smelt are in very much the same position as in the salmon. Each vomer possesses a pair of teeth.

The parasphenoid (Fig. 10. par) of salmon is of great length. This bone is large, long, leaf-like, with descending laminae and split in front. It is upwardly keeled in front,

downwardly keeled behind, and flattened in the middle. In the smelt, it (Fig. 12. PS) is the largest bone of the skull and upwardly keeled in front and downwardly keeled behind but not flattened in the middle.

The suborbital bones (Fig. 10. 1a, So 2-5, dsp, sop) of the salmon are thick and strong-rimmed where they lie more or less in a ring about the eye. In the smelt, they (Fig. 12. LA, SB 2-6, SO 7) are weak and border almost three-fourths of the orbit. The lacrymal is quite long, situated ventroanteriorly while the remaining bones are arranged in the semi-circular fashion about the ventral and posterior margin of the eye.

The premaxillaries and the maxillaries (Fig. 10. pmx, mx) of the salmon are dentigerous. The premaxillaries are the broader and more massive of the two. They have a region where the structure is peculiarly sponge-like and tubuliferous. The smelt has premaxillaries, maxillaries and supramaxillaries (Fig. 12. PM, MX, & SMX). The premaxillaries as well as maxillaries are dentigerous although the maxillaries bear the weaker teeth.

The maxillaries in the salmon are concave where they are overlapped by the premaxillaries. They send inwards a concave facet for the articulation with the palatines, are rod-like in their dentigerous portion, and flatten out below, especially on the upper edge which is overlapped by the jugal (Fig. 10. ju). The maxillaries in the smelt have large knob-like structures at their anterior ends which fit into the distal concavity of the submaxillary cartilage.

The dentaries (Fig. 10. dn) of the salmon bear teeth which are strongly hooked. They are the principal bones of the mandibles, which are turned up so as to fit into the anterior end of the snout, giving the peculiar characteristic of the salmon's face. The dentaries (Fig. 12. D) of the smelt also bear teeth which are sharp and pointed upwards. The posterior half of these bones is very wide but they narrow anteriorly where they meet the fellow of the other side. The lower jaw is slightly longer than the upper jaw.

In the salmon, on the angle of each mandible another splint is found, the angular (Fig. 10. an), which is small and rough. In the smelt the angular (Fig. 12. A) is very small, almost at the same location as the angular in the salmon.

The articulators (Fig. 10. art) in the salmon are fairly big and occupy almost one half of each mandible, while the articulators (Fig. 12. AR) of the smelt are quite small and located at the junction of angulars and posterior knobs of dentaries.

The preoperculars (Fig. 10. preo) of the salmon are quite membranous; they have the usual falcate form, are furrowed in a radiating manner by mucous glands; their attachments are by their anterior edges, above the posterior edge of the hyomandibular and below that of the quadrate. In the smelt, the location and structure is the same, except that their posterior edges overlap the anterior edges of operculars.

The operculars (Fig. 10. op) of the salmon are large and

subquadrate. They are elegantly marked with growth-lines, and they articulate with the hyomandibulars by ball and socket joints. The operculars (Fig. 12. OP) in the smelt are glassy and transparent; anteriorly, they articulate with the hyomandibulars and ventroposteriorly overlap the suboperculars, cleithrums, and postcleithrums. They show no markings of growth-lines.

The suboperculars (Fig. 10. sop) of the salmon are somewhat below the operculars; they are subfalcate, broad in front, very thin and elegantly marked with growth-lines. The suboperculars (Fig. 12. SO) of the smelt are semi-lunar shaped and there is no trace of growth-lines. The operculars overlap the upper edge of suboperculars. The suboperculars overlap the cleithrums, scapulae and coracoids of pectoral girdle.

The interoperculars (Fig. 10. iop) of the salmon are ear-shaped; their narrow ends passing behind the preoperculars are very thin. They are marked concentrically and radially by growth-lines. In the smelt (Fig. 12. io), these bones are small and are overlapped by the edges of preoperculars, and show no trace of growth-lines.

The hyomandibulars (Fig. 10. hyom) of the salmon are broad, flat bones, which articulate anteriorly with the pterotics, but partly also with the sphenotic elements of the otic capsules. Below they are connected with the slender symplectic bones and form the cartilage connecting the entopterygoids and quadrates. They support the rest of hyoid arch, consisting in succession of interhyal, epihyal, ceratohyal and hypohyal bones,

with the median tooth-bearing basihyal. In the smelt, the hyomandibulars (Fig. 12. HM) are peculiar^{ly} shaped bones with the anterior triangular pieces attaching to the posterior pieces by a narrow joint. They are almost in two pieces in the smelt.

