Marine Fish Osteology

A Manual for Archaeologists

Debbi Yee Cannon
Acknowledgements

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To my husband Aubrey Cannon I am indebted for the inspiration, encouragement and support without which this work could not have been accomplished. I owe him also for the many suggestions, criticisms and diligent editing which helped to make this manual a polished work.
Introduction

The present work is a fully illustrated field and laboratory manual of practical interest to the experienced fish bone analyst and the student of fish osteology. It was especially designed with regard to the particular problems and requirements of archaeologists. In the field it is intended to be useful for preliminary identification when comparative material is not available. As a laboratory handbook, it will familiarize the user with all the bony elements to be found in archaeological and comparative material. Because the drawings are of disarticulated elements, and organized according to anatomical origin, this convenient illustrated guide will help make sense of the jumble of bones that results from the processing of specimens into a comparative skeletal collection. Above all, the prime objective of this manual is to show basic osteological differences between various fish taxa on the basis of complete osteologies.

Despite the limited number of species depicted, this manual can at the very least help to rough sort archaeological remains into a general category of fish as opposed to other vertebrates. Because it encompasses several of the most common marine forms found in the Northern Hemisphere, it will help to narrow identification in many cases down to the level of family, if not to genus or species. Finally, this manual can help reduce problems of quantification and interpretation by making the user familiar with all identifiable elements of the fish, and not just those most easily recognized. Although it is not practical to produce an exhaustive manual covering all fish species found in this area of the world, it is hoped that this handbook will precipitate further interest and offer practical aid in the generation of osteological collections of different fish species, and emphasize the importance of continued work in this previously neglected area of archaeological analysis.

Fish Identification

For the archaeologist interested in working with fish bones, the availability of published osteologies is very restricted. Those that have been produced are found widely scattered throughout the zoological literature, and are often difficult to obtain. Illustrated osteologies of fish are inevitably general, buried in general works of biological or zoological origin, and picturing mainly articulated skeletons. Most osteological studies were conducted in the early part of this century, and the early works such as Starks (1901), Allis (1909), Gregory (1933), and Tchernavin
(1938) are still the best illustrated. Later fish osteologies tend to focus on a single species, genus or family, and although some authors such as Norden (1961) have provided drawings of disarticulated elements, not every element is depicted individually. Other works such as those by Harrington (1955) and Mujib (1967) contain only very schematic diagrams. These fail to show sufficient detail for the identification purposes of the archaeologist. Most fish osteologies have naturally enough been prepared by zoologists for zoologists.

Until recently, fish remains in archaeological sites were largely ignored; partly due to the lack of adequate reference material, and partly due to the lack of familiarity with the bone elements. As more archaeologists have become concerned with the recovery and uses of fish remains, more attention has been paid to their analysis (eg. Olsen 1968; Casteel 1976; Jones 1976, 1982; Wheeler and Jones 1976; Morales and Rosenlund 1979; Marhn 1981; Huelsbeck 1981; Nichol 1982; Ham 1982; Le Gall 1984; Singer 1985; Leach 1986). To date, however, there has been little done towards producing illustrated material specifically for archaeological identification. Olsen (1968) has produced a general guide for the identification of fish, amphibians, and reptiles, but his intention in this work is to aid archaeologists in separating fish bones from those of other vertebrates. He does not attempt to provide an exhaustive guide to fish osteology.

Another basic reference in the archaeological analysis of fish remains is Casteel (1976), which functions primarily as an introduction to fish osteology, and as an invaluable source describing a variety of archaeological uses for identified fish remains. Other published references include Morales and Rosenlund (1979) and Le Gall (1984). The former is an attempt to standardize fish bone measurements, while the latter concentrates on fish vertebrae and a few other elements such as quadrates, dentaries, and angulars. None of these were ever intended as a comprehensive guide for the identification of fish remains in any part of the world.

Olsen (1968:4), Casteel (1976:7) and others agree that a detailed published study of many fish skeletons is badly needed. The present handbook is a collection of the osteologies of several different species, and its production was inspired by this recognized need. The fact that each osteology is a complete work in itself allows for additions to be made in the future. At present, however, it will perhaps suffice to produce a field and laboratory manual that will permit the archaeologist to begin a rough classification of his material, and make more effective use of comparative osteological collections as these become increasingly available.
Fish Remains in Archaeology

Fish remains have the same role to play in archaeological analysis as any other class of faunal remains; i.e. as an aid in the reconstruction of palaeoeconomies and palaeoecology (see for example in Casteel (1976) and Jones (1982:79)). It is toward this end that the identification of fish remains should be undertaken. It is not the aim of this manual to solve the problems of identification to species; in fact its scope is far too limited for such a purpose. However, one of the purposes of this manual is to encourage the complete identification of all fish osteological elements. A basic understanding of the morphological characteristics of all elements is necessary if fish remains are to be treated to the same standards as other classes of faunal remains. Among archaeologists generally, basic knowledge of the forms of disarticulated fish bones is not as well developed as it is for mammal bones. As a result, there is from the beginning a potential for fish remains to be under represented to an unknown extent. Methods for the reconstruction and interpretation of palaeoeconomy and palaeoecology from faunal remains assume that the material has been identified as completely as possible. An unknown element of bias is introduced if quantification and interpretation are attempted on the basis of incomplete identification.

