



# **A Key for Identifying Preyfish in the Columbia River Based on Diagnostic Bones**

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## **Overview**

Identification of fish from fragmentary remains such as bones and scales has been used for purposes such as characterization of the diet of piscivores (Laidig et al., 1991; Sharp and Bernard, 1988; Borodulina, 1986), the estimation of fish size (Uyeno, 1961; Casselman, 1983; Casselman, 1974; Casteel, 1974b; Casteel, 1974a; Hansel et al., 1988; Harrison and Hadley, 1979; Le Cren, 1947; Marzolf, 1955; McConnell, 1951; Menon, 1950; Pikhu and Pikhu, 1970; Rojo, 1986; Scott, 1977) and zooarchaeological studies (Butler, 1993; Casteel, 1976; Casselman, 1972). In the Columbia River basin, fish remains, specifically bones, have been used to help determine ecological effects of piscivorous fish (Jollie, 1980; Poe et al., 1991; Rieman et al., 1991; Ward et al., 1995; Vigg et al., 1991), and the management implications of those effects (Beamsderfer et al., 1990). However the work has generally depended on the knowledge and experience of people already familiar with the bones of Columbia River fish, along with some informal and incomplete keys. This report is an effort to provide a tool for

identifying selected Columbia River fish bones that may be used by anyone who is not already familiar with the material.

These keys were derived from work conducted at the Columbia River Research Laboratory (CRRL, U.S. Geological Survey) at Cook, Washington, characterizing the diets of predatory fish in the Columbia River. The keys are an elaboration of work done by Hansel et al. (1988), and a laboratory manual prepared for use at CRRL for analysis of diets of predatory fish, particularly northern pikeminnow, smallmouth bass and walleye. A principal predator in the Columbia, and the focus of several studies, the northern pikeminnow (*Ptychocheilus oregonensis*) has a non-acidic digestive system that leaves the bones of prey fish completely disarticulated but otherwise undamaged. The bones selected for use in the keys are bones that survive digestion in pikeminnow in generally good condition, are readily recognizable, and differ enough among taxa to identify to genus or species relatively easily. Although most bones were collected from the digestive tracts of northern pikeminnow, the keys should be applicable to bones collected from other sources or predator species, as long as the bones are undamaged and their parts are discernible.

The illustrations and identifying criteria were based on a collection of osteological specimens at the Columbia River Research Lab. As individual fish and their bones vary, the bones used in the illustrations were selected to be typical of the type of bone described in the key. Some bones are copiously represented in this collection, while others are not. The illustrations were made with the help of a dissecting microscope fitted with a drawing tube. An effort was made to illustrate bones from the left side, but some examples were better illustrated with undamaged or more typical right side specimens.

The bulk of specimens in the collection were assembled for other projects, and not with the intention of producing a key. The bones in the collection are mostly of small fish; consequently, the illustrations and the descriptions are based on small fish. The keys were compared with specimens of adult fish that were available in the collection and from other sources. As stated above, allometric differences in the bones between young and old fish were taken into account in writing the keys in order to make the keys useful for large as well as small fish. As piscine predators' diet in the Lower Columbia river consists mainly of small fish, typically less than 150mm in the case of pikeminnow, the keys are

intended for use with small fish. This includes fish that are small as adults, e.g. stickleback, or small only as juveniles, e.g. salmon. However, as the bones used here undergo relatively little allometric change (Sharp and Bernard, 1988), the keys can be used for adult fish. Use of features that do change have been avoided, and where change does occur, it is mentioned.

The bones were prepared by maceration with porcine pancreatase and sodium sulfite. Addition of a solution of sodium hydroxide for a few seconds or minutes before the slurry of macerated flesh and bones were rinsed through sieves yielded bones that were entirely free of flesh with all details visible.

### Use of the keys

Included here are keys for use with cleithra, dentaries and pharyngeal arches. Keys for cleithra and dentaries include multiple families and may be used to identify Columbia River fish generally, with the caveats given above. The key for pharyngeal arches is for use with cyprinids and catostomids only.

These keys are dichotomous. All but the first two statements begin with a pair of numbers and letters. Each step in the key is indicated by a number/letter pair, where dichotomous choices are made by comparing statements (for example, 1a versus 1b). The second number/letter pair, in parentheses, denotes the number of the statement from which the present sequential choice was derived. The parenthetical number/letter pair permits retracing steps backwards through the key.

Simply matching a bone with an illustration will suffice in many cases, though care should be taken to read the relevant sections to understand diagnostic features and to know exactly which fish are included or excluded for a particular entry. For example, catostomid pharyngeal arches are instantly identified as such, but they do not permit identification past the generic level for Columbia River fish.

The bones used in these keys will identify most fish found in the mainstem of the lower Columbia River above the estuary. Not all the fish represented by these keys can be identified to species, though nearly all can be identified to genus. Interspecific variation with respect to the bones used in these keys in the genera *Oncorhynchus*, *Ictalurus*, *Micropterus*, *Lepomis*, *Catostomus*, and *Cottus* is not reliable enough to allow identification to species. Not all species of fish living in the stretch of the river for which these keys are intended are included here. Missing are fish that live within the watershed but are rare or

not commonly found in the mainstem of the lower Columbia, e.g. tui chub, banded killifish, eulachon, tadpole madtom, or whose skeleton is cartilaginous. Species with not enough material at hand in the collection to yield reliable data, i.e. sturgeon, green sunfish and warmouth, are also missing from the keys.

These keys are but one means of identifying Columbia River fish remains. Other bones and structures such as scales or otoliths may actually be of equal or greater help in identifying particular species (see appendix 1). For example, the preopercals of *Cottus*, *Perca*, and *Stizostedion* are readily seen, distinctive and diagnostic, as are the fringed scales of *Percopsis*, the glass-like spines of *Gasterosteus*, and the latticed basioccipitals of *Catostomus*. On some fish other structures may be misleading, such as the dorsal spines of *Cyprinus* easily mistaken for pectoral spines of *Ictalurus*.

The lengths of the fish from which the figures were drawn are given next to the figures. Depending on the shape of the tail of the species concerned, the lengths are given as fork lengths (FL) or total lengths (TL).

Table 1. lists the species and genera included in these keys. Material from some species was available in only limited amounts, so that conclusions drawn from these keys must be considered uncertain in those cases. Tadpole madtom *Noturus*, and two species of dace, leopard dace *Rhinichthys falcatus* and speckled dace *R. osculus*, fit this category. The keys will identify dace to genus, though the illustrations are of longnose dace *R. cataractae* which was better represented in the material available than the other two species. *Noturus gyrinus* will be identified as *Ictalurus* with this key. *N. gyrinus* is, however, so rare in the Columbia River that any bone from that river characterized with these keys as belonging to *Ictalurus* is almost certain to be *Ictalurus* rather than *N. gyrinus*. Based on the limited material available for examination (two skeletons), *N. gyrinus* apparently differs from *Ictalurus* in having a deep pocket in the caudal margin of the cleithrum between the dorsoposterior spines. Paloumpis (1963) and Taylor (1969) provide means of identifying ictalurids by their pectoral spines.

Table 1.

List of genera and species included in the keys.

The columns under "key listing" correspond to listings of species in the respective keys. Cleithrum = Cleith; dentary = Dentary; pharyngeal arch = Ph. arch. Within the "key listing" columns "gen." indicates that the bone can be identified to genus, "sp." indicates that the bone can be identified to species, and "no" indicates that the species or genus is not represented in the key.

<u>Scientific name</u>	<u>Common name</u>	<u>Key listing</u>		
		Cleith.	Dentary	Ph. arch
<i>Acrocheilus alutaceus</i>	Chiselmouth chub	sp	sp.	sp.
<i>Alosa sapidissima</i>	American shad	sp.	sp.	no
<i>Carassius auratus</i>	Goldfish	gen.	sp	sp.
<i>Catostomus spp.</i>	Suckers	gen.	gen.	gen.
<i>Cottus spp.</i>	Sculpins	gen.	gen.	no
<i>Cyprinus carpio</i>	Common carp	gen.	sp.	sp.
<i>Gambusia affinis</i>	Mosquitofish	sp.	sp.	no
<i>Gasterosteus aculeatus</i>	Threespine stickleback	sp.	sp.	no
<i>Ictalurus spp.</i>	Catfish, bullheads	gen.	gen.	no
<i>Lepomis spp.</i>	Pumpkinseed, bluegill,	gen.	gen.	no
<i>Lota lota</i>	Burbot	sp.	sp.	no
<i>Micropterus spp.</i>	Large-, smallmouth bass	gen.	gen.	no
<i>Mylocheilus caurinus</i>	Peamouth chub	sp.	sp.	sp.
<i>Oncorhynchus spp.</i>	Salmon	gen.	gen.	no
<i>Oncorhynchus mykiss</i>	Steelhead, rainbow trout	gen.	sp.	no
<i>Perca flavescens</i>	Yellow perch	sp.	sp.	no
<i>Percopsis transmontana</i>	Sandroller	sp.	sp.	no
<i>Platichthys stellatus</i>	Starry flounder	sp.	sp.	no
<i>Pomoxis spp.</i>	Black-, white crappie	gen.	gen.	no
<i>Prosopium williamsoni</i>	Mountain whitefish	sp.	sp.	no
<i>Ptychocheilus oregonensis</i>	Northern pikeminnow	sp.	sp.	sp.
<i>Rhinichthys spp.</i>	Dace	gen.	gen.	gen.
<i>Richardsonius balteatus</i>	Redside shiner	sp.	sp.	sp.
<i>Stizostedion vitreum</i>	Walleye	sp.	sp.	no
<i>Tinca tinca</i>	Tench	sp.	sp.	sp.

## Glossary

Anterior angle of ph. arch:	The angle between the anterior and posterior limbs, often marked by a distinct corner on the lateral edge of the bone.
Anterior edentulous process:	The angle between the anterior and posterior limbs, often marked by a distinct corner on the lateral edge of the bone.
Anterior limb of ph. arch:	Anteroventral portion of pharyngeal arch from the anterior tip to the anterior angle.
Anterior tip:	Tip of medial rib and usually anteriormost projection of the horizontal limb of the cleithrum.
Body of dentary:	The anterior part of the dentary, that is, that part exclusive of the coronoid and ventral limbs.
Buccal:	Pertaining to, or directed toward, the cheek.
Caniniform:	Resembling a canine tooth.
Coronoid limb:	The dorsal of the two rami caudad of the body of the dentary.
Denticulate:	Finely dentate or serrate.
Dorsal notch:	The juncture, or an incisure at the juncture of the dorsoposterior lobe with the dorsal spine of the cleithrum. May be angular or rounded.
Dorsal spine:	Dorsal terminus of the vertical limb of the cleithrum, extending from the dorsal notch up. Usually distinct from the rest of the vertical limb.
Dorsoposterior lobe:	Caudally directed, usually wing- or fan-like lobe on the vertical limb of the cleithrum, extending from the dorsal notch to the heel.
Foramen (ina):	A small opening, perforation, or orifice.
Fossa (ae):	A small cavity, hollow or depression.
Heel:	A heel-like lobe, protrusion, or angle at the base of the dorsoposterior lobe of the cleithrum. Variably developed: it may range from a spine-like process to nonexistent.
Heterodont:	Having teeth of different types.
Homodont:	Having teeth of a uniform type.
Horizontal limb:	The ventral and anteriormost half of the cleithrum extending from the anterior tip to the heel or, where a heel does not exist, to where the cleithrum is angled.
Lacuna (nae):	A small pit or hollow cavity; a general term for such a compartment within or between other body structures.
Lamina (nae):	A thin, flat plate or layer.