The symplectics (Fig. 10. SY) of the salmon have a real suspensorium with the hyomandibulars, and they are fused with the anterior margins of the quadrate and the metapterygoid bones. In the smelt, similar attachments of symplectics, quadrates and metapterygoids are found.

The comparison of smelt and salmon skull bones is summarized in tabular form below.

TABLE NO. I

COMPARISON OF SMELT'S SKULL WITH THE SKULL OF SALMON

No.	<u>Name of bone</u>	<u>Salmon (<i>Salmo salar</i>)</u>	<u>Smelt (<i>Osmerus mordax</i>)</u>
1.	Parietal.	Strong; separated by supra-occipital.	Fairly strong. They meet mesially quite evident from the dorsal side.
2.	Frontal.	Large and joined by a suture.	Comparatively weak and have a very large foramen in between them.
3.	Vomer.	Teeth are present.	Teeth are present.
4.	Parasphenoid.	Flattened in the middle.	Not flattened in the middle.
5.	Suborbital ring.	Strong rimmed and thick.	Weak and thin rimmed, lacrymal is fairly large.
6.	Premaxillary.	Massive, broad and dentigerous.	Thin, small and dentigerous.
7.	Maxillary.	Concave shaped, dentigerous and flattened out below.	Concave shaped, dentigerous and broad at the posterior end. They meet in the middle.
8.	Palatine.	Rod like and dentigerous.	Rod like and dentigerous.
9.	Dentary.	Teeth are strongly hooked and give the peculiar shape of the salmon's face.	Teeth are sharp and long in comparison to its skull size. The lower jaw is slightly longer than upper jaw. They are not hooked.
10.	Angular.	Small and rough.	Small.
11.	Articular.	Fairly large and covering the hinder part of dentary.	Fairly small and covers only dorsoposterior edge of the dentary.

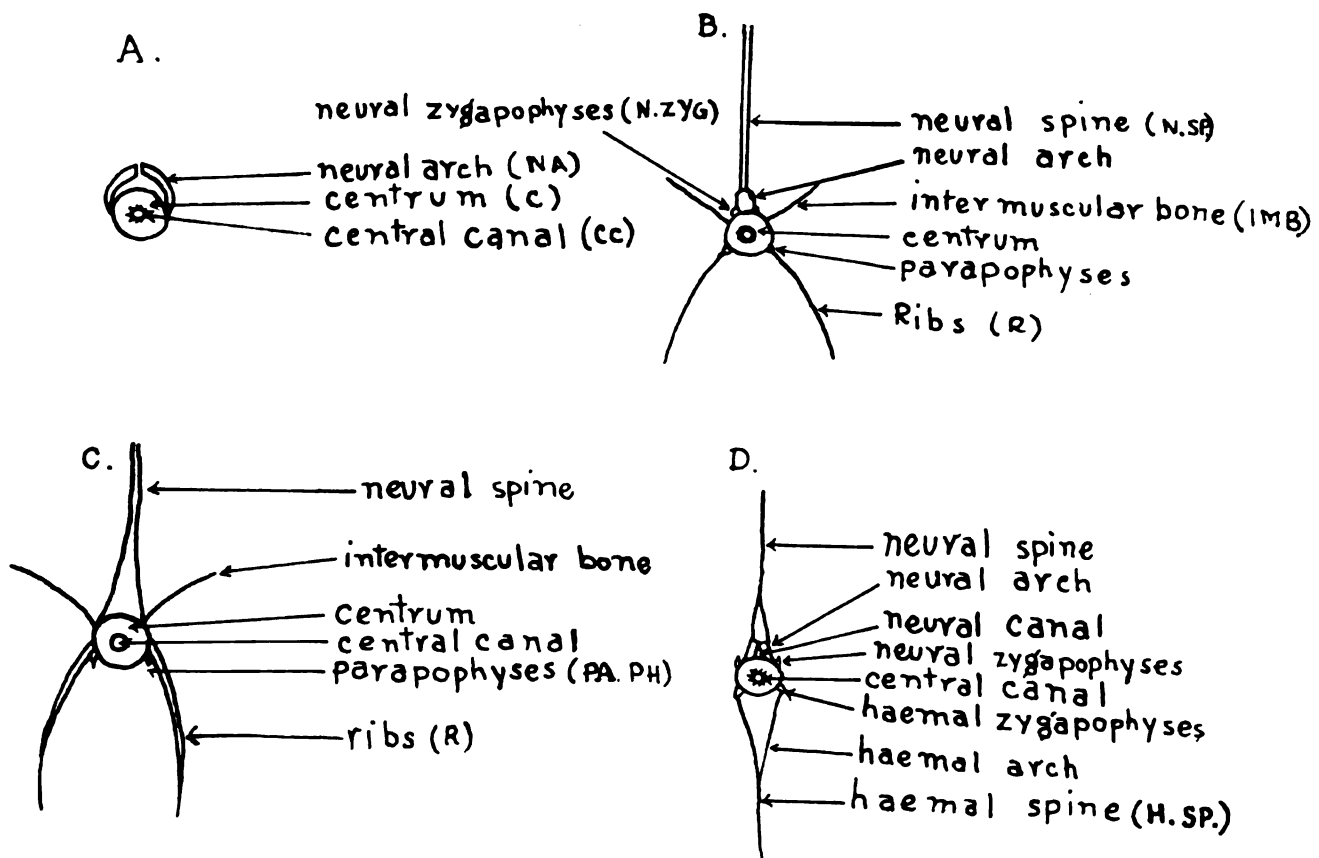
TABLE NO. I (Contd.)