Much zooarchaeological literature is entirely devoted to methods of quantifying faunal assemblages (eg. Casteel 1976; Grayson 1979), with an aim toward overcoming the biases introduced by archaeological preservation and recovery techniques, and providing as 'true' a picture as possible of the relative importance of species in the economy or environment of a region. However, all methods assume that basic standards of element identification have been attained. The truth of this assumption of course depends upon the knowledge and skills of the individual investigator. In regard to fish remains, the necessary knowledge is not readily available.

In the area of mammal bone identification, fairly comprehensive manuals have been published (Olsen 1964; Gilbert 1973; Glass 1973). Arguably, it is the dissemination of knowledge by manuals such as these that has done so much to bring the analysis of mammalian remains into archaeological prominence. In the identification of fish remains, standards are likely to be much more variable between investigators, and it is perhaps for this reason that fish remains have not attained a greater significance in archaeology, despite the efforts of Casteel (1976) and others to promote their use. Therefore it is important for a fish osteology
manual to depict all of the elements present in a fish skeleton if possible, regardless of whether such a range of elements has been previously identified in archaeological sites.

The fact that there are such a large number of fish elements, and the tendency for fish bone to break into tiny fragments has meant that identification and interpretation has come to focus mainly on the more substantial elements such as: vertebrae centra, otoliths, pre-maxillae, maxillae, dentaries, dermal structures, and head bones such as angulars and posttemporals (Rackham et al. 1984:40). The less familiar elements are sometimes mistaken for chips of mammal or bird bone and thus excluded from proper identification and quantification (Olsen 1968:ix). Without specialized knowledge, the best that can be done with such unfamiliar elements is to classify them as unidentified fish. As a result, a potentially incorrect or at least altered picture of palaeoeconomy or palaeoecology is likely to emerge.

There are a number of reasons for wanting to obtain as complete an identification of fish elements as possible; including cranial elements. Even though these may be less likely to survive archaeologically, they cannot be disregarded simply because they are not recognized, and they cannot be recognized unless their basic form is familiar to the investigator. The presence of cranial elements can help to answer questions concerning processing practices and help to establish a possible distinction between fishing/processing sites and habitation sites. Cranial elements are also important because they are either median or paired and can therefore be used to aid in the calculation of the minimum number of individuals of different species. Because an individual fish has many different vertebrae, the number of these is often a less adequate representation of the number of individuals present.

One further reason for attaining as complete an identification of fish elements as possible concerns the importance of sampling in the analysis of faunal remains. Often, fish and other remains are present in such large numbers that it is only economically feasible to conduct their analysis on the basis of small samples of the originally recovered material. Such sampling severely restricts the number of elements of any one species available for potential identification. If the investigator’s lack of knowledge further restricts identification to only a subset of available elements, then very serious distortion may arise, and even the presence of some species may be overlooked.
To whatever purpose the analysis of fish remains is applied, a basic knowledge of fish osteology is essential. As archaeologists are often forced to rely on their own efforts in the identification of fish or other remains which they recover, it is essential that they themselves develop the requisite level of knowledge and skill. It is for this reason that the drawing of each element of the species represented in this manual was undertaken.

**Scope of Coverage**

Four of the most common families of marine fish in the Northern Hemisphere are represented in this handbook; the Salmonidae, Gadidae, Scorpaenidae, and Pleuronectidae. They were chosen because they comprise species which are indigenous to both the North Atlantic and North Pacific Oceans, and were, according to a range of archaeological and ethnographic evidence, economically exploited in both regions in the past.

One species from each of the above families is illustrated.

*Oncorhynchus keta* (*Pacific*)

The first osteology constitutes a Pacific salmon (*O. keta*). Its Atlantic cousin, *Salmo salar*, belongs to a different genus, but both are of the sub-family Salmoninae, and the family Salmonidae. The external appearance of these species is distinct, but their skeletons, like those of all salmonids, are very characteristic. (see Tchernavin 1938 plates II,III, and V, for an illustrated comparison of the articulated skulls of *O. keta* and *S. salar*). In fact, it is difficult to identify bones of the Salmonidae to species, even with the aid of a comparative collection. There is also considerable variation introduced through breeding changes. As Tchernavin concludes in his study of the breeding changes in salmon:

> The skulls of adult migratory *Salmo* and *Oncorhynchus* are subject to striking changes throughout the whole life of the fish. These changes are so marked that the study of the salmon skull becomes in fact, a study of its changes. Many characteristics regarded as 'fortuitous variations' or 'taxonomic distinctions' are found to be features of particular phases of these regular changes. [Tchernavin 1938:165]

In this respect, the osteology of *Oncorhynchus keta* is typical of the salmon.
Of the four species of fish depicted in this manual, only the salmon (both Pacific and Atlantic) are anadromous; the remainder (cod, rockfish, and halibut) are exclusively marine. Anadromous fish breed in freshwater and migrate to marine feeding grounds where they spend the majority of their life cycle.