Lateral ridge:	A ridge originating on the anterior margin of the vertical limb of the cleithrum and running ventrally and laterally, sometimes meeting the lateral edge of the lateral shelf.
Lateral shelf:	A lateral widening of the horizontal limb of the cleithrum into a winglike surface that meets the caudal margin of the opercle.
Length of pharyngeal arch:	The distance from the anterior tip to the caudal most point of the bone.
Lingual wall:	The sheet of bone forming the mesial side of the Mecklian fossa
Lingual:	Pertaining to, or toward the tongue.
Major tooth row:	The teeth along the mesial edge of the ventral surface of the pharyngeal arch. They are larger and stouter than those in the minor row.
Mandibular symphysis:	The joint between left and right dentaries.
Mecklian notch:	The notch formed where coronoid and ventral limbs of the dentary meet on the buccal / lateral side of the dentary.
Mecklian fossa:	The central cavity in the body of the dentary into which the anterior limb of the angular bone inserts.
Medial rib:	A ridge or thickened rise running along the dorsal / anterior aspect of the horizontal limb of the cleithrum from its juncture with the vertical limb to the anterior tip.
Mental foramen:	A hole through the anterior end of the body of the dentary patent from buccal to lingual surfaces or from buccal surface to Mecklian fossa.
Minor tooth row:	Teeth lateral and dorsal to the major tooth row. These are smaller and fewer than those in the major tooth row.
Posterior angle of ph. arch:	The angle at the distal part of the posterior limb situated where the posterior limb bends obliquely cephalad.
Posterior limb of ph. arch:	That part of the pharyngeal which is turned dorsad to surround the lumen of the esophagus. Measured from the anterior angle to the posteromesial end of the bone.
Posteroventral notch:	An incisure, recess or arch of the cleithrum ventral and anterior to the heel.
Ridge:	A projection or projecting structure (of bone).
Scapulocoracular ridge:	A ridge, variously developed and shaped on the ventral / posterior aspect of the horizontal limb of the cleithrum, that articulates with the scapula and coracoid bones.

Sensory canal:	The passageway for the nerves of the lateral line along the buccal sides of the body of the dentary and ventral limb. It may be an open channel or a tunnel opening through sensory pores.
Sensory pore:	Lateral openings into the sensory canal.
Socket:	Depressions in the dentary into which teeth fit.
Spiculate:	Covered with or having spicules: minute spike like bodies.
Sulcus:	A groove, trench or furrow.
Ventral limb:	The ventral of the two rami caudad of the body of the dentary.
Vertical limb:	The dorsal half of the cleithrum extending from the end of the dorsal spine to the heel or, where a heel does not exist, to where the cleithrum is angled.
Width of pharyngeal arch:	The greatest distance between the concave mesial and convex lateral margins of the body of the pharyngeal arch at the level of the teeth.

### Key to dentaries

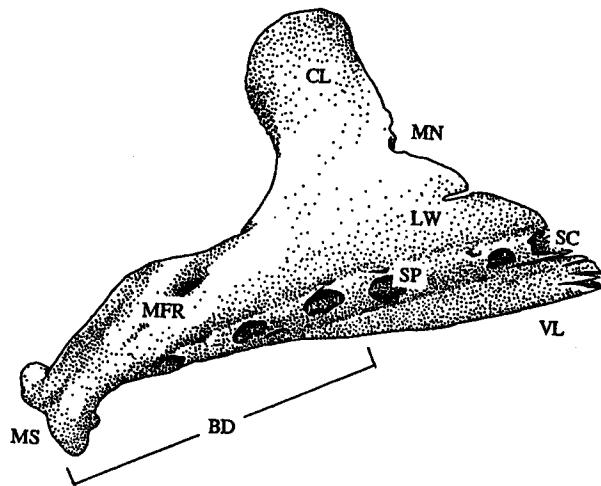
The dentaries are paired V-shaped bones forming the anteriormost and greater part of the lower mandible. The dentaries form the lower margin of the mouth and bear teeth in those fish that normally have teeth in the lower jaw. For most species of fish in the Columbia River dentaries can be readily identified as such even among completely disarticulated skeletons.

There is no fixed nomenclature with which parts of the dentary are described. The terms used in this key are derived from several sources. (Vladykov, 1934; Weisel, 1960b; Weisel, 1960a; Rojo, 1991; Mujib, 1967; Harrington, 1955).

Each dentary meets its abaxial twin cephalad at the mandibular symphysis, that is, the chin. The bone extends laterally then curves caudad to meet the anterior end, or ends, of the next paired bones of the mandible, variously: the angular, articular, retroarticular and coronomecklian. One must remember that fish jaws are made of a series of paired, unfused bones, unlike mammals in which these same elements have ankylosed to form a single jaw bone. Caudally, the dentary is forked into a dorsal or coronoid limb and a ventral limb. At the junction of the limbs the body of the dentary is hollowed out to varying degrees to form the mecklian fossa into which the next mandibular bones fit. Along the ventrolateral aspect of the ventral limb and continuing forward along the anterior part, here called the body of the dentary, is a sulcus or tube, the sensory canal, bearing a branch of the lateral line system. If enclosed to form a tube, the tube has openings along the lateral side called sensory pores. In many fish the the body of the dentary is pierced from lingual to buccal surfaces by a mental foramen located ventral to the tooth row or lip where the teeth would be.

Depending on the species, in the living fish dentaries may or may not bear teeth; also, in disarticulated skeletons teeth often fall away from the dentaries. This key, therefore, makes sparing use of the presence or absence of teeth or their shapes as identifying characteristics, using them mainly for those species in which the teeth are likely to be retained in disarticulated specimens. Though teeth may be missing, their placement and size can be determined to a certain extent by the sockets remaining on the surface of the dentary.

Terms used to describe dentaries in this key include the following: body of dentary, coronoid limb, lingual wall, mandibular symphysis, mecklian notch, mecklian fossa, mental foramen, sensory canal, sensory pore, ventral limb. Views are of left lateral sides of left dentaries unless otherwise specified.

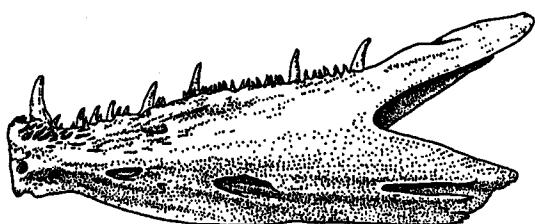


Lateral view of left dentary of *Mylocheilus caurinus*.

BD, body of dentary; Cl, Coronoid limb; LW, Lingual wall; MFR, mental foramen; MN, mecklian notch; MS, mandibular symphysis; SC, sensory canal; SP, sensory pore; VL, ventral limb.

- 1a Dentary distinctly heterodont. A buccal row of small conical to caniniform teeth along margin with an adjacent lingual row of large caniniform teeth. Anteriormost large tooth usually largest of all. (Teeth generally well anchored enough to be present.)

.....*Stizostedion vitreum*



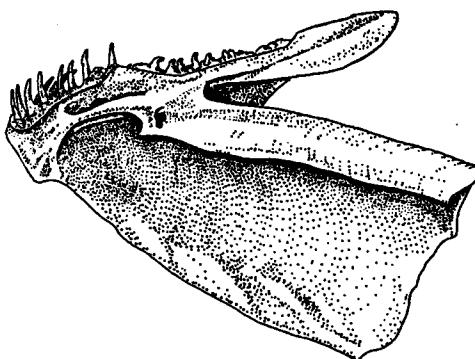
*Stizostedion vitreum* FL = 189mm  
Left dentary, lateral view

- 1b Teeth homodont or teeth entirely lacking, i.e. neither teeth nor sockets present. (Though see 4b)

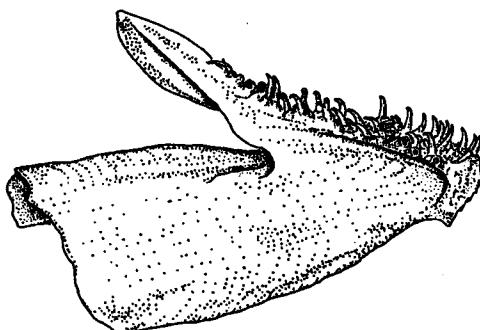
.....2

- 2a (1b) Ventral limb enormously broadened to form a sublingual, ventrolaterally concave plate or shelf.  
Sensory canal open. Teeth caniniform if present.

.....*Percopsis transmontana*



*Percopsis transmontana* FL = 77mm  
Left dentary lateral-inferior view



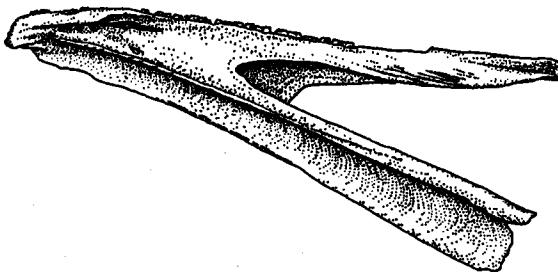
*Percopsis transmontana* FL = 77mm  
Left dentary mesial-superior view

- 2b (1b) Ventral limb not broadened into sublingual plate or shelf.

.....3

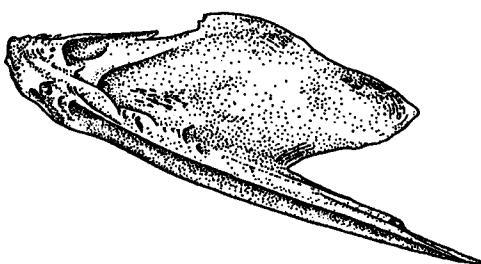
- 3a (2b) Sensory canal a long trench open ventrolaterally, and running nearly the length of the dentary.

- .....4
- 3b (2b) Sensory canal absent, enclosed, or, if open, then open for less than two thirds the length of the dentary.
- .....5
- 4a (3a) Coronoid limb narrow, with numerous teeth (or evident sockets), extending halfway or more along margin. Sensory canal a broad trench, comprising a dominant feature of almost the entire ventral margin of the dentary. Lingual wall of mecklian fossa visible in lateral view.
- .....*Lota lota*



*Lota lota* TL = 193mm  
Left dentary, lateral view

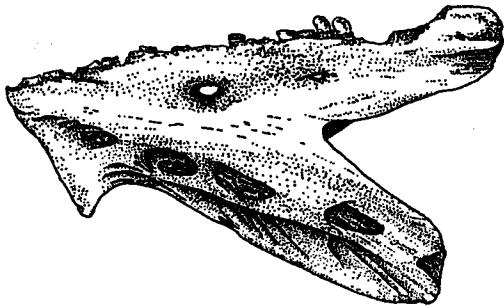
- 4b (3a) Coronoid limb broad, flat, almost papery thin. Teeth few, slightly hooked, and confined to the anterior sixth of the dentary. Teeth are very often missing, in which case sockets are not evident. Ventral limb tapers to a narrow point.
- .....*Alosa sapidissima*



*Alosa sapidissima* FL = 80mm  
Left dentary, lateral view

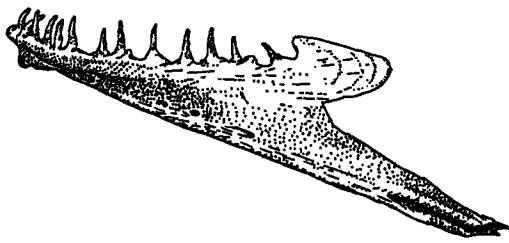
- 5a (3b) Teeth and/or sockets present.
- .....6
- 5b (3b) Teeth and/or sockets absent.
- .....15

- 6a (5a) Dentary has a single row of teeth. .... 7
- 6b (5a) Dentary has more than one row of teeth. .... 9
- 7a (6a) Mandibular symphysis broad. Sensory pores large. Dentary overall short, stout. Small foramen through dorsal half of dentary body patent in lateral view. Sockets somewhat rectangular. Left and right dentaries differ, one being more bowed out laterally than the other. .... *Platichthys stellatus*



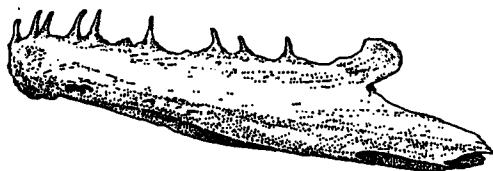
*Platichthys stellatus* TL = 210mm  
Left dentary, lateral view

- 7b (6a) Mandibular symphysis narrow. Teeth caniniform and of roughly uniform size. .... 8
- 8a (7b) Dentary strongly bowed out laterally. Buccal surface ventral to anterior teeth nearly horizontal and almost perpendicular to plane of coronoid limb. Ratio of the length from the mandibular symphysis to the apex of the mecklian notch to the length of the perpendicular from the ventral of the ventral limb to the apex of the notch is less than or equal to four. Angle formed by the tips of the coronoid and ventral limbs and the mandibular symphysis usually larger than that in other species of *Oncorhynchus*. .... *Oncorhynchus mykiss*