12. Preopercular.	It is falcate shaped.	It is strongly falcate, form .
13. Opercular.	Large and subquadrate with markings of growth-lines.	Glassy in appearance without any markings of growth-lines.
14. Subopercular.	Subfalcate, broad in front and elegantly marked with growth-lines.	Semi-lunar shaped, broad upward and without any growth-lines.
15. Interopercular.	Ear-shaped and growth-lines are present.	Small and without any concentric and radial marking of growth-lines.
16. Hyomandibular.	Broad flat bone, articulates anteriorly with the pterotic.	Divisible into two parts, i.e., anteriorly a triangular piece attaches to the posterior piece by a narrow joint.
17. Symplectic.	Has real suspensorium with the hyomandibular.	Same as in the salmon.
18. Quadrate.	Strongly triangular in shape.	More or less triangular in shape.
19. Metapterygoid.	Falcate form and has connection with hyomandibular and entopterygoid.	Triangular in shape and its one edge has a complete union with hyomandibular.

DESCRIPTION OF VERTEBRAL COLUMN OF THE SMELT (OSMERUS MORDAX)

FIGURE 14. VERTEBRAE OF THE SMELT (OSMERUS MORDAX).

- A. First vertebra (Atlas), Posterior view.
- B. & C. A typical vertebra (3-41), Posterior view.
- D. Caudal vertebra (42-62), Posterior view.