**Gadus morhua (Atlantic)**

The Atlantic cod (G. morhua) is illustrated as a typical example of the family Gadidae. The same genus of cod exists in the Pacific (G. macrocephalus), and in terms of osteology, these two species show no discernible differences. In fact, in all respects the species are very similar. As early as 1887, investigators such as Bean (1887:198-199) questioned the validity of classifying Atlantic and Pacific cods as separate species. Schultz and Welander (1935:131-133) noted only visceral differences and differences in length of barbel and dorsal fin. Midgalski and Fichter (1977) noted no difference between the species, apart from the fact that the fins of the Pacific species are more pointed.

References: Bean 1887; De Beer 1928; Gregory 1933; Schultz and Welander 1935; Mujib 1967; Midgalski and Fichter 1977.

**Sebastes marinus (Atlantic)**

Rockfish are present in both the Atlantic and the Pacific, but are represented by a much greater number of Pacific species. The species illustrated here, the red rockfish, commonly called red snapper, is today highly valued commercially. Its common name is applied to different rockfish species from both the Pacific and the Atlantic, but each is a member of the genus Sebastes. The scientific name for the Atlantic species is Sebastes marinus, and it is this species that is used here to represent the family Scorpaenidae. Osteologically, all members of this family are very similar in appearance, and as a basic guide to fish elements, this family is a useful illustration of the osteology of the 'higher' bony fishes.

References: Starks 1898; Allis 1909; Gregory 1933; Echeverra 1986.

**Hippoglossus stenolepis (Pacific)**

The final osteology is of the Pacific halibut (H. stenolepis), of the family Pleuronectidae. When compared to the skeleton of the Atlantic species (H.
hippoglossus), there is little apparent difference in form. Personal examination of both species and consultation with experts left little doubt that the vertebrae and caudal bones of the two species are quite indistinguishable. Any variation in form was not easily detected in the individual elements of the head, and is therefore considered negligible for archaeological purposes.

References: Traquair 1865; Boulenger 1902; Regan 1910; Gregory 1933.

Comparative analysis of fish skeletons was conducted at the Museum of Zoology, University of Cambridge in England, where Atlantic specimens were available for examination. Pacific specimens were obtained from Vancouver, B.C., Canada.

Interoceanic comparative studies of fish osteologies are very rare. However, from an archaeological point of view, specimens from either ocean can be considered as representative of their respective families. This conclusion is based on an examination of the general form and particular distinguishing features and attributes of the individual bony elements. The aim of this comparative study was not to develop new criteria for species classification, but rather to confirm that the above specimens are representative of species from both oceans. Archaeologists working on the North Atlantic Coast can identify their material on the basis of illustrations of Pacific species, and the converse holds for North Pacific archaeologists.

Organization

The manual is divided into five sections. The first section is an introduction to the general fish skeleton; the cranium and lateral facial bones, the appendicular skeleton, and the axial skeleton. The subsequent sections are individually illustrated osteologies, presented in taxonomic order, of the salmon, cod, rockfish, and halibut. The bone elements are disarticulated and organized by anatomical region. The drawings are organized by species rather than element because the range and morphology of skeletal elements varies considerably between species. As an aid to preparing reference collections it is more useful to have the elements of each species kept together.

Because the goals of archaeologists differ from those of biologists, the bones are not necessarily represented at the angle in which they naturally occur in the articulated skeleton. Most of the elements show at least two viewpoints from
which the most identifiable and recognizable features are visible. Unless otherwise
specified, the drawings are of the right side. Due to the asymmetric skull of the
halibut, several elements from right and left sides show distinct differences. Where
this applies, both sides are illustrated, unless the difference is merely one of size.

Each element is depicted actual size in order to emphasize as much detail
as possible. Drawings at this scale and level of detail will enable the analyst to
differentiate between various fish taxa through recognition of characteristic bone
structures and features. At this scale, the relative size differences among various
elements of different species also become apparent. For example, the coracoid of a
90cm long salmon is just slightly smaller than that of a rockfish just over half its
size. However, it is important to remember that within families and within
species, elements can exhibit a wide range of size and morphological variability.
Within species element size is a direct function of fish size which continues to
increase with the age of the fish.

Terminology

As far as terminology is concerned, five major sources have been drawn
upon. These are Starks (1901), Gregory (1933), Norden (1961), Mujib (1967), and
Bond (1979). Much controversy still exists among ichthyologists concerning the
standardization of nomenclature. Therefore, most of the terminology used here is
derived from Starks (1901) and Gregory (1933). Where there are bones specific to
certain species, the terms have been taken from the relevant literature; ie. Mujib
(1967) for the cod, and Norden (1961) for the salmon. Where new terms have
come into common usage, these have been substituted for the older terms of Starks
(1901) and Gregory (1933) (ie. from Gifford and Crader 1977; Bond 1979;
Courtemanche and Legendre 1985).