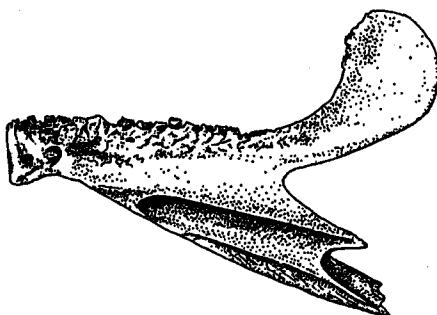
*Oncorhynchus mykiss* FL = 155mm  
Left dentary, lateral view

- 8b (7b) Dentary not bowed out as in *O. mykiss*. Ratio described in 8a greater than four.  
.....*Oncorhynchus nerka*, *O. kisutch*, *O. tshawytscha*



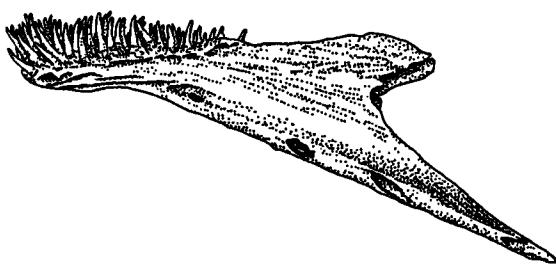
*Oncorhynchus kisutch* FL = 125mm  
Left dentary, lateral view

- 9a (6b) Sensory canal entirely open. Dentary very small with spongiform internal construction and a wrinkly surface. Coronoid limb spatulate.  
.....*Gasterosteus aculeatus*



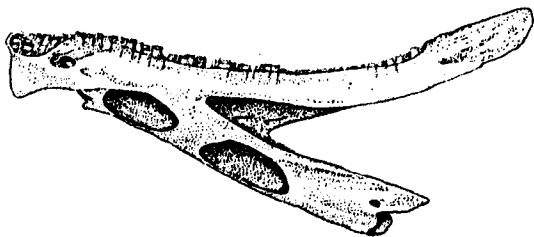
*Gasterosteus aculeatus* FL = 53mm  
Left dentary, lateral view

- 9b (6b) Sensory canal largely closed, opening laterally through sensory pores. .... 10
- 10a (9b) Ventral limb much longer than coronoid limb, and tapering to a point enclosing a narrow sensory canal with (usually) three small sensory pores along the ventral margin of the dentary. Teeth and or sockets very numerous. Mecklian fossa open on lingual side with lingual wall very much reduced. .... *Ictalurus spp.*



*Ictalurus punctatus* FL = 149mm  
Left dentary, lateral view

- 10b (9b) Ventral limb approximately the same length or shorter than the coronoid limb. .... 11
- 11a (10b) Three very large sensory canal pores. Coronoid limb long and narrow: midway approximately the width of the sensory pores. In lateral view, the ventrally opening anterior sensory pore appears in profile as a notch, while the laterally opening posterior sensory pores face the viewer. Coronoid limb longer than the ventral limb. .... *Cottus spp.*



*Cottus* sp. FL = 115mm  
Left dentary, lateral view

11b (10b) Sensory pores relatively small: widest dimension far less than the width of the mid section of the coronoid limb.

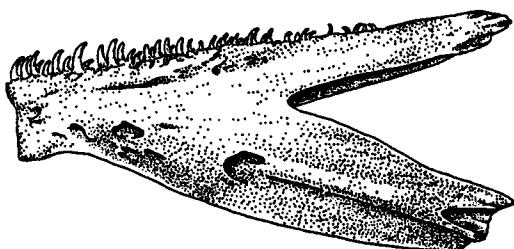
..... 12

12a (11a) Large, deep fossa on lateral surface of dentary body just below tooth row.

..... 13

12b (11b) Lateral surface of dentary body below tooth row lacking a large fossa, though there may be small lacunae. Teeth caniniform when present.

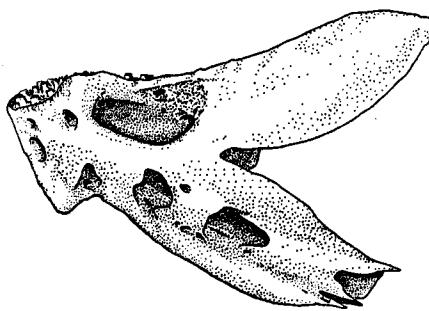
..... *Micropterus dolomieu*, *M. salmoides*.



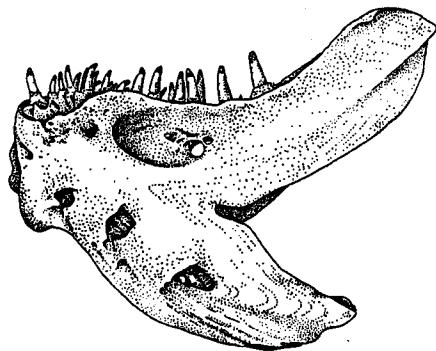
*Micropterus dolomieu* FL = 148mm  
Left dentary, lateral view

13a(12a) Mandibular symphysis very broad. Dentary short, stout. Teeth conical to caniniform, may be tipped with black.

..... *Lepomis gibbosus*, *L. macrochirus*.



*Lepomis gibbosus* FL = 175mm  
Left dentary, mesial view



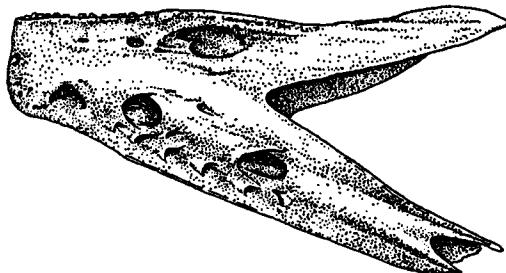
*Lepomis macrochirus* FL = 131mm  
Left dentary, lateral view

13b(12a) Mandibular symphysis narrow.

..... 14

14a (13b) Sulcus delineating ventrolateral border of sensory canal marked by small lunate foramina. Teeth small, conical, often missing.

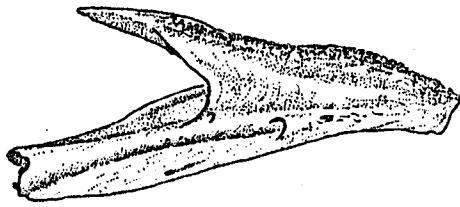
..... *Pomoxis spp.*



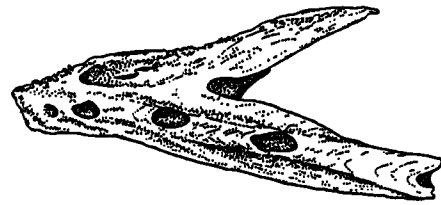
*Pomoxis annularis* FL = 104mm  
Left dentary, lateral view

14b(13b) Sulcus delineating ventrolateral border of sensory canal smooth, without foramina.

..... *Perca flavescens*



*Perca flavescens* FL = 85mm  
Left dentary, mesial view



*Perca flavescens* FL = 85mm  
Left dentary, lateral view

15a (5b) Sensory canal entirely absent.

.....16

15b (5b) Sensory canal present.

.....17

16a (15a) Ventral limb large, flat and descending. Coronoid limb low, rounded and separated by a very shallow mecklian notch. Large mental foramen patent in anterior view. (Caution: this bone may be perceived as upside down due to its unusual shape.)

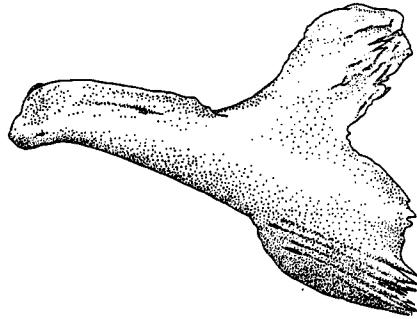
.....*Catostomus catostomus, C. columbianus, C. macrocheilus*



*Catostomus macrocheilus* FL = 200mm  
Right dentary, lateral view

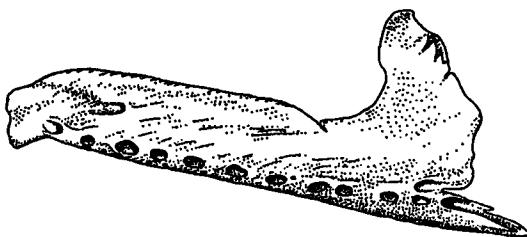
16b (15a) Ventral limb crossed by furrows running in a direction parallel with the ventral edge of the body of the dentary, terminating caudad between denticulate limbs. Coronoid limb high and distinct with a rough posterior surface and margin.

.....*Tinca tinca*



*Tinca tinca* FL = 209mm  
Left dentary, lateral view

17a (15b) Sensory pores number nine or more. Dentary body long with a small ventral limb.  
.....*Ptychocheilus oregonensis*

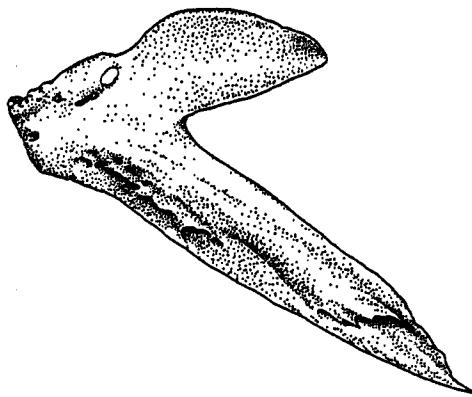


*Ptychocheilus oregonensis* FL = 126mm  
Left dentary, lateral view

17b (15b) Sensory pores fewer than nine.  
.....18

18a (17b) Length from tip of coronoid limb to apex of mecklian notch slightly greater than the length between the mecklian notch and mandibular symphysis and less than one half the length from the mecklian notch to the tip of the pointed ventral limb. A foramen often located just below the dorsal margin of the body of the dentary.  
.....

*Prosopium williamsoni*



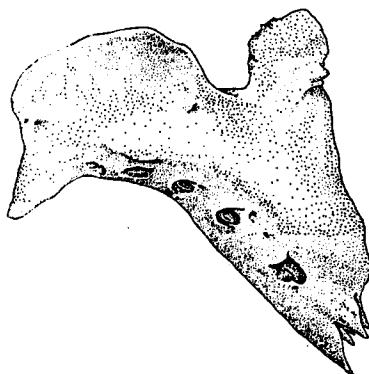
*Prosopium williamsoni* FL = 83mm  
Left dentary, lateral view

18b (17b) Distance from mandibular symphysis to mecklian notch much greater than that from mecklian notch to the tip of the coronoid limb.

..... 19

19a (18b) Dentary body short, stout, curving mesiad at an angle of approximately 90 degrees, with a broad mandibular symphysis. Curvature most pronouncedly angular on anterolateral - dorsal "lip." Coronoid limb short and angled slightly forward. Sensory pores four to six. Mental foramen patent in ventrolateral view under lip.

..... *Acrocheilus alutaceus*



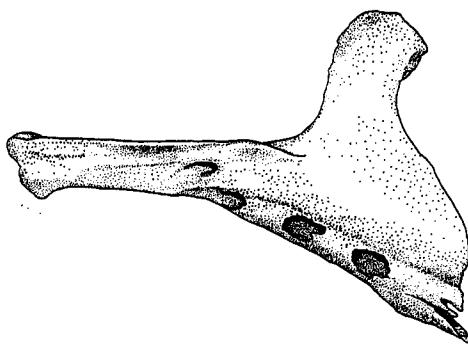
*Acrocheilus alutaceus* FL = 156mm  
Left dentary, lateral view

19b (18b) Curvature of dentary body not as pronounced as in 18a. Dentary body lacks angular "lip."

..... 20

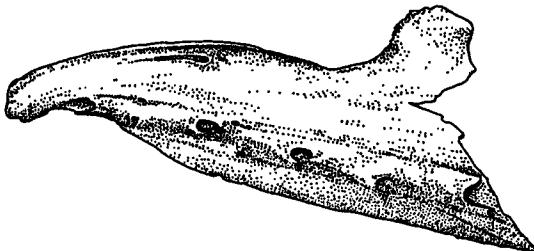
20a (19b) Dentary body long and narrow, largely without a sensory canal. Length from center of anterior sensory pore to tip of ventral limb less than or equal to 1.25 the length from the center of the anterior pore to the mandibular symphysis.