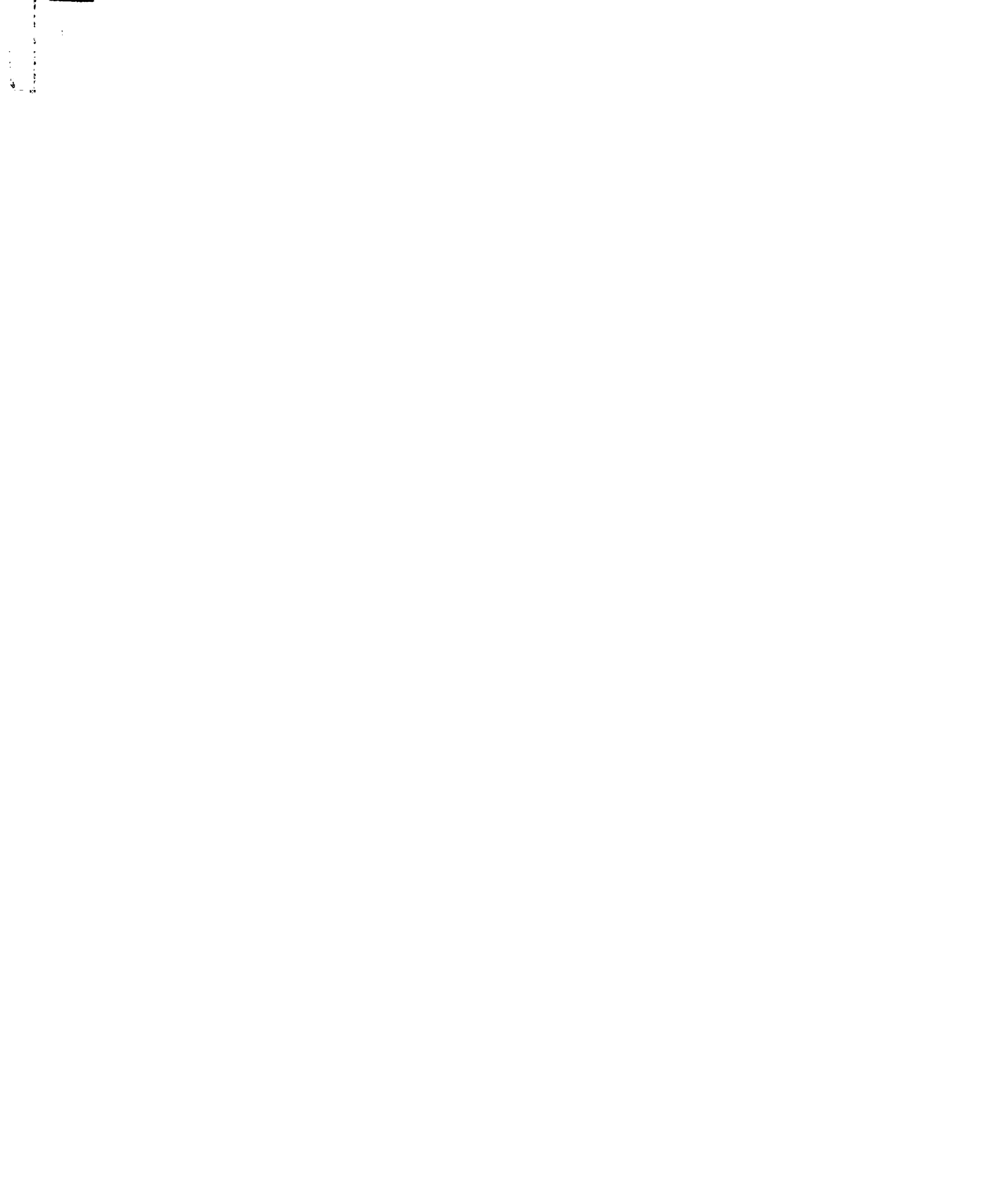
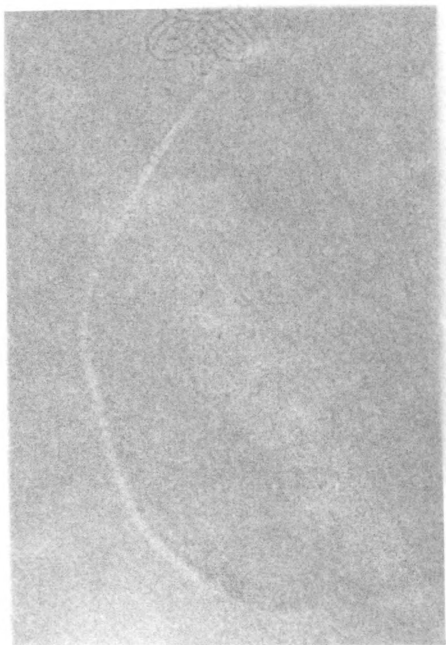


FIGURE 15. THE COMPLETE VERTEBRAL COLUMN WITH THE CAUDAL FIN OF THE
SMELT (OSMERUS MORDAX)

X





DESCRIPTION OF VERTEBRAL COLUMN OF THE SMELT (OSMERUS MORDAX)

The vertebral column is completely ossified with an aperture in the centrum of each vertebra. It is divisible into an anterior or trunk region and a posterior or caudal region, together comprising about sixty-one to sixty-two vertebrae.

The first forty-one vertebrae comprise the trunk region while the remaining twenty or twenty-one constitute the caudal region. The vertebrae from the trunk region possess pleural ribs while the caudal region vertebrae have the ribs fused to form haemal spines.