An important factor to note in the naming of fish bones is the difference in
the number of bones present among various fish taxa. While much of the skeleton
of the lower bony fishes is cartilagenous, it also tends to have a greater variety of
bones (Bond 1979). For example, the salmons have 7-8 circumorbitals, a
mesocoracoid, orbitosphenoid, supramaxilla, suprapreopercle, and numerous caudal
bones. The halibut (a higher teleost) lacks most of the above mentioned elements,
and has only one nasal. The caudal fin has been reduced to two epurals and two
hypurals, and the orbitals have been reduced to several minute tubular ossicles.
Although the skeletal elements of the higher and lower bony fishes basically correspond, some of the names of the bones will be different due to specialization and particular adaptations. For example, there is no true mesethmoid in the salmon (Norden 1961:727). It has a supraethmoid bone which is not present in the cod, rockfish, or halibut. A further example is the basihyal of the salmon which is cartilaginous, overlaid with a well-ossified lingual plate (Norden 1961:734). It is the lingual plate which survives archaeologically. The basihyal of the rockfish and halibut is completely ossified. The cod has no basihyal.

Method of Specimen Preparation

For all intents and purposes, this manual is meant to supplement and complement a comparative fish bone collection. It is not intended to be a total replacement for a comparative collection, and the importance of access to such a collection for precise identification must be stressed. Adequate collections, however, are not always available, and the services of a specialist can be difficult to obtain and expensive. Making up a basic fish collection may be difficult and time consuming, but it is sometimes the only solution. What follows, is a short description of the method used for the preparation of specimens for the present manual.

The method of maceration used was a modification of the enzyme-base laundry presoaker and warm water technique described in Casteel (1976). The fish specimen was first gutted, being careful not to cut or remove any bones. To accelerate the maceration process, the fish was lightly steamed until superficial flesh flaked off easily. This excess flesh was carefully removed without damaging any bones. The remaining carcass was then left submerged in a strong presoaker solution for a few days, with checks on its progress made every day. Accurate graphic representation of the individual bony elements required a skeleton that was in the best condition possible. This meant that constant monitoring was necessary to ensure that the bones did not warp, dry-out, or begin to break down.

When the cartilage appeared to be sufficiently dissolved, the skeleton was removed in sections (ie. caudal, left and right pectoral, pelvic, and lateral facial sections, etc.). The neurocranium tended to take the longest to disarticulate. The bones were removed from the solution while they were still attached but soft enough to separate easily by hand. In this way left and right sides were not
confused, and the articulated bones could be compared with the drawings in biological studies.

Once separated, the bones were hand cleaned under tepid water. Care was taken to work over a fine-meshed screen. Finally, the bones could be laid out to dry and later labelled.

The process used here was painstaking and time consuming. This was necessary in order to identify elements in comparison with the articulated drawings and descriptions of zoological osteologies. It is hoped that with the aid of the present manual, much quicker and more effective maceration techniques could be used (see Casteel 1976:7-16). During the maceration process, it should not be necessary to maintain articulations, or separate left from right, as these precise element identifications can be made later with reference to the drawings in this manual. However, it is important to stress again that for the recognition of morphological differences between various species, and their precise archaeological identification, a comparative osteological collection is essential. This manual is only intended as a useful adjunct to such a collection. It can be used in field situations in which the fragility of comparative fish collections makes their use impractical, and can also help prevent the deterioration of a collection by reducing the amount of handling required in laboratory analysis.


Additional Notes

Although an attempt has been made to produce osteologies as complete as possible, some bones have been omitted. The otoliths of the salmon (Oncorhynchus keta) are so small as to make a to-scale drawing useless. Included is a detailed series of enlarged drawings of salmonid otoliths redrawn after Norden (1961). In addition, the following bones are absent: the extrascapulars of the salmon, suborbitals 4 and 5 of the rockfish, and the supratemporals, and orbitals of the halibut. Drawings of the extrascapulars and supratemporals were not attempted because they are merely a thin line of tubular bones enclosing a sensory canal. The orbitals of the halibut and supraorbitals 4 and 5 of the rockfish were omitted for the same reason. These bones are all extremely small or fragile, and therefore are not considered of essential importance. Their recovery is unlikely in archaeological sites.
The salmon bones are those of a spawning male, and therefore show the characteristic increase in the size of jaws and teeth, etc. (see Tchernavin 1938 for a description of breeding changes in the skull). It is interesting to note that in all species of sea-run *Oncorhynchus*, with the possible exception of *O. kisutch*, the teeth of half-grown and adult fish of both sexes are not fastened to the various teeth bearing bones. It is only close to the time of spawning that the teeth become fused to their respective bones (Vladykov 1962:50-52). In addition, unlike *Salmo*, the breeding teeth of *Oncorhynchus* are not set in sockets (Tchernavin 1938:164). Instead, they have large ossified bases which are easily recognized in archaeological specimens.