..... *Rhinichthys cataractae*



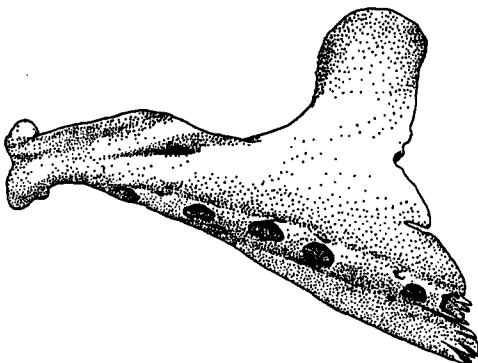
*Rhinichthys cataractae* FL = 93mm  
Left dentary, lateral view

- 20b (19b) Dentary body not long and narrow. Ratio defined in 19a much greater than 1.25.  
..... 21
- 21a (20b) Dentary body broad, tapering to a narrow mandibular symphysis. Length of perpendicular from ventral margin of dentary body to convergence of coronoid limb and dorsolateral margin (lip) of dentary body equal to, or greater than three times the length of the mandibular symphysis. Coronoid limb relatively small.  
..... *Richardsonius balteatus*



*Richardsonius balteatus* FL = 98mm  
Left dentary, lateral view

- 21b (20b) Ratio of lengths described in 20a much less than three.  
..... 22
- 22a (21b) Lateral surface of coronoid limb smooth, lacking folds, grooves or lamellae.  
..... *Mylocheilus caurinus*



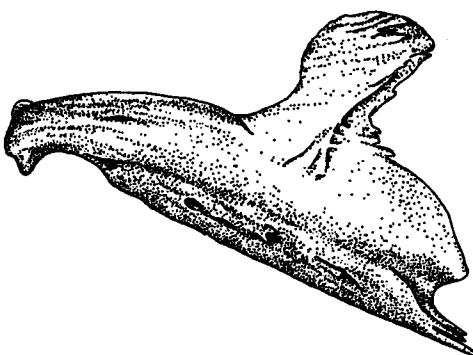
*Mylocheilus caurinus* FL = 280mm  
Left dentary, lateral view

22b (21b) Lateral surface of coronoid limb marked by one or more folds, forming narrow furrows opening caudad and laterad.

.....23

23a (22b) Folds on lateral surface of coronoid limb restricted to dorsal and posterior portions of limb.  
Mental foramen and sensory pores small.

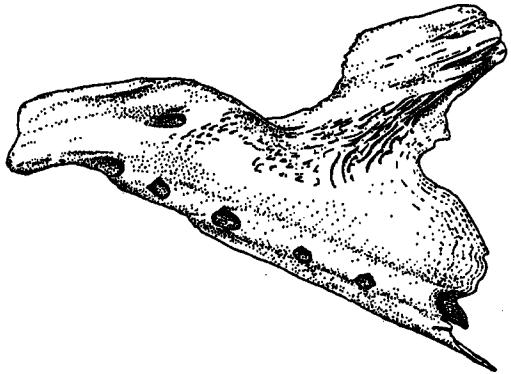
.....*Carassius auratus*



*Carassius auratus* FL = 207mm  
Left dentary, lateral view

23b (22b) Folds lamellate, and extending from lateral surface of coronoid limb ventrally onto dorsal half of dentary body, where they tend to become broken to form lacunae rather than furrows.  
Mental foramen and sensory pores larger than those of *Carassius auratus*.

.....*Cyprinus carpio*



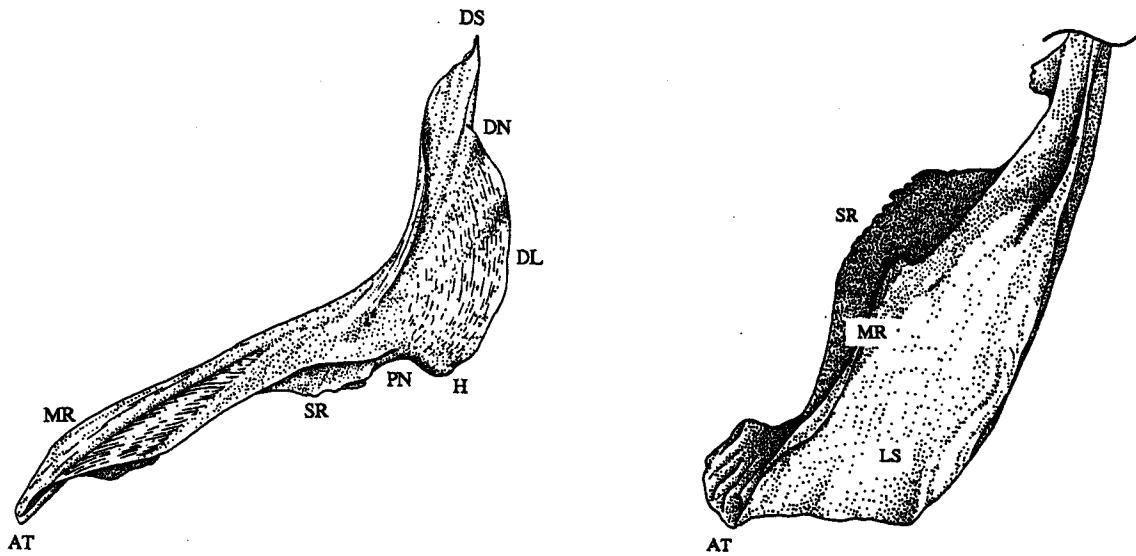
*Cyprinus carpio* FL = 125mm  
Left dentary, lateral view

### Key to cleithra

The cleithra (sing. cleithrum) are paired bones forming part of the pectoral girdle which in turn forms the frame of the body wall behind the branchial cavity and supports the pectoral fins. The cleithra articulate dorsad with the supercleithra and ventrad with the scapulae and coracoids. (Rojo, 1991). The anterior tips of the cleithra meet mesiad under the heart. From the anterior tips they angle caudad and outward, then curve or angle upward to meet the supercleithra. The right cleithrum in many fish thus resembles an upper case L rocking to the right. The cleithra form the main part of the bony surface against which the caudal margins of the operculae close.

The nomenclature used here to describe cleithra is adapted from several sources. There is no agreed-upon terminology, each author having worked out a solution suitable for the taxa and function appropriate to their own work. (Silverberg, 1991; Hansel et al., 1988; Harrison and Hadley, 1979; Casselman, 1974; Hubbs et al., 1974; Uyeno and Miller, 1965).

Terms used to describe cleithra in this key include the following: anterior tip, dorsoposterior lobe, dorsoposterior spine, heel, horizontal limb, lateral ridge, lateral shelf, lateral sulcus, posteroventral notch, scapulocoracular ridge, vertical limb. Views are of left lateral sides of left cleithra unless otherwise specified.



Lateral view

Dorsal view

Lateral (*Pomoxis annularis*, entire) and dorsal (*Acrocheilus alutaceus*, horizontal limb only) views of left cleithra.

AT, anterior tip; DN, dorsal notch; DS, dorsal spine; DL, dorsoposterior lobe; H, heel; LR, lateral ridge; LS, lateral shelf; MR, medial rib; PN, posteroventral notch; SR, scapulocoracular ridge.

- 1a      Vertical limb distinctly bifurcated/forked with dorsal spine flanked on mesial side with an additional spatulate, blunt-ended, process. Curved ridge on lateral shelf creates a crescent shaped, ventrally concave groove or pocket.

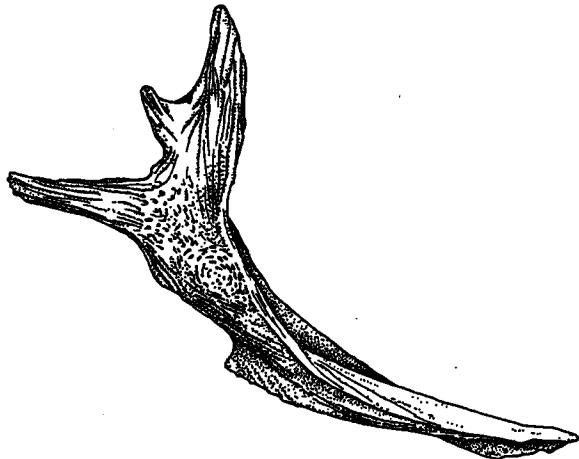
.....*Cottus spp.*



*Cottus sp.* FL = 88mm  
Right cleithrum, lateral view

*Cottus sp.* FL = 88mm  
Right cleithrum, mesial view

- 1b      Vertical limb variously shaped, but not forked into two distinct processes. .... 2
- 2a (1b)    Vertical limb distinctly trifurcated into three pointed spines in which the dorsal spine is bifurcated and the dorsoposterior lobe is drawn into a dorsoposterior spine. .... *Ictalurus spp.*



*Ictalurus punctatus* FL = 149mm  
Right cleithrum, lateral view

Posteroventral notch robust to receive pectoral spine. For a means of distinguishing *Ictalurus* by spines see Paloumpis (1963) and Taylor (1969).

- 2b      Vertical limb not trifurcated into three spines. .... 3
- 3a (2b)    Horizontal limb terminates in three projections of which the central one is longest. .... *Catostomus spp.*



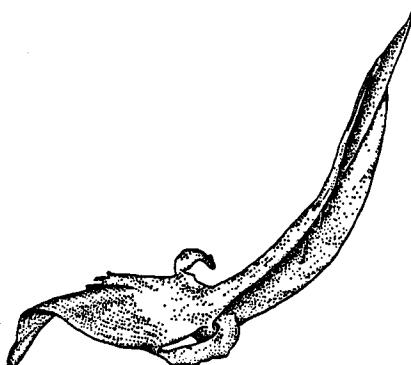
*Catostomus macrocheilus* FL = 200mm  
Left cleithrum, lateral view

Lateral shelf broad and anterodorsally concave with a variously cancellous central surface.

- 3b (2b)    Horizontal limb does not terminate in three projections. .... 4

- 4a (3b) Terminus of horizontal limb folded mesially and ventrally, leaving the anterior tip pointed in a direction directly opposite that of the dorsal spine. Also, a flat, sickle shaped process angled mesiad, dorsad and caudad located on the mesial edge of the lateral shelf near the anterior arch.

.....*Alosa sapidissima*



*Alosa sapidissima* FL = 80mm  
Left cleithrum, lateral view

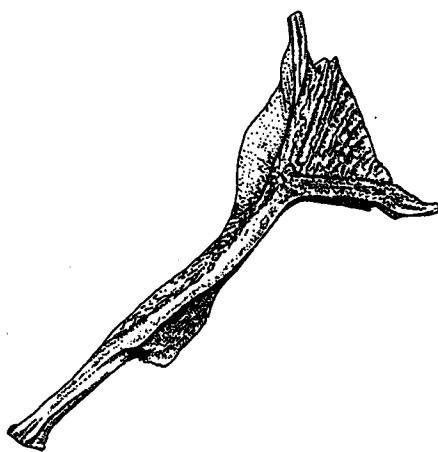
Vertical limb long, with a deep lateral sulcus. Bone overall fragile and thin. Bone in sulcus, and in older fish on lateral shelf, cancellous.

- 4b (3b) Terminus of horizontal limb not folded, no process on mesial edge of lateral shelf.

.....5

- 5a (4b) Dorsoposterior lobe distinctly triangular, very coarsely wrinkled, with a thickened ventral margin extending into a dorsoposterior spine which is slightly curved upward.

.....*Gasterosteus aculeatus*



*Gasterosteus aculeatus* FL = 53mm  
Left cleithrum, lateral view

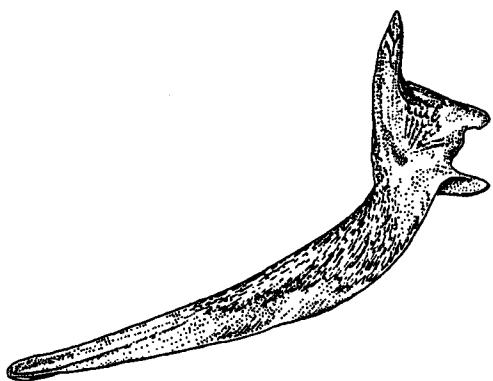
Thickened margin of dorsoposterior lobe and spine minutely knobbed or spiculate under magnification. Bone clear and almost glasslike.

- 5b (4b) Dorsoposterior lobe not distinctly triangular, coarsely wrinkled, with a thickened ventral margin.