A typical trunk vertebra consists of a cylindrical centrum (Fig. 14, B and C) with deeply concave anterior and posterior faces (amphicoelous), and perforated in the center by the narrow central canal (Fig. 14). The edges of the centra are united by ligaments and the biconvex spaces between them are filled with the remains of the notochord. There are also articulations between the neural arches by means of small bony processes, the zygapophyses (Fig. 14, B and C). The low neural arch is attached to the dorsal surface of the vertebrae anteriorly by ligaments and posteriorly by ankylosis. To the ventro-lateral region of the vertebrae are attached by a ligament, a pair of long and slender pleural ribs (Fig. 14. R), which curve downwards and backwards between the muscles and the peritoneum, thus encircling the abdominal cavity. In the first two vertebrae they are

attached directly to the centrum, the rest to short downwardly directed bones, the parapophyses (Fig. 14. PA, PH), immovably articulated by broad surfaces to the centrum. At the junction of the neural arch with the centrum are attached, also by fibrous union, a pair of delicate inter-muscular bones (Fig. 14. IMB), which extend outwards and backwards in the fibrous septa between the myomeres. The first and second vertebrae bear no ribs. There are no ribs on the last 2 or 3 vertebrae of the trunk region. In all the trunk vertebrae the neural arches are produced dorsally to form a spine.

The caudal vertebrae have an amphicoelous centrum, which is perforated in the center by a narrow canal. The outgrowths corresponding to the parapophyses are fused with the centrum and form part of the roof of the haemal canal, through which the caudal artery and vein run. In each caudal vertebra, the ribs are fused into a single arch, which is produced downwards and backwards into a haemal spine (Fig. 14. H.SP).

The posterior end of the caudal region is curiously modified for the support of the tail fin. The ultimate centrum (Fig. 15), has the axis not horizontal, but deflected upwards, and following the last undoubted centrum is a rod-like structure, the urostyle (Fig. 21. UST), consisting of the partly ossified end of the notochord, which has thus the same upward flexure as in the Dog fish (*Scyliorhinus canicula*). The neural and haemal spines (Fig. 14. N.SP., H.SP), of the last two or three vertebrae

are very broad and closely connected with one another, and more numerous than the centra: and five or six haemal arches are attached to the urostyle. In this way a firm vertical plate of bone is formed, to the edge of which the caudal fin rays (Fig. 2I. CFR) are attached fan-like in a symmetrical manner. It will be obvious, however, that this homocercal tail fin is really quite as unsymmetrical in structure as the heterocercal caudal fin of the Dog fish, and since its morphological axis is constituted by the notochord, nearly all of its rays are, in strictness, ventral.

DESCRIPTION OF DORSAL FIN OF THE SMELT (OSMERUS MORFAX)

FIGURE 16. DORSAL FIN OF THE SHELTER (OSMERUS MOPIAX)

3 X



DESCRIPTION OF DORSAL FIN OF THE SMELT (OSMERUS MORDAX)

The total number of dorsal fin rays varies from 10 to 12. The number of branched rays is variable from 8 to 10.

Each dorsal fin ray is supported by a triple set of pterygiophores. The dorsal end of a pterygiophore fits under the base of the dorsal ray. There are small nodules of cartilage forming the third series of radials which are situated below the dorsal fin rays. These radials are connected to the second series. The proximal series consists of slender bony rays - the interspinous bones, lying in the median plane, between the muscles of right and left sides, and more numerous than the myomeres of the regions in which they occur.

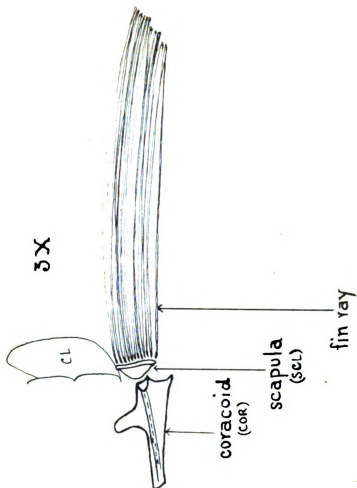
The dermal fin rays (Fig. 16), which lie in the substance of the fin itself, are slender bones, joined like the antennae of an arthropod, and mostly branched in the sagittal plane. Each is formed of distinct right and left pieces in close contact for the most part, but diverging below to form a forked and dilate end, which fits over one of the cartilaginous nodules.

The second dorsal or adipose fin has no bony support. It is one of the significant characteristics of the family, *Osmeridae*.

DESCRIPTION OF PECTORAL GIRDLE AND FIN OF THE SMELT

(OSMERUS MORDAX)

FIGURE 17. LEFT CORACOID, SCAPULA, CLEITHRUM AND PECTORAL FIN OF THE SKELETON
(OSMERUS MORDAX), MESIAL VIEW.