The cod otolith that was drawn came from a smaller specimen of the same species, while all of the other cod elements came from a single larger specimen. The branchial arches of the rockfish are from a Pacific species of rockfish (*Sebastes* sp.). The frontals, sphenotic and supraoccipital of the halibut were drawn from a larger specimen of the same species (*H. stenolepis*).
<table>
<thead>
<tr>
<th>Species</th>
<th>Total Length</th>
<th>Weight</th>
<th>Source</th>
<th>Date</th>
</tr>
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<tr>
<td>Oncorhynchus keta (Chum salmon, Pacific)</td>
<td>90cm</td>
<td>unknown</td>
<td>Chehalis River, B.C. Canada</td>
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<tr>
<td>Gadus morhua (Atlantic cod)</td>
<td>109cm</td>
<td>12,115g</td>
<td>Dogger Bank England</td>
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<td>57.5cm</td>
<td>2105g</td>
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<td>Sebastes sp. (Rockfish, Pacific)</td>
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<td>1361g</td>
<td>Market Chinatown Vancouver Canada</td>
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<td>Hippoglossus stenolepis(a) (Pacific halibut)</td>
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<td>unknown</td>
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<td>unknown</td>
<td>unknown</td>
<td>Banks Island B.C. Canada</td>
<td>06/74</td>
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Table 2.
Anatomical Regions of the General Teleost Skeleton

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<th>PECTORAL GIRDLE</th>
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<tr>
<td>(supraethmoid,</td>
<td>Retroarticular</td>
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<tr>
<td>mesethmoid)</td>
<td>Supraopercle</td>
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<tr>
<td>Prefrontal</td>
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<td>Vomer</td>
<td>Supramaxilla</td>
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<td>OPERCULAR SERIES</td>
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<tr>
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<td>Opercle</td>
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<td>Subopercle</td>
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<tr>
<td></td>
<td>Interopercle</td>
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<tr>
<td></td>
<td>Branchiostegal Ray</td>
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<td>PELVIC GIRDLE</td>
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<td>Interhaemal Spine</td>
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<td>Orbitosphenoid</td>
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<td>Basioccipital</td>
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<td>Uroneural</td>
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<td>Otolith</td>
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<td>Caudal Bony Plate</td>
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<td>Expanded Neural Spine</td>
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<td>Expanded Haemal Spine</td>
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<tr>
<td>INVESTING BONES</td>
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<td>(Extrascapular)</td>
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<td>LATERAL SKULL BONES</td>
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<td>Maxilla</td>
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<tr>
<td>Dentary</td>
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INTRODUCTION TO THE GENERAL FISH SKELETON
THE CRANIUM - *Roccus saxatilis*

A. Ventral
B. Dorsal
C. Posterior
D. Left Lateral
Roccos saxatilis

THE CRANIUM

(after Starks 1901)
THE LATERAL FACIAL BONES AND APPENDICULAR SKELETON

Roccus saxatilis

KEY

A Angular
B Basipterigium
BH Basihyal
BR Branchiostegal Ray
C Cleithrum
CC Coracoid
CH Ceratohyal
D Dentary
E Ectopterygoid
EH Epiphyal
H Hyomandibular
HH Hypohyal
I Interhyal
IO Interopercle
L Lachrymal
M Maxilla
MES Mesopterygoid
MET Metapterygoid

N Nasal
O Opercle
PA Palatine
PC Postcleithrum
PM Premaxilla
PO Preopercle
PR Pectoral Ray
PT Posttemporal
Q Quadrate
R Radial
RA Retroarticular
S Scapula
SC Supracleithrum
SOB Suborbital
SOP Subopercle
ST Suprtemporal
SY Symplectic
UH Urohyal
VS Ventral Spine
Roccus saxatilis

THE LATERAL FACIAL BONES AND APPENDICULAR SKELETON

(after Starks 1901)
THE AXIAL SKELETON - *Roccus saxatilis*
THE AXIAL SKELETON

neural spine
neural arch
neural canal
centrum
zygopophysis
haemal canal
haemal spine

pterygiophore
interneural
rib
epileural spine
interhaemal spine

dorsal rays and spines

ultimate vertebra
penultimate vertebra
anal rays and spines

Thoracic
Precaudal
Caudal

Roccus saxatilis

(after Starks 1901)
KEY TO ELEMENT VIEW

L Lateral
M Mesial
A Anterior
P Posterior
D Dorsal
V Ventral
FAMILY SALMONIDAE

(after Gregory 1933)
SALMONIDAE  *Oncorhynchus keta*

OLFACTORY REGION

L

Vomer

Prefrontal

D

V

Supraethmoid
SALMONIDAE  *Oncorhynchus keta*

ORBITAL REGION

Parasphenoid

Alisphenoid

Orbitosphenoid
SALMONIDAE  *Oncorhynchus keta*

**OCCIPITAL REGION**

- **Exoccipital**
- **Supraoccipital**

- **Atlas Vertebra**
  - **Basioccipital**

**OTIC REGION**

Otoliths of some Marine Species of Salmonidae

- **Oncorhynchus mykiss**
  - 2.3x

- **Salmo trutta**
  - 1.0x

- **Oncorhynchus gorbuscha**
  - 2.9x

- **Oncorhynchus keta**
  - 1.6x

- **Oncorhynchus nerka**
  - 1.6x
SALMONIDAE  *Oncorhynchus keta*

OTIC REGION

- Opisthotic
- Sphenotic
- Epiotic
- Prootic
- Pterotic
SALMONIDAE  *Oncorhynchus keta*