.....6

- 6a (5b) Horizontal limb long, narrow and evenly tapered for most of its length. Distance from anterior tip of horizontal limb to apex of angle formed by anterior margins of horizontal and vertical limbs equal to or greater than 1.9 times distance from apex of angle to end of dorsal spine.

.....*Lota lota*



*Lota lota* TL = 193mm  
Left cleithrum, lateral view

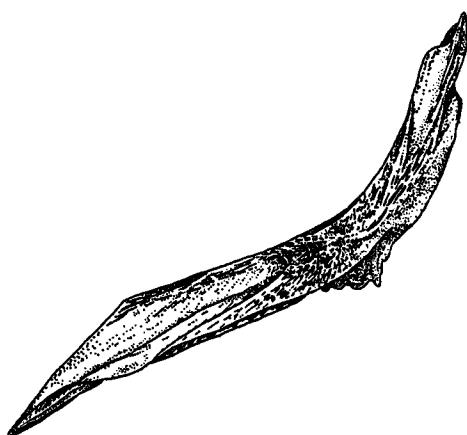
Ventral edge of tab shaped heel runs underneath lateral edge of lateral shelf.

- 6b (5b) Horizontal limb as measured in 6a less than 1.9 times length of vertical limb.

.....7

- 7a (6b) Dorsoposterior lobe narrow. Width from anterior to posterior margins of vertical limb nowhere greater than maximum width between margins of horizontal limb. (Scapulocoracular ridge not included here.)

.....*Platichthys stellatus*



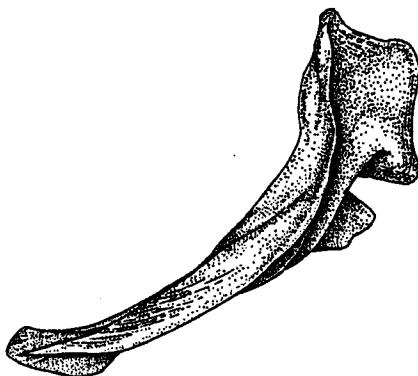
*Platichthys stellatus* TL = 210mm  
Left cleithrum, lateral view

Cleithrum overall narrow. Horizontal limb lanceolate with a simple, acutely pointed tip.

- 7b (6b) Width of vertical limb greater than that of horizontal limb.

.....8

- 8a (7b) Dorsal spine short, blunt, lobular rather than sharp or spine-like. .... 9
- 8b (7b) Dorsal spine a pointed, usually sharp projection, not short or rounded. .... 10
- 9a (8a) A prominent lateral ridge merges directly, and is continuous with margin of lateral shelf. Dorsoposterior lobe expanded into a distinct heel. .... *Gambusia affinis*

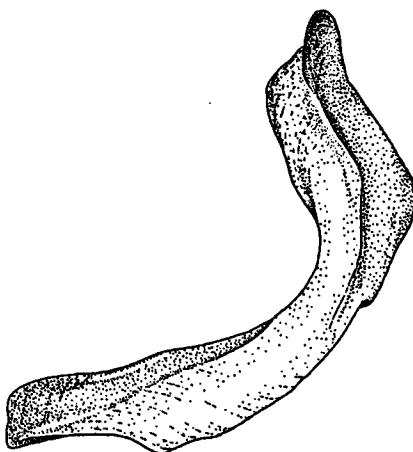


*Gambusia affinis* TL = 45mm  
Left cleithrum, lateral view

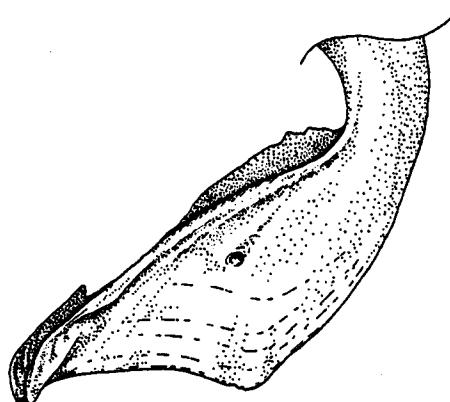
Cleithrum always very small commensurate with size of fish. Horizontal limb longer than vertical limb. Bone clear, vitreous.

- 9b (8a) Lateral ridge does not merge directly with margin of lateral shelf. Dorsoposterior lobe not expanded into a distinct heel.

..... *Rhinichthys spp.*



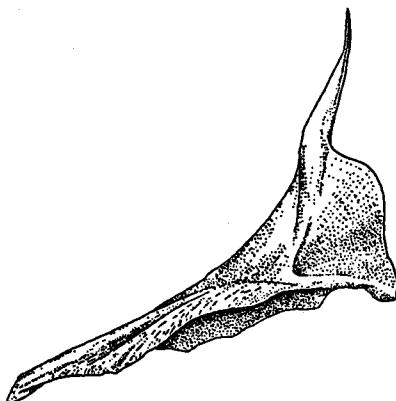
*Rhinichthys cataractae* FL = 93mm  
Left cleithrum, lateral view



*Rhinichthys cataractae* FL = 93mm  
Left cleithrum, dorsal view

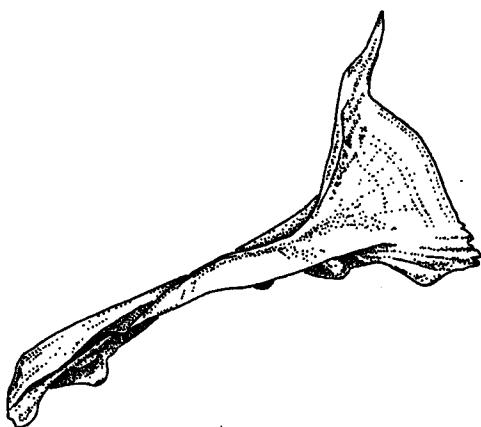
Vertical and horizontal limbs roughly equal in length and smoothly rounded at their juncture.  
Compare with other cyprinids below.

- 10a (8b) Dorsoposterior lobe extended to form a caudally projecting angular heel, with the heel thus extending further caudad than any other part of the posterior lobe or any other part of the cleithrum. .... 11
- 10b (8b) Dorsoposterior lobe not extended to form a caudally projecting angular heel, with the heel thus lying in a plane cephalad of at least some of the rest of the dorsoposterior lobe; or the dorsoposterior lobe does not form a heel. .... 13
- 11a (10a) Posterodorsal notch deep. Dorsal spine long: tip of dorsal spine to dorsal notch  $0.6x$  to  $0.8x$  distance from dorsal notch to heel ..... *Percopsis transmontana*



*Percopsis transmontana* FL = 77mm  
Left cleithrum, lateral view

- Dorsal spine a long tapered rod, continuing a prominent lateral ridge.
- 11b (10a) Posterodorsal notch relatively shallow. Dorsal spine shorter than described in 11a. .... 12
- 12a (11b) Anterior margin of dorsal spine distinctly concave. Heel serrate. .... *Perca flavescens*

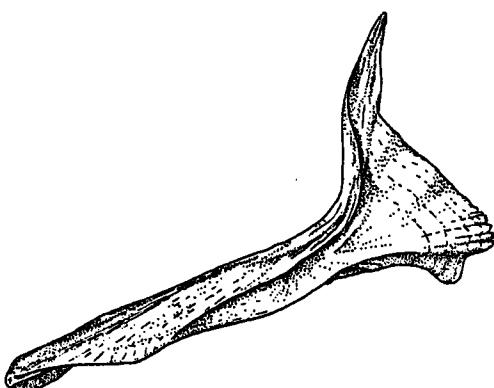


*Perca flavescens* FL = 85mm  
Left cleithrum, lateral view

Concavity on anterior margin of spine makes it appear horn-like, bent up and slightly forward.  
Heel descends below a line marking the axis of the horizontal limb.

12b (11b) Anterior margin of dorsal spine not distinctly concave. Heel may or may not be serrate.

.....*Stizostedion vitreum*



*Stizostedion vitreum* FL = 189mm  
Left cleithrum, lateral view

Dorsoposterior lobe may have a variously curved or straight dorsoposterior margin.

13a (10b) Cleithrum overall crescent-shaped. Medial rib expanded and flattened to form a broad wing along horizontal limb and extending up anterior third or more of vertical limb. Dorsoposterior lobe and anterior shelf both broadened and meet each other seamlessly to form a continuous lateral surface. Dorsal spine thin, rod-like. (Salmonidae)

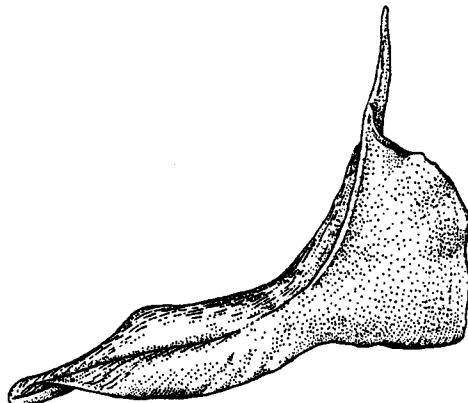
.....14

13b (10b) Cleithrum not crescent shaped. Medial rib not broadened and flattened. Lateral surface not continuous.

.....15

- 14a (13a) Dorsoposterior lobe very broad and fan-like, forming a distinct notch or arch where it meets the lateral shelf.

.....*Prosopium williamsoni*

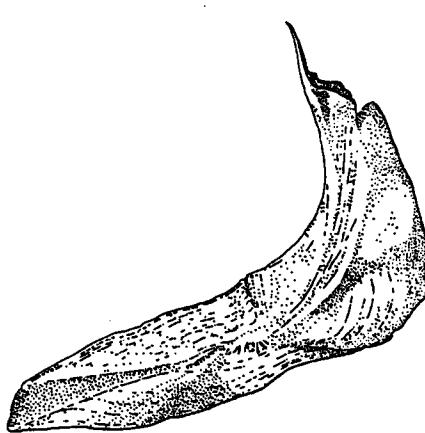


*Prosopium williamsoni* FL = 83mm  
Left cleithrum, lateral view

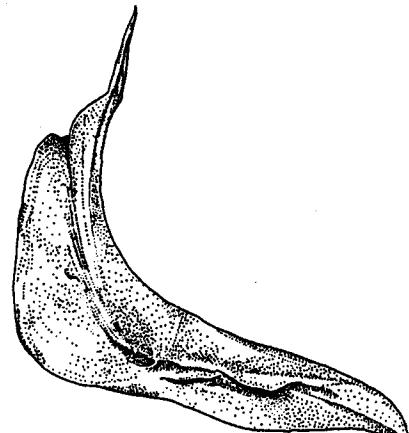
Lateral shelf rolled or creased between central and lateral surfaces.

- 14b (13a) Cleithrum resembles a twisted bay leaf. Dorsoposterior lobe not expanded to as great a degree as *Prosopium*. No notch or arch where dorsoposterior lobe and lateral shelf meet..

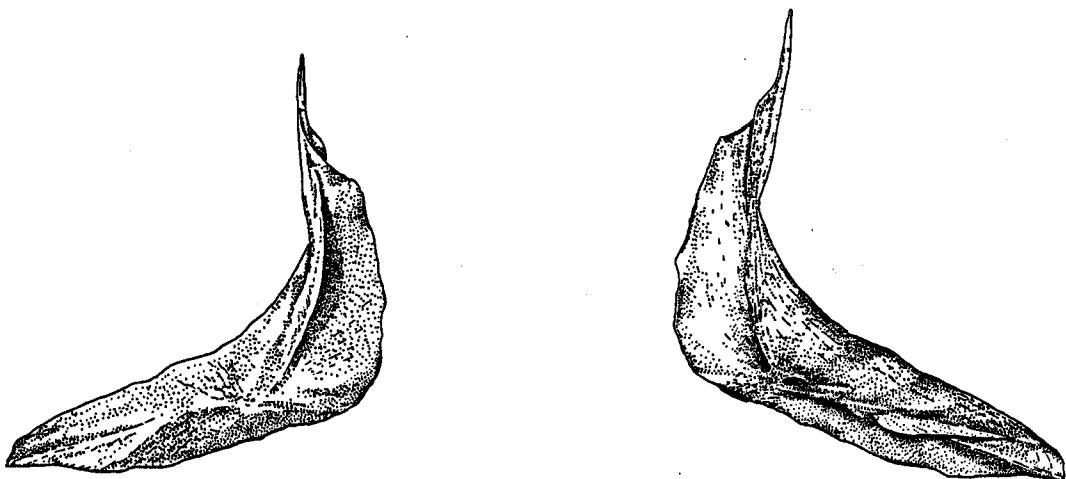
.....*Oncorhynchus* spp.