DESCRIPTION OF PECTORAL GIRDLE AND FIN OF SMELT (OSMERUS MORDAX)

The pectoral girdle consists of three bones, the scapula, the coracoid and the cleithrum. The scapula (Fig. 17, SCP), is situated dorsally to the glenoid fossa which is the articulating surface of the pectoral fin. The coracoid (Fig. 17, COR)

is situated ventrally to glenoid fossa and the mesocoracoid is situated above the coracoid and anterior to the scapula. Externally to these is formed a large investing bone, the cleithrum (Fig. 2, CL), extending downwards under the throat. Dorsally it is connected with the supracleithrum (Fig. 2, SCL), and the supracleithrum is connected to the forked post-temporal (Fig. 2, PT), one branch of which articulates with the epiotic and the other with the pterotic process. The postcleithrum has an attachment with the postero-dorsal side of cleithrum.

The post-temporal, supracleithrum and the cleithrum form a chain of essentially long narrow bones which attaches the pectoral girdle to the skull. The postcleithrum (Fig. 2, PCL), is smaller than the cleithrum and it is a spindle-shaped bone placed at an angle with its longitudinal axis directed postero-ventrad. Its anterior end lies underneath the cleithrum while the posterior end is embedded in muscle underneath the pectoral fin.

The coracoid is a roughly triangular bone with the base at its posterior end. The apex of the triangle attaches to the cleithrum by a tough ligament. The scapula is a

small, subquadrate bone with a deep notch on its ventral border. The anterior half lies underneath the cleithrum and is fused to it.

The radial bones support the pectoral fin rays. Radials as well as the coracoid and the scapula apparently arise as separate centres of ossification. The number of pectoral fin rays varies from 12 to 13.

DESCRIPTION OF PELVIC FIN OF THE SMELT (OSMERUS MORDAX)

FIGURE 18. LEFT PELVIC FIN OF THE SMALT (OSMERUS MORDAK). LATERAL VIEW

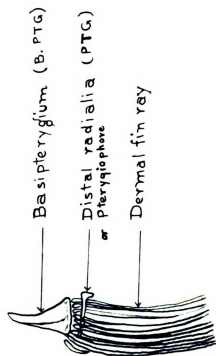


FIGURE 19. PELVIC FINS OF THE SHELT (OSMERUS MORDAX), LATERAL VIEW





DESCRIPTION OF PELVIC FIN OF THE SMELT (OSMERUS MORDAX)

There is no pelvic girdle, its place is taken by a large, flat triangular bone, the basipterygium (Fig. 18, B. PTG); to its posterior border are attached three partly ossified nodules, the distal pterygiophores (Fig. 13. PTG), and with these the dermal fin-rays are articulated. The number of pelvic fin-rays varies from 8 to 9.

DESCRIPTION OF ANAL FIN OF THE SMELT (OSMERUS MORDAX)

FIGURE 20. ANAL FIN OF THE SMELT (OSMERUS MORDAX)

3 X





DESCRIPTION OF ANAL FIN OF THE SMELT (OSMERUS MORDAX)

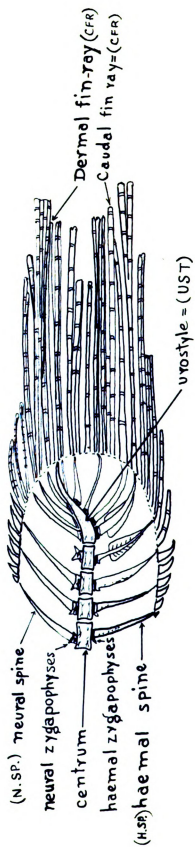
The total number of anal fin-rays (Fig. 20) varies from 15 to 17. The number of branched rays is variable.

The number of pterygiophores in the anal fin is 15 to 17. The anal fin rays are supported each by a triple set of pterygiophores. The proximal series consists of slender bony rays - the interspinous bones lying in the median plane, between the muscles. Their distal ends are broadened, and with them are connected the second series; to these finally are connected small nodules of cartilage forming the third series of radials.

The proximal series of the radials are long and pointed upwards while ventrally they possess the broad articulating surfaces. The second series of radiales are smaller than the first series, and are situated in between the first and third series. The third series of radiales are the smallest of the three and connect the second series to the anal fin rays.

DESCRIPTION OF CAUDAL FIN OF THE SMELT (OSMERUS MORDAX)

FIGURE 21. CAUDAL END AND CAUDAL FIN RAYS OF THE SMELT
(OSMERUS NORDAX). DIAGRAMMATIC.