INVESTING BONES

Frontal

Parietal

Nasal
SALMONIDAE *Oncorhynchus keta*

LATERAL SKULL BONES

Dentary

Angular

Retroarticular
SALMONIDAE  *Oncorhynchus keta*

LATERAL SKULL BONES

Premaxilla

Supramaxilla

Maxilla
SALMONIDAE  *Oncorhynchus keta*

LATERAL SKULL BONES

Circumorbital Series

- Suborbitals
- Supraorbitals
- Lachrymal

Suprapreopercle

Preopercle
SALMONIDAE  *Oncorhynchus keta*

**OPERCULAR SERIES**

Branchiostegal Ray

Opercle
SALMONIDAE  *Oncorhynchus keta*

**OPERCULAR SERIES**

Subopercle

Interopercle
SALMONIDAE  *Oncorhynchus keta*

MANDIBULAR ARCH

L  |  M
---|---

*Palatine*

L  |  M
---|---

*Ectopterygoid*

L  |  M
---|---

*Quadrates*

L  |  M
---|---

*Metapterygoid*
SALMONIDAE  *Oncorhynchus keta*

MANDIBULAR ARCH

![Mesopterygoid](image)

HYOID ARCH

![Hyomandibular](image)
SALMONIDAE  *Oncorhynchus keta*

HYOID ARCH

Ceratohyal

Interhyal

Epihyal

Symplectic
SALMONIDAE  *Oncorhynchus keta*

HYOID ARCH

Lingual Plate

BRANCHIAL ARCH

Urohyal
SALMONIDAE  *Oncorhynchus keta*

**HYOID ARCH**

Basihyal with Lingual Plate

1  2  Hypohyal

**BRANCHIAL ARCH**

Basibranchial

Basibranchial Plate

Hypobranchial

Ceratobranchial

Pharyngobranchial

Pharyngeal Plate

Epibranchial

Pharyngeal Plate
SALMONIDAE  *Oncorhynchus keta*

PECTORAL GIRDLE

Cleithrum

Supracleithrum

Postcleithrum

1 upper

2 middle

3 lower
SALMONIDAE  *Oncorhynchus keta*

PECTORAL GIRDLE

Scapula

Mesocoracoid

Coracoid

Radials

Posttemporal
SALMONIDAE  *Oncorhynchus keta*

PELVIC GIRDLE

Basipterygium

VERTEBRAL COLUMN

Thoracic Vertebra

Precaudal Vertebra
SALMONIDAE  *Oncorhynchus keta*

CAUDAL SKELETON

Caudal Vertebra

Epural

Caudal Bony Plate

Ultimate Vertebra

Penultimate Vertebra

Hypural

Expanded Neural Spine

Vertebra Centrum

Expanded Haemal Spine

Lateral View
KEY TO ELEMENT VIEW

L  Lateral
M  Mesial
A  Anterior
P  Posterior
D  Dorsal
V  Ventral
FAMILY GADIDAE

(after De Beer 1928)
GADIDAE  *Gadus morhua*

**OLFACTORY REGION**

![Diagram of Mesethmoid](image1)

![Diagram of Vomer](image2)
GADIDAE  *Gadus morhua*

OLFACTORY REGION

![Prefrontal](image)

ORBITAL REGION

![Alisphenoid](image)
GADIDAE  *Gadus morhua*

ORBITAL REGION

Parasphenoid
GADIDAE  *Gadus morhua*

**OCCIPITAL REGION**

Basioccipital

Exoccipital
GADIDAE  Gadus morhua

OCCIPITAL REGION

Supraoccipital
GADIDAE  *Gadus morhua*

OTIC REGION

Pterotic

Epiotic

Sphenotic
GADIDAE  *Gadus Morhua*

OTIC REGION

Opisthotic

Prootic

Otolith
GADIDAE  *Gadus morhua*

INVESTING BONES

Nasal

Frontal
GADIDAE  *Gadus morhua*

INVESTING BONES

L

Supratemporals

M

Parietal
GADIDAE  *Gadus morhua*

LATERAL SKULL BONES

Dentary

Retroarticular

Angular
GADIDAE  *Gadus morhua*

LATERAL SKULL BONES

Premaxilla

Maxilla
GADIDAE  *Gadus morhua*

LATERAL SKULL BONES

Suborbitals

Circumorbital Series
GADIDAE  *Gadus Morhua*

LATERAL SKULL BONES

Preopercle

OPERCULAR SERIES

Opercle
GADIDAE  *Gadus morhua*

**OPERCULAR SERIES**

- **Subopercle**
- **Branchiostegal Ray**
- **Interopercle**
GADIDAE  *Gadus morhua*