*Oncorhynchus mykiss* FL = 116mm  
Left cleithrum, lateral view



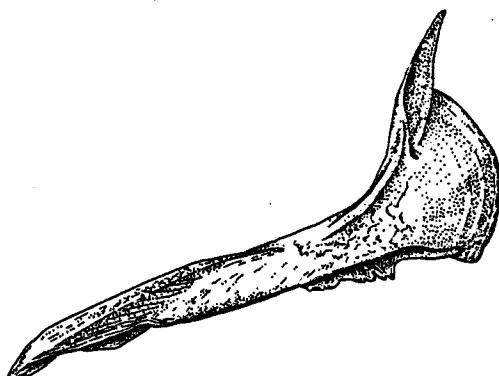
*Oncorhynchus mykiss* FL = 116mm  
Left cleithrum, mesial view



*Oncorhynchus kisutch* FL = 115mm  
Left cleithrum lateral view

*Oncorhynchus kisutch* FL = 115mm  
Left cleithrum, mesial view

- 15a (13b) Angle of vertical and horizontal limbs much greater than  $90^\circ$ . Horizontal limb longer than vertical limb, and anterior edge of lateral shelf not broadened. (Centrarchidae) ..... 16
- 15b (13b) Angle of vertical and horizontal limbs approximately  $90^\circ$  or slightly greater. Vertical limb as long or slightly longer than horizontal limb. Lateral shelf wide and bordered on mesial side by a ridge formed from the medial rib. In the context of Cyprinidae, Hubbs aptly calls what is here called the medial rib, a keel. Anterior edge of lateral shelf broadened. (Cyprinidae) ..... 18
- 16a (15a) Length of horizontal limb (anterior tip to heel) greater than 2x distance between dorsal notch and posteroventral notch. Dorsoposterior lobe broadly rounded, distinctly fan shaped. ..... *Micropterus* spp.



*Micropterus dolomieu* FL = 150mm  
Left cleithrum, lateral view

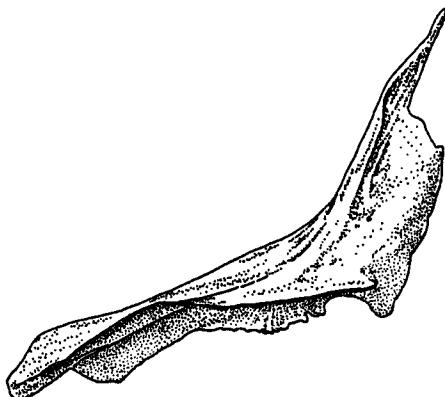
Dorsal spine narrow compared to *Pomoxis*.

16b (15a) Length of horizontal limb (anterior tip to heel) 2x or less than distance between dorsal notch and posteroventral notch. Dorsoposterior lobe usually not clearly fan shaped.

.....17

17a (16b) Margin of medial rib rises from tip at a steep angle then angles, does not gently curve, back at approximately  $135^{\circ}$  towards axis of horizontal limb.

.....*Lepomis spp.*

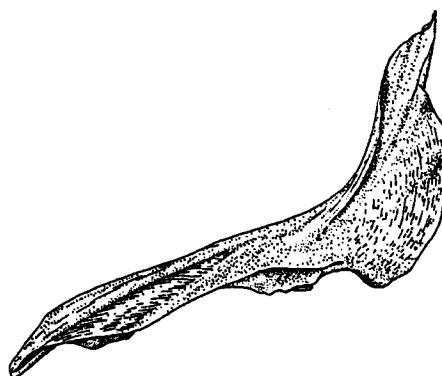


*Lepomis gibbosus* FL = 131mm  
Left cleithrum, lateral view

Dorsal spine narrow compared to *Pomoxis*. Dorsoposterior lobe least fan-like of the centrarchids.

17b (16b) Margin of medial rib rises from tip at a shallow angle then curves gently towards axis of horizontal limb. Dorsal spine relatively broad.

.....*Pomoxis spp.*



*Pomoxis annularis* FL = 104mm  
Left cleithrum, lateral view

(Note: The cleithra of the following cyprinid fish are illustrated in lateral (entire) and dorsal (horizontal limb) views. In the lateral views the cleithra are lying on their mesial sides with the anterior

tips, dorsal spines, and heels or scapulocoracular ridges touching the surface. Foramina in the lateral shelf and the scapulocoracular ridge as depicted in some of the illustrations may or may not be present.)

- 18a (15b) Dorsal view: Anterior tip projecting as a process well beyond insertion of lateral shelf into medial rib. Anterior shelf strongly convex upward and deeply indented.

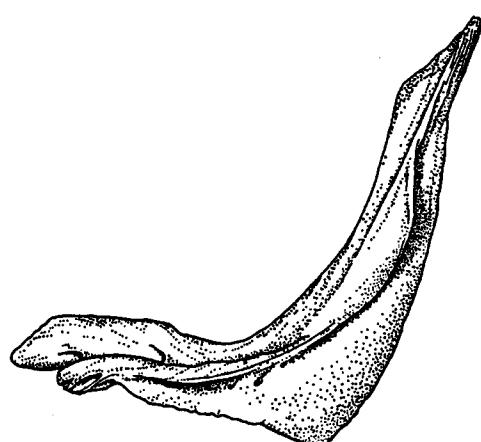
.....19

- 18b (15b) Dorsal view: Anterior tip projecting only very shortly or not at all beyond insertion of lateral shelf into medial rib. Lateral shelf not strongly convex upward and not deeply indented.

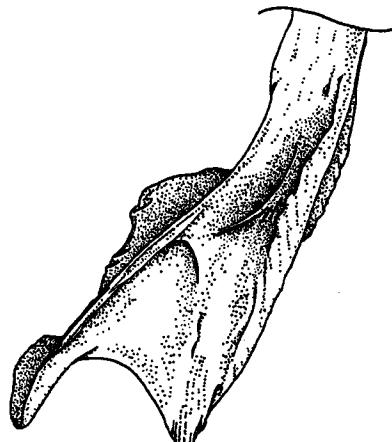
.....20

- 19a (18a) Dorsal view: Scapulocoracular ridge clearly visible halfway along medial rib.

*Tinca tinca*



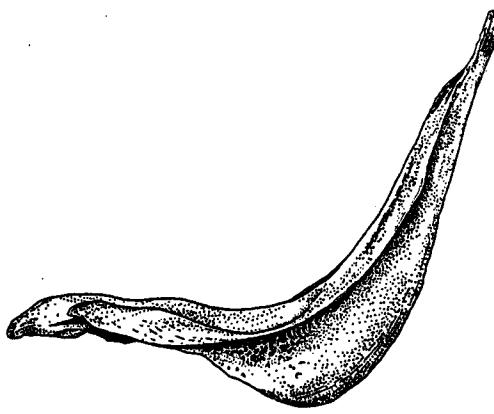
*Tinca tinca* FL = 185mm  
Left cleithrum, lateral view



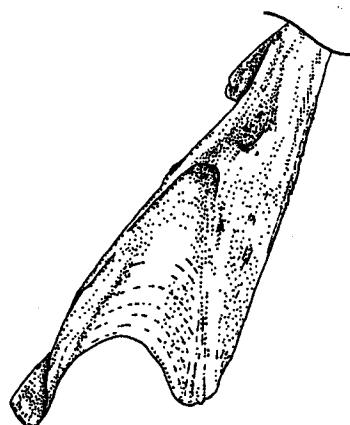
*Tinca tinca* FL = 185mm  
Left cleithrum, dorsal view

- 19b (18a) Dorsal view: Scapulocoracular ridge only slightly visible, if at all; otherwise concealed by medial rib.

.....*Cyprinus carpio, Carassius auratus*

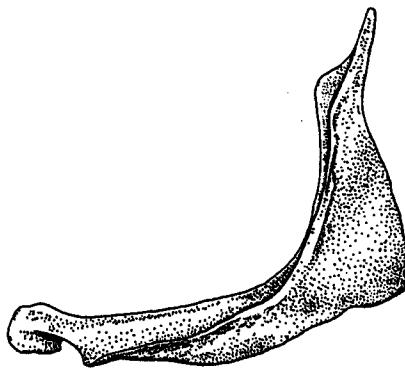


*Cyprinus carpio* FL = 125mm  
Left cleithrum, lateral view

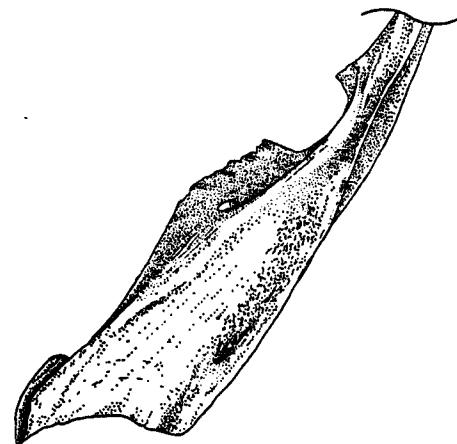


*Cyprinus carpio* FL = 125mm  
Left cleithrum, dorsal view

- 20a (18b) Dorsal view: Angle between medial rib and anterior margin of anterior shelf acute. .... 21
- 20b (18b) Dorsal view: Angle between medial rib and anterior margin of anterior shelf not obviously an acute angle. .... 22
- 21a (20a) Lateral view: Medial rib conspicuously humped at anterior tip anterior to corner of lateral shelf where lateral ridge and sulcus terminate. Juncture of lateral shelf with medial rib clearly visible, as junctional angle is obtuse and lateral shelf is not trenched adjacent to juncture. .... *Ptychocheilus oregonensis*



*Ptychocheilus oregonensis* FL = 126mm  
Left cleithrum, lateral view



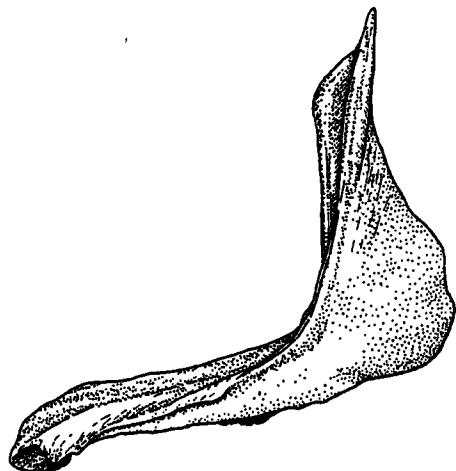
*Ptychocheilus oregonensis* FL = 178mm  
Left cleithrum, dorsal view

- 21b (20a) Lateral view: Medial rib at anterior tip not humped as described in 22a. Medial rib straight or very shallowly convex upward past corner of lateral shelf. Juncture of medial rib and lateral

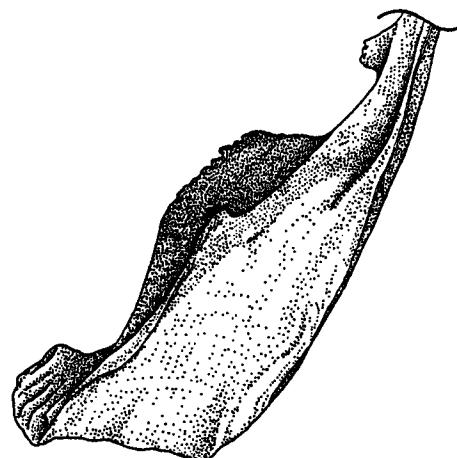
shelf not visible, as lateral shelf is nearly perpendicular to viewer and is trenched adjacent to medial rib.

Dorsal view: Medial rib midway bears a process that varies from a mere thickening to a hooked flange. The latter, if present, is diagnostic.