3X

FIGURE 22. CAUDAL END AND CAUDAL FIN OF THE SMELT (OSMERUS MORDAX)

2 X





DESCRIPTION OF CAUDAL FIN OF THE SMELT (OSMERUS MORDAX)

The posterior end of the caudal region is curiously modified for the support of the anal fin. The centrum of the last vertebra (Fig. 22) has been deflected upwards, and following the last undoubted centrum is a rod-like structure, the urostyle (Fig. 2I, UST), consisting of the partly ossified end of the notochord. The haemal spines (Fig. 2I, H.SP) of the last five vertebrae are very broad and closely connected with one another, and are more numerous than the centra. They are known as hypurals. There are four or five haemal arches which are attached to the urostyle. The last three or four neural spines are also broad and are known as epiurals. The hypurals and the epiurals form a firm vertical plate, hypural plate, to the edge the caudal fin rays (Fig. 2I, CFR) are attached fan-like in a symmetrical manner. It is obvious, however, that this homocercal tail fin is really more or less unsymmetrical in structure.

The caudal fin rays are variable in size and number from 38 to 40. The fin rays which are located dorsally and ventrally at the beginning of the fin are usually small and unbranched. Posteriorly, they gradually increase in size and are mostly branched. The longest caudal rays are situated near the dorsal and ventral edges. From this region mesiad, the fin rays again gradually decrease in size, although here all of them are branched.

PHYLOGENETIC RELATIONSHIP OF THE SMELT IN TELEOSTEAN FISHES

PHYLOGENETIC RELATIONSHIP OF SMELT IN TELEOSTEAN FISHES

Regan, Tate (1929) divided the Isosponyli into six suborders; Clupeoidea; Salmonoidea; Stomiatoidea; Osteoglossoidea; Mormyroidea and Gonorhynchoidea. The suborder Salmonoidea consists of families: Salmonidae, Microstomidae, Argentinidae, Opisthoproctidae, Osmeridae, Salangidae, Retropinnidae, Hiplochitonidae and Galaxiidae.

Gregory, William K. (1933) remarked that the typical salmon skull (Fig. 10) is probably paedogenetic in the high degree to which its endocranium has become cartilaginous, but it is distinctly progressive in the fact that median supraoccipital is broadly in contact with the frontals and parietals are very much reduced. The ethmoid and the pair of proethmoids are large & cartilaginous. A subtemporal bone lying above the opercular is present in the skull of the salmon, and its origin is unknown. The maxillaries are thin and elongate. They are main bones of upper jaws. Anteriorly they are attached to the premaxillaries, posteriorly reaching to the edge of quadrate.

Starks (1926) noted that in the Salmonidae, the ethmoid in general resembles that of the fishes of the family, Clupeidae.

Professor Walter Garstange (1931), in his phyletic classification of the teleostei, wrote,

"The subdivisions (Orders) of the Teleostei are based on the following alternative of structure, each of which, I will briefly characterize with the descriptive terms - ovisacs or coelomic ducts (i.e. Idiödinic or coelomodinic); parietal bones meeting

one another or separated by the supraoccipital (Archicraniate or Metacraniate); upper jaw with premaxillary fixed in line and toothed (Eugnathous or Metagnathous with various subdivisions); maxillary with or without supplemental bones (0, 1 or 2 supramaxillaries); fins soft or spiny (Malacopterus or Acanthopterus); fin rays segmented and branching; or segmented and simple, or unsegmented and spiny (Cladotrichs, Haplotrichs, Acanthotrichs); pelvic bones posterior and free, or anterior and free, or anterior and fixed to pectoral girdle (Opisthopod, Prosopod, Cleithropod); air bladder open (Physostome) or closed (Physoclist); simple (Haplophysete) or with extension into otic region (Otophysete).

Pectoral girdle with or without a mesocoracoid (Mesozonal or Metazonal); vertebrae all alike or partly fused and transformed into weberian ossicles (Isospondylous or Plectospondylous); parapophyses autogenous or coossified with their centra (Archispondylous or Neospondylous), and the following characters of the median, dorsal fin consisting of an anterior or median rayed fin and a posterior adipose fin (Heteropterus) or of a rayed fin alone, which may be either near the middle of the back (Notopterus) or approximated to the caudal (Opisthopterous)."

Gregory (1933, pp. 410), in the transaction of American Philosophical Society, suggested a tentative phylogeny of the teleost fishes graphically.