MANDIBULAR ARCH

Ectopterygoid

Palatine

Quadrate
GADIDAE  *Gadus morhua*

MANDIBULAR ARCH

Mesopterygoid

Metapterygoid

HYOID ARCH

Hyomandibular
GADIDAE  Gadus morhua

HYOID ARCH

Ceratohyal

Interhyal

Epihyal
GADIDAE  *Gadus morhua*

**HYOID ARCH**

Symplectic

1. upper

2. lower

**BRANCHIAL ARCH**

Urohyal
GADIDAE  *Gadus morhua*

BRANCHIAL ARCH

- Hypobranchial
- Ceratobranchial
- Basibranchial
- Pharyngeal Plate
- Epibranchial
- Pharyngobranchial
GADIDAE - *Gadus Morhua*

PECTORAL GIRDLE

Scapula

Postcleithrum

Coracoid
GADIDAE  *Gadus morhua*

PECTORAL GIRDLE

**Radials**

**Posttemporal**

**Supracleithrum**
GADIDAE  *Gadus morhua*

PECTORAL GIRDLE
GADIDAE  *Gadus morhua*

PELVIC GIRLDE

Basipterygium

VERTEBRAL COLUMN

Atlas Vertebra
GADIDAE  *Gadus morhua*

**VERTEBRAL COLUMN**

Thoracic Vertebra

Precaudal Vertebra
GADIDAE  *Gadus morhua*

CAUDAL SKELETON

Caudal Vertebra

Penultimate Vertebra

Ultimate Vertebra

Hypural

Lateral View
KEY TO ELEMENT VIEW

L  Lateral
M  Mesial
A  Anterior
P  Posterior
D  Dorsal
V  Ventral
FAMILY SCORPAENIDAE

(after Gregory 1933)
SCORPAENIDAE  *Sebastes marinus*

OLFACTORY REGION

- Ethmoid
- Prefrontal
- Vomer
SCORPAENIDAE  *Sebastes marinus*

ORBITAL REGION

Parasphenoid

Alisphenoid
SCORPAENIDAE  *Sebastes marinus*

OCCIPITAL REGION

Supraoccipital

Exoccipital

Basioccipital
SCORPAENIDAE  

*Sebastes marinus*

OTIC REGION

- Sphenotic
- Pterotic
- Epiotic
- Opisthotic
- Prootic
- Otolith
SCORPAENIDAE  *Sebastes marinus*

INVESTING BONES

Nasal

Supratemporal

Frontal

Parietal
SCORPAENIDAE  *Sebastes marinus*

**LATERAL SKULL BONES**

Preopercle

Maxilla

Suborbitals

Lachrymal

Circumorbital Series
SCORPAENIDAE  Sebastes marinus

LATERAL SKULL BONES

Premaxilla

Dentary

Retroarticular

Angular
SCORPAENIDAE  *Sebastes marinus*

**OPERCULAR SERIES**

Opercle

Subopercle

Interopercle
SCORPAENIDAE  *Sebastes marinus*

OPERCULAR SERIES

Branchiostegal Ray

MANDIBULAR ARCH

Palatine

Ectopterygoid
SCORPAENIDAE  *Sebastes marinus*

MANDIBULAR ARCH

**Quadrate**

**Metapterygoid**

**Mesopterygoid**
SCORPAENIDAE  
*Sebastes marinus*

HYOID ARCH

Symplectic  
Hyomandibular

Ceratohyal

Interhyal  
Epihyal
SCORPAENIDAE  *Sebastes*  sp

HYOID ARCH

1. Basihyal
2. Hypohyal

BRANCHIAL ARCH

- Basibranchial
- Hypobranchial
- Pharyngeal Plate
- Epibranchial
- Ceratobranchial
- Pharyngobranchial
SCORPAENIDAE  *Sebastes marinus*

BRANCHIAL ARCH

Urohyal

PECTORAL GIRDLE

Posttemporal

Supracleithrum
SCORPAENIDAE  *Sebastes marinus*

PECTORAL GIRDLE

Cleithrum
SCORPAENIDAE  *Sebastes marinus*

PECTORAL GIRDLE

**Radials**

**Scapula**

**Postcleithrum**

**Coracoid**
SCORPAENIDAE  
*Sebastes marinus*

PELVIC GIRDLE

Basipterygium

Interhaemal Spine

VERTEBRAL COLUMN

Atlas Vertebra
SCORPAENIDAE  *Sebastes marinus*

VERTEBRAL COLUMN

Thoracic Vertebra  Precaudal Vertebra

CAUDAL SKELETON

Caudal Vertebra
SCORPAENIDAE  *Sebastes marinus*

CAUDAL SKELETON

Penultimate Vertebra  Ultimate Vertebra

Lateral View
KEY TO ELEMENT VIEW

L  Lateral
M  Mesial
A  Anterior
P  Posterior
D  Dorsal
V  Ventral
FAMILY PLEURONECTIDAE