.....*Acrocheilus alutaceus*



*Acrocheilus alutaceus* FL = 160mm  
Left cleithrum, lateral view

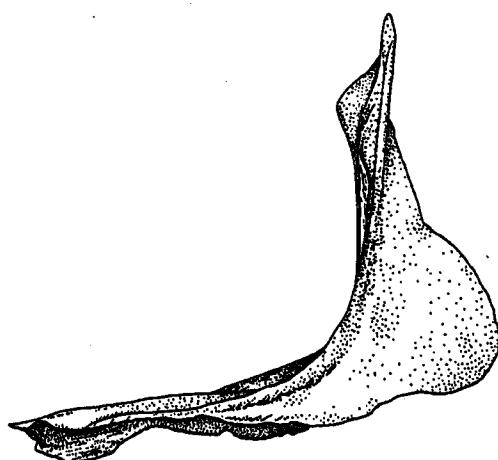


*Acrocheilus alutaceus* FL = 160mm  
Left cleithrum, dorsal view

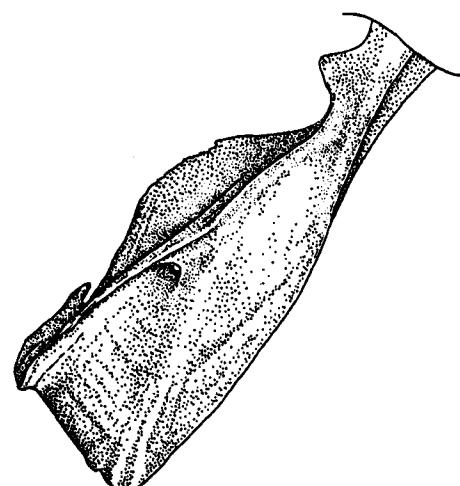
22a (20b) Lateral view: Opercular surface of lateral shelf is tipped mesiad, making the ventral surface of the anterior margin of the lateral shelf clearly visible.

Dorsal view: Anterior and lateral margins of anterior shelf meet each other at roughly right angles with a distinct corner. A convex ridge crosses the opercular surface from the corner to mid-medial rib with varying concavity to either side.

.....*Mylocheilus caurinus*



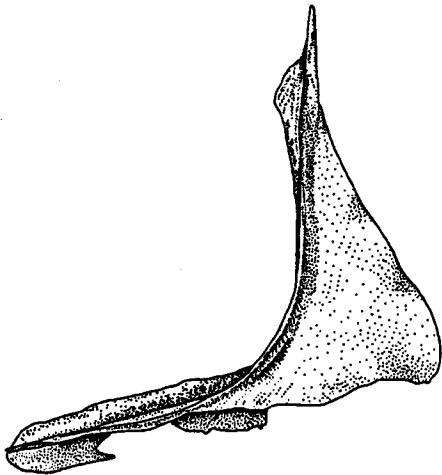
*Mylocheilus caurinus* FL = 179mm  
Left cleithrum, lateral view



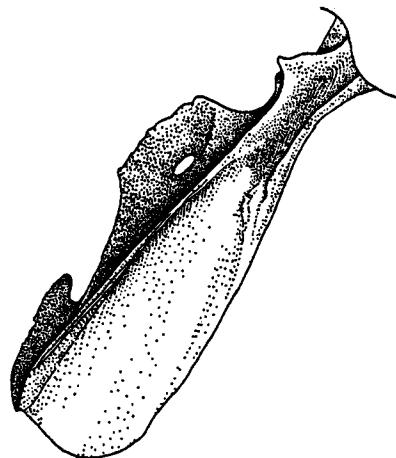
*Mylocheilus caurinus* FL = 134mm  
Left cleithrum, dorsal view

- 22b (20b) Lateral view: Anterior shelf is nearly perpendicular to plane on which cleithrum lies, obviating a clear, or any, view of the ventral surface of the anterior margin of the lateral shelf.  
 Dorsal view: Anterior and lateral margins of anterior shelf meet one another in a rounded corner or a broad curve. Opercular surface essentially flat.

.....*Richardsonius balteatus*



*Richardsonius balteatus* FL = 98mm  
 Left cleithrum, lateral view



*Richardsonius balteatus* FL = 98mm  
 Left cleithrum, dorsal view

### Key to Pharyngeal arches

Pharyngeal arches are modified fifth gill arches bearing teeth which vary from fine, comb-like structures in catostomids to coarse grinding plates or sharp, hooked teeth in cyprinids. The pharyngeal teeth assume some of the ordinary functions of teeth in fish whose jaws are toothless. The arrangement and number of pharyngeal teeth and the shape of the arch itself is diagnostic in many cyprinids, though variation exists in the number of teeth in some species. (Eastman and Underhill, 1973). Pharyngeal arches may be used to identify cyprinids from the Columbia River to genus and/or species and to distinguish catostomids from other fish.

To visualize the position of the arches within the fish one must realize that the teeth grind or bite upwards and forwards against a tough chewing pad on the basioccipital bone at the bottom of the skull. The teeth lie within the lumen of the esophagus, while the arches themselves surround the lumen on the ventral and lateral sides of the esophagus. As the pharyngeal arches are derived from gill arches, their

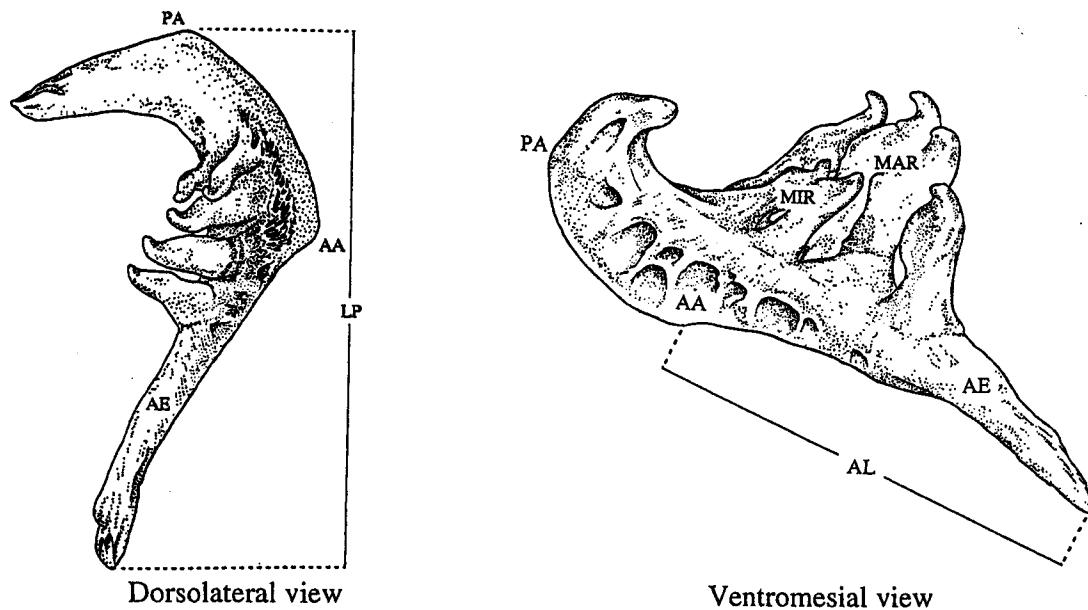
position and orientation remain the same as ordinary gill arches. These bones resemble a pair of left and right handed sickles, joined at the ends of the handles, tipped back, blades facing one another, with teeth arrayed on the sharp sides of the blades. The pharyngeals meet ventrally as gill arches do, curving back, out, then up and back mesiad. The anterior limbs of the pharyngeal arches point forward under the throat. The tips of the anterior limbs have a roughened area on the mesial sides where they articulate with one another. The teeth are born on the dorsomesial part of the arches where they bend around the esophagus. The posterior limbs of the pharyngeal arches bow dorsad and curve partly around the esophagus, bending finally cephalad. The posterior limbs do not articulate with each other, but pivot against the base of the skull in separate saggital planes.

In native cyprinids teeth are arranged in one or two (major and minor) rows on each arch. If one holds a pair of pharyngeal arches in the position they are in in the living fish, one sees that the teeth of the major tooth rows are arrayed in two parallel series. Minor tooth rows, if present, are positioned laterally and dorsally with respect to the major tooth row, that is, major rows are mesial and the minor rows are lateral. The introduced carp has three rows of teeth, with the two minor rows on this fish consisting of one tooth apiece. In the cyprinids considered here the major (greater or primary teeth) row of each arch usually has four or five teeth. The minor (lesser or secondary teeth) row, when present, has one or two smaller teeth. The formula is expressed in terms of half formulae for the left, then the right arch with the number of teeth in the minor arches expressed first and last, and the number of teeth in the major rows expressed in between. A formula of 2,5-4,2 means that there are two teeth apiece in the minor rows on either side, while the major teeth number five on the left and four on the right. The most common tooth formulas are listed in the key. Since teeth may be broken or missing in disarticulated specimens, corresponding alveoli may be used to help determine tooth counts. The central portion of an arch should be examined carefully for evidence of broken or lost teeth. A well defined pit adjacent to other teeth, or the broken base of a tooth, constitutes evidence of a lost tooth and should be included in the count.

All figures are of the ventromesial view of the left pharyngeal bone unless otherwise stated. These bones have more or less flat dorsolateral sides and were drawn as they lay on that side with the teeth

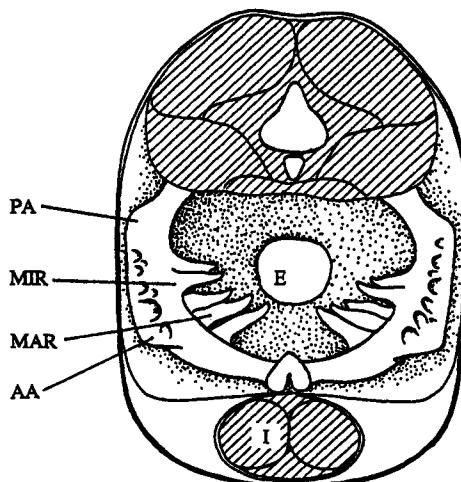
pointing up. The “flat” dorsolateral side is more hollow than solid, as it is composed mostly of trabeculae and struts. The terminology and nomenclature is largely adapted from Uyeno (1961).

Terms used to describe pharyngeal arches in this key include the following: anterior angle of pharyngeal arch, anterior edentulous process, anterior limb of pharyngeal arch, length of pharyngeal arch, major tooth row, minor tooth row, posterior angle of pharyngeal arch, posterior limb of pharyngeal arch, width of pharyngeal arch.



Dorsolateral view of left pharyngeal arch of *Ptychocheilus oregonensis* and ventromesial view of right pharyngeal arch of *Rhinichthys cataractae*.

AA, anterior angle; AE, anterior edentulous; AL, anterior limb; LP, length of pharyngeal arch; MAR, major tooth row; MIR, minor tooth row; PA, posterior angle.



Anterior aspect of pharyngeal arches of *Ptychocheilus*, cross section behind last gill arch with musculature and other soft tissue removed. Adapted from Bond (1979).

AA, anterior angle; E, esophagus; I, sectioned isthmus; MAR, major tooth row; MIR, minor tooth row; PA, Posterior angle.

- 1a Pharyngeal arch distinctly falcate with more than ten teeth set into a single comb-like row  
.....*Catostomus catostomus*, *C. columbianus*, *C. macrocheilus*

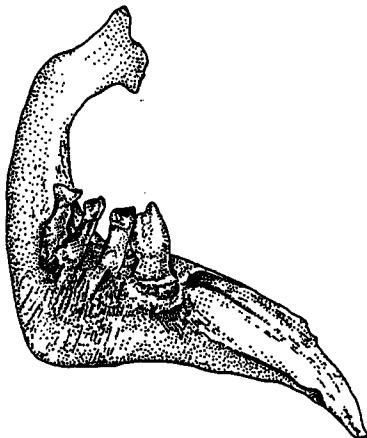


*Catostomus macrocheilus* FL = 200mm  
Left pharyngeal arch

*Catostomus columbianus* FL = 225mm  
Left pharyngeal arch

- 1b Pharyngeal arch variable, teeth fewer than ten and not set in a comb-like row. ....2  
2a (1b) Pharyngeal arch bears no secondary teeth. ....3

- 2b (1b) Pharyngeal arch with secondary teeth.  
.....5
- 3a (2a) Anterior edentulous process acuminate: broad at origin of tooth row and tapering to a sharp point at tip of anterior limb. Posterior limb broadened at tip with small dentiform process pointing antero-ventrally. Tooth formula 0, 4 - 4, 0. grinding surfaces of teeth flattened, but not as molariform, nor with furrows as in *Cyprinus carpio*.  
.....*Carassius auratus*



*Carassius auratus* FL = 104mm  
Right pharyngeal arch

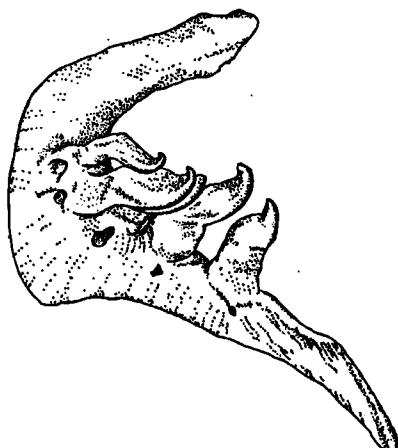
- 3b (2a) Anterior edentulous process not acuminate, not broad at origin of tooth row, not tapering to a sharp point.  
.....4
- 4a (3b) Posterior limb spatulate, flattened towards tip, teeth not hooked. Unworn teeth tend to be molariform. Posterior teeth cantilevered away from main body of pharyngeal arch. Few or no conspicuous foramina below bases of teeth as described below for *Acrocheilus*. Tooth formula 0, 5 - 4, 0 or 0, 5 - 5, 0.  
.....*Tinca tinca*



*Tinca tinca* FL = 201mm  
Left pharyngeal arch

- 4b (3b) Posterior limb not spatulate, not noticeably flattened toward tip. Conspicuous foramina below bases of teeth on lateral side (though may be fewer and smaller in juvenile fish). Teeth slightly hooked in older fish and more strongly so in juvenile fish. Tooth formula 0, 5 - 4, 0, occasionally 0, 5 - 5, 0.