Comparing the main points of the skull of salmon with that of the smelt, we see a great degree of similarity and one is justified in putting them in the same suborder (Berg, 1940) of the fishes.

The angular of the salmon occupies a special small position at the posterior angle of mandible, the same position it occupies in the smelt.

The symplectic of the salmon has a true suspensorium with the hyo-mandibular. Similar arrangement of the symplectic is found in the smelt. The quadrate of both fishes is similar in its morphology, location and relationship.

Preopercular, opercular, subopercular and interopercular are morphologically similar in smelt and salmon. The supra-cleithrum, cleithrum and postcleithrum of salmon are located posterior to the skull one after another. The same relationship is found in smelt, though they are comparatively smaller than the salmon.

Premaxillary, maxillary, dentary and palatine are denticulous in both of the fishes. The teeth are sharp and pointed in both cases.

The proethmoid and ethmoid are situated anteriorly make an articulation with the premaxillary in both the salmon and the smelt.

The degree of similarity in the bones of the skull of the salmon and the smelt leads to the conclusion that the previous workers; Jordan (1905), Bridges and Boulenger (1910), and Berg, L. S. (1940), have realistically assessed the relationship of these fishes.

In contrast, there is a significant difference in the comparative size of articular in the skull of smelt and salmon. The salmon's skull has a comparatively bigger articular than that of smelt.

The interopercular in the smelt is comparatively much smaller than it is in the salmon.

The subopercular has a straight line union with the opercular in the case of smelt, while in the salmon, the union between subopercular and opercular is wavy, and posterior angle of this union is extended upwards and subtriangular.

The frontals in the salmon are massive and do not possess any significant fontanelle, while a significant fontanelle is present in between the frontals, longitudinally in the skull of the smelt.

The parietals meet mesially in the smelt while they do not meet in the salmon.

In the salmon, the supraoccipital has a direct attachment with the paired frontals as well as with the parietals; in the case of smelt the supraoccipital does not have direct contact with the frontals, but are attached to the paired parietals, which are interposed between the supraoccipitals and the frontals.

These differences are sufficient to lead to a conclusion that the salmon and the smelt should be placed in the separate families, Salmonidae and Osmeridae respectively.

Berg (1940); Jordan (1905) and Bigelow and Schroeder (1953) in their systematic studies of fishes, placed these fishes in different families in the same superfamily or suborder, Salmonoidea. This study adduces no evidence to warrant changing this situation.

SUMMARY

SUMMARY

The skeleton of the American smelt, Osmerus mordax (Mitchill) possesses a very similar pattern of bones as found in most of the bony fishes. The opercular series of bones are weak and membranous in nature. The palatine, vomer, premaxillary, maxillary, dentary and basi-hyal are dentigerous.

A splint bone, the articular at the posterior angle of dentary, is small. In the salmon, the articular is comparatively bigger than in the smelt.

Two frontals in the dorsal side do not meet mesially and leave a fissure which is known as ^aforamen.

The vomers, which are dentigerous in the smelt, are located underneath the proethmoid and they are not seen clearly from the dorsal side. A pair of teeth pointing downwards posteriorly are present on each vomer. The teeth, 2-4 on the ventral side of vomers are characteristic feature of this species, Osmerus mordax.

The family, osmeridae is characterized by the teeth present on the inner side of the entopterygoids. The last vertebrae are not upturned significantly in this species. The parietals meet in the mid-dorsal line and they are not divided by the supraoccipital.

The skeleton of smelt has a great similarity with the skeleton of the salmon, such as suspensorium of symplectic

with the hyomandibular; four bones of opercular series; dentigerous nature of premaxillary, maxillary, dentary and palatine; more or less square shaped quadrate; position of hyomandibular and metapterygoid.

In contrast, some significant differences are noted in the skeleton of the salmon and the smelt, such as: the parietals are not divided by the supraoccipital in the smelt, while they are divided in the salmon; the opercular series are weak and very membranous in the smelt, while they are bony in the salmon; a foramen is present between the frontals in the smelt, and insignificant in the salmon; the articular of the smelt is comparatively smaller than the articular of the salmon.

As a whole the salmon's skeleton is strong and bony in nature while most of the bones of smelt's skeleton are weak and membranous. Thus the recent workers in the field of ichthyology placed these two fishes into separate families, Salmonidae and Osmeridae.

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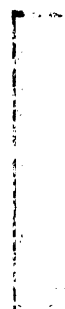
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1