(after Gregory 1933)
PLEURONECTIDAE  *Hippoglossus stenolepis*

OLFACTORY REGION

Ethmoid

Vomer

Prefrontal

left

right
PLEURONECTIDAE  *Hippoglossus stenolepis*

ORBITAL REGION

Alisphenoid

Parasphenoid
PLEURONECTIDAE  *Hippoglossus stenolepis*

OCCIPITAL REGION

![Diagram of occipital region](image)

Supraoccipital

from larger specimen - *Hippoglossus stenolepis* (b)

right

Exoccipital

left
PLEURONECTIDAE  *Hippoglossus stenolepis*

**OCCIPITAL REGION**

Basioccipital

**OTIC REGION**

Sphenotic

*from larger specimen - Hippoglossus stenolepis (b)*
PLEURONECTIDAE  Hippoglossus stenolepis

OTIC REGION

Pterotic  right  left

Opisthotic

right  left

Epiotic
PLEURONECTIDAE  *Hippoglossus stenolepis*

OTIC REGION

Prootic

L  right  M

L  left  M

Otolith

right

left
PLEURONECTIDAE  *Hippoglossus stenolepis*

INVESTING BONES

from larger specimen -  *Hippoglossus stenolepis*  (b)
PLEURONECTIDAE  
Hippoglossus stenolepis

INVESTING BONES

L  
Nasal

M

right

Parietal

left
PLEURONECTIDAE  *Hippoglossus stenolepis*

LATERAL SKULL BONES

![Diagram of lateral skull bones](image)

- **Premaxilla**
  - L
  - M

- **Maxilla**
  - L
  - M

- **Dentary**
  - L
  - M
PLEURONECTIDAE  

*Hippoglossus stenolepis*

LATERAL SKULL BONES
PLEURONECTIDAE  *Hippoglossus stenolepis*

**OPERCULAR SERIES**

![Opercle](image)

L

M

![Subopercle](image)

L

M
PLEURONECTIDAE  *Hippoglossus stenolepis*

**OPERCULAR SERIES**

Interopercle

Branchiostegal Ray
PLEURONECTIDAE  *Hippoglossus stenolepis*

MANDIBULAR ARCH

L  

right

Palatine

L  

left

Ectopterygoid

M  

L  

M
PLEURONECTIDAE  *Hippoglossus stenolepis*

MANDIBULAR ARCH

**Quadrate**

**Mesopterygoid**

L  
M  

right  
left
PLEURONECTIDAE  *Hippoglossus stenolepis*

MANDIBULAR ARCH

M.

Metapterygoid

HYOID ARCH

L.

Symplectic

Hyomandibular
PLEURONECTIDAE  *Hippoglossus stenolepis*

**HYOID ARCH**

- Ceratohyal
- Interhyal
- Epiphyal
- Hypohyal

1. Upper
2. Lower
PLEURONECTIDAE

Hippoglossus stenolepis

HYOID ARCH

D  Basihyal  L

BRANCHIAL ARCH

Hypobranchial
Basibranchial
Ceratobranchial
Pharyngeal Plate
Epibranchial
Pharyngobranchial
PLEURONECTIDAE  
*Hippoglossus stenolepis*

**BRANCHIAL ARCH**

[Diagram of branchial arch structures, labeled as Urohyal (L and M).]

**PECTORAL GIRDLE**

[Diagram of pectoral girdle structures, labeled as Posttemporal (L and M) and Postcleithrum.]

PLEURONECTIDAE  *Hippoglossus stenolepis*

PECTORAL GIRDLE

Scapula

Supracleithrum

Radials

Coracoid
PLEURONECTIDAE  *Hippoglossus stenolepis*

PECTORAL GIRDLE

Cleithrum
PLEURONECTIDAE
Hippoglossus stenolepis

PELVIC GIRDLE

Interhaemal Spine

Basipterygium

L

M
PLEURONECTIDAE  *Hippoglossus stenolepis*

**VERTEBRAL COLUMN**

![Atlas Vertebra](image1)

![Thoracic Vertebra](image2)
PLEURONECTIDAE  Hippoglossus stenolepis

VERTEBRAL COLUMN

Precaudal Vertebra
PLEURONECTIDAE  
*Hippoglossus stenolepis*

CAUDAL SKELETON

Caudal Vertebra
PLEURONECTIDAE  

Hippoglossus stenolepis

CAUDAL SKELETON

Caudal Vertebra - articulates with Interhaemal Spine
PLEURONECTIDAE  *Hippoglossus stenolepis*

CAUDAL SKELETON

![Caudal Skeleton Diagram](image)

- Epural
- Ultimate Vertebra
- Hypural
- Penultimate Vertebra

Lateral View
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