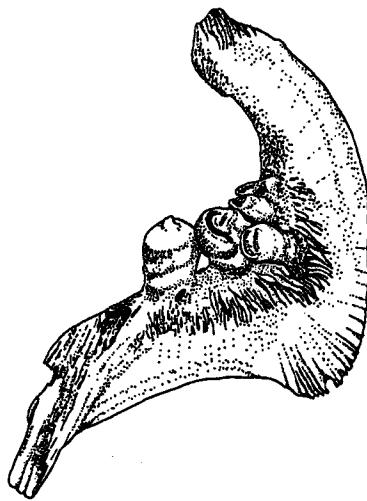
.....*Acrocheilus alutaceus*



*Acrocheilus alutaceus* FL = 106mm  
Right pharyngeal arch

- 5a (2b) Tooth formula 1, 1, 3 - 3, 1, 1. Minor teeth small and set in a series of two at right angles to main tooth row, thus making three rows. Anterior edentulous process acuminate, tapering from a very pronounced anterior angle to a pointed anterior tip. Teeth in major and first minor rows strongly molariform with furrowed grinding surfaces. Juvenile fish may have unfurrowed teeth as depicted in the figure.

.....*Cyprinus carpio*



*Cyprinus carpio* FL = 125mm  
Left pharyngeal arch

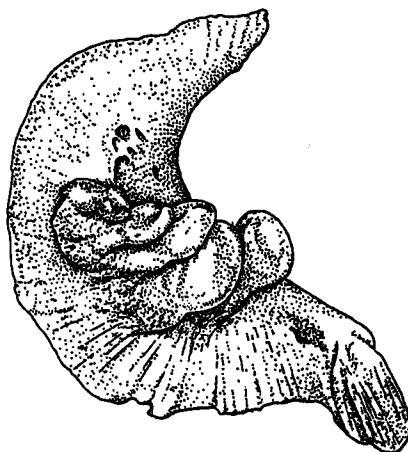
Anterior angle may be marked by shallow, narrow furrows running from the anterior angle to the base of major tooth row.

5b (2b) Tooth formula not 1, 1, 3 - 3, 1, 1

.....6

6a (5b) Pharyngeal arch very broad: length of anterior edentulous process less than width of pharyngeal arch between anterior angle and mesial edge of body of pharyngeal arch below tooth rows.  
Teeth hooked in very young fish. Grinding surfaces round and smooth on molariform teeth.  
Teeth in main row progress from hooked caudad to molariform cephalad. Minor teeth very small and peg like.

.....*Mylocheilus caurinus*



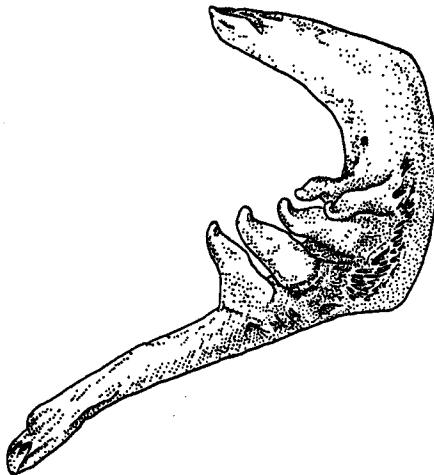
*Mylocheilus caurinus* FL = 179mm  
Right pharyngeal arch

6b (5b) Pharyngeal arch very narrow: length of anterior edentulous process greater than width of pharyngeal arch as described in *Mylocheilus*.

.....7

- 7a (6b) Length of pharyngeal arch ranges from 5.5 times to 7.0 times width. Teeth elongate, caniniform, and hooked at tip. Anterior and posterior angles approach 90 degrees making the posterior half of the arch distinctly rectangular. Tooth formula 2, 5 - 4, 2.

.....*Ptychocheilus oregonensis*



*Ptychocheilus oregonensis* FL = 178mm  
Left pharyngeal arch

Pharyngeal arch in figure missing one tooth from minor row.

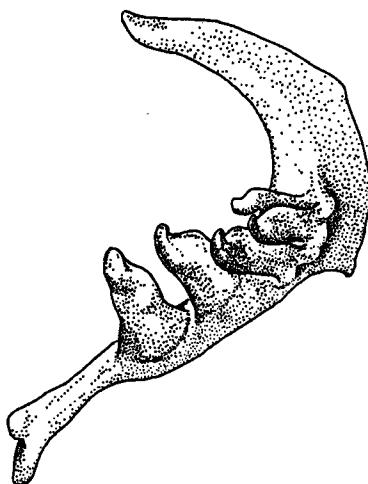
- 7b (6b) Length of pharyngeal arch less than 5.5 times to 7.0 times width.

.....8

- 8a (7b) Caveat: variability in the pharyngeal arches of *Rhinichthys spp.* and *Richardsonius balteatus* is such that identification based on pharyngeal arches alone must be considered uncertain. The anterior edentulous process is thin and short; often as short as, or shorter than, the length of major tooth row. Anterior edentulous process often necks down in ventromesial view to appear narrower than the base of the anteriormost major tooth. Tooth formula 2, 4 - 4, 2.

.....*Rhinichthys spp.*

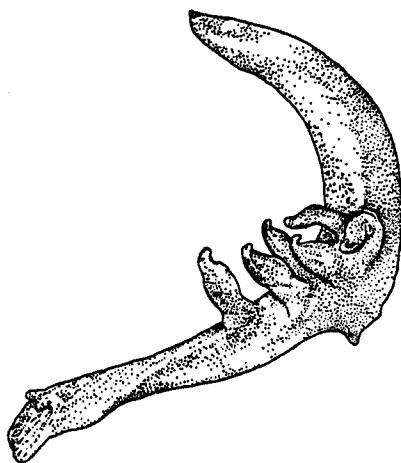
(See also diagram of ventromesial view of *Rhinichthys cataracta* pharyngeal arch in the introduction to pharyngeal arch key above.)



*Rhinichthys cataractae* FL = 93mm  
Left pharyngeal arch

- 8b (7b) (See caveat at 8a, above.) Anterior edentulous process longer and thicker than that described in 8a under *Rhinichthys*.

.....*Richardsonius balteatus*



*Richardsonius balteatus* FL = 98mm  
Left pharyngeal arch

## Acknowledgments

Funding for this work was provided through a series of contracts with the Bonneville Power Administration administered by Bill Maslen. Numerous employees of the U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and the U.S. Geological Survey assisted with sample collection and key development, which we appreciate. Specifically, Hal Hansel, Stephen Duke, Peter Lofy, Gerard Gray, Roger Tabor and Craig Burley assembled the original bone collection, determined the feasibility of various diagnostic bones, and produced a working key based on those bones. Abundant thanks are owed those people who endured the noisome task of picking through thousands of fish gut samples for the consumption index studies at Columbia River Research Lab and

who provided much of the material used to make this key. These last include, among others, R.D. Nelle, Sally Sauter, Mindi Sheer, and Dave Jepsen.

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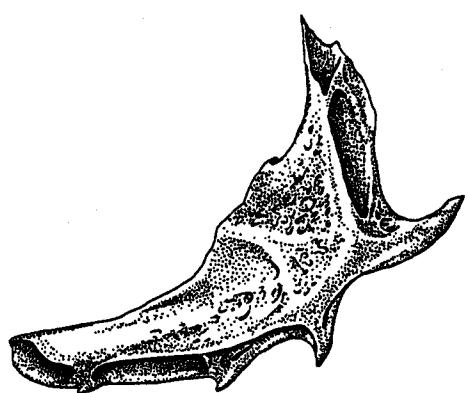
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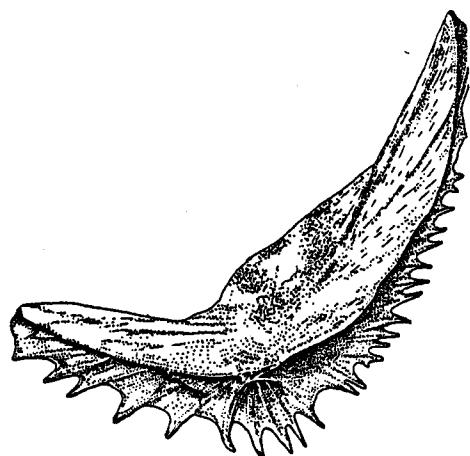
#### **Appendix 1: Supplemental figures**

Certain bones belonging to the fish considered in these keys are diagnostic, easily found and recognized, and may obviate toiling through the keys. Five such bones are illustrated here.

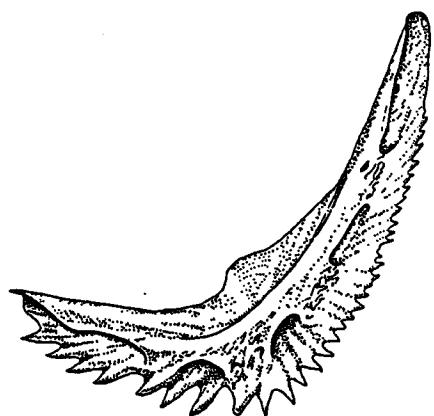
Dorsal spines from *Carassius* and *Cyprinus* may be a source of confusion if not properly identified. The spines tend to split down the middle and subsequently twist so that the two halves do not appear to have been joined. At first sight, the split spines logically and incorrectly suggest *Ictalurus* pectoral spines. Once recognized though, these half-spines readily identify goldfish and or carp.



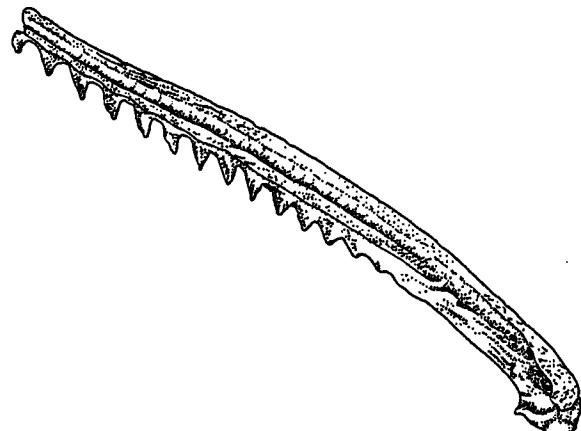
*Cottus sp.* FL = 115mm  
Left preopercal, lateral view



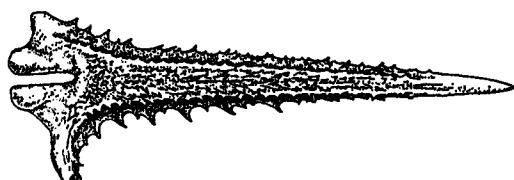
*Stizostedion vitreum*. FL = 130mm  
Left preopercal, lateral view



*Perca flavescens*. FL = 125mm  
Left preopercal, lateral view



*Cyprinus carpio*. FL = 125mm  
Mesial view of split dorsal spine.  
Tip is broken off.



*Gasterosteus aculeatus*. FL = 53mm  
Left pectoral spine, lateral view

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