Small-bodied and Juvenile Fishes of the Mid-Columbia Region

including keys to diagnostic otoliths and cranial bones

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Table of Contents

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Introduction

This guide is designed specifically for the identification of fish found in the guts of piscivorous predators of the Columbia River and its tributaries. As such, the guide focuses on small-bodied fish and juveniles up to 30 cm fork length. Diagnostic characteristics, as well as illustrated and photographed bones and otoliths, are reflective of this size range.

Twenty-nine species or species-groups are included (Table 1). Taxonomy follows Wydoski and Whitney (2003). Selection of fish species was based on gut content analysis of approximately 2400 avian predators taken from the Potholes Reservoir, and Rock Island Dam on the mid-Columbia River, including Caspian Terns (*Sterna caspia*), Common Mergansers (*Mergus merganser*), Double-crested Cormorants (*Phalacrocorax auritus*), and California and Ring-billed gulls (*Larus californicus*, and *L. delawarensis*).

Because fish are quickly digested, making intact specimens rare, the guide allows the user to identify species from whole or partial fish, as well as from diagnostic hard parts, including cranial bones and otoliths. Several studies have used fish remains to determine piscivorous predator diet, including partial fish and bone remains (Collis et al, 1995; Zimmerman, 1999; Collis et al, 2002; Naughton & Collis, 2003) and otoliths (Jobling & Breiby, 1986; Cottrell et al, 1996; Walker et al, 2002; Ross et al, 2005).

In addition to identification, this guide provides basic information on the allometry and energy density of prey fish found throughout the Columbia Plateau, to facilitate estimation of total diet and energetic intake of fish and bird predators.

METHODS

Fish Collection

From 2002-2004, Chelan County PUD personnel at the Rocky Reach Surface Collector and Washington Department of Fish and Wildlife (WDFW) personnel at the Rock Island Bypass collected fish for this study. Species not listed under the Endangered Species Act were collected as needed. Listed fish were collected only if mortally wounded. Salmonid (chinook, coho, sockeye) and steelhead smolts were also provided by major hatcheries releasing fish upstream of or into the study area (Lake Wenatchee, Simalkameen Ponds, Winthrop, Leavenworth, Chiwawa Ponds, Turtle Rock, and Chelan). In 2004, additional fish were collected from the River via minnow trapping, angling, beach seining, and electro-shocking. Finally, some species were provided to us by WDFW Ephrata office personnel from sites downriver of Chelan County. In total, 3000 fish of 30 species were collected. Fish were individually bagged and tagged with the date and place of collection, and kept frozen at -20^{o}C until processed.

Allometry

All measurements were made on previously frozen specimens. Fish were unfrozen, blotted dry, and weighed to the nearest 0.1g. Morphometrics included: fork length, standard length, and dorsal standard length (Figure 1). The latter

measurement was designed specifically to account for partial fish found in the foregut of birds, as these predators tend to swallow fish prey head first, leaving the posterior section of the most recent prey intact. All morphometric measurements are in centimeters. Allometry equations included in this guide allow conversion among morphometrics, as well as between length and mass. Sample sizes and correlation coefficients are included.

Calorimetry

Energy content of whole fish prey (kJ/g wt weight) was determined via bomb-calorimetry. Specimens were thawed, measured, weighed and dried at 60°C until daily mass changes remained below 0.1g. Dried fish were ground into a fine homogeneous powder and allowed to dry overnight (60°C). Ground samples were made into pellets (<0.2g) using a Parr Pellet Press (Parr Instrument Company, Moline, IL). Three pellets per fish were combusted in a Parr 1425 Semimicro Calorimeter (Parr Instrument Company, Moline, IL), and gross heat (cal/g) values determined. Where applicable, species were taken from multiple locations (Columbia River, Potholes Reservoir, or hatchery), and energy densities calculated separately. Average energy density, in kilo-Joules per gram, standard deviation, and sample size are reported.

Bone Extraction and Key Development

All cranial bones were extracted by submerging thawed fish in boiling water for 20-40 seconds. Loosened flesh was removed from the bones with a toothbrush. Bones were soaked in 3% hydrogen peroxide for two days to further loosen any remaining tissue. Bones were brushed again until clean, and placed into 95% ethanol. After three days, bones were air dried, and placed into clay-lined petri dishes. These reference collections are available at the University of Washington Fish Collection. A subset of these bones (dentary, hyomandibular, opercle, cleithrum, lower pharyngeal) were used to develop and extend species-specific keys (Hansel et al, 1988; Frost, 2000). Final keys were blind-tested on novice technicians, and key characters were refined until the rate of correct identification (per blind test) was greater than 95%.

Otolith Extraction and Key Development

Otoliths were extracted from semi-frozen specimens by slicing down the rostrum, peeling back the brain case, and exposing the brain cavity. Otoliths were soaked in 3% hydrogen peroxide for several minutes to loosen any tissues, and then cleaned and place into 95% ethanol. After three days, otoliths were air dried, and stored in gel capsules. Otolith identifications were developed by William Walker. Verification of otolith identification was assured by blind testing with 'dummy samples' constructed from the reference collection; of 64 dummy samples, 96% were identified correctly.

Use of the Guide and Keys

Table 1 lists the taxonomic level of identification possible, as a function of specific cranial bones and otoliths. For rare species, or species known to hybridize, it was impossible to judge identification to species, and instead report lowest possible taxonomic group (e.g., sculpins).

The guide allows the user to identify, or confirm the identification of, fish specimens in two ways. Family pages and species pages contain diagnostic characters for whole and partial fish, as well as a description of diagnostic cranial bones and otoliths. Cranial bone keys and otolith keys allow identification to species (or higher taxonomic group in some cases) from individual hard parts.

General information on the family pages comes from Fishbase (Froese & Pauly, 2005), as well as Wydoski and Whitney (2003). When families possess specific natural history or morphological characteristics generally useful in identification, they are listed. For some families where identification to species was not possible given partial fish or hard parts, distinguishing characters *to the family or subfamily level*, including cranial bones and otoliths, are included on the family page (e.g., suckers and sculpins).

Distinguishing characteristics at the family level are inclusive. That is, must be included in order to properly identify specimens to the species level. On the species pages, distinguishing characters include both whole and partial fish characters, with an emphasis on partial fish characters. Sets of characteristics that can be used to definitively identify the fish to species (given family-level characters), are listed as *unique identifiers*. In many cases, there are several to many possible sets of unique identifiers. Unique identifiers highlighted with asterisks are unique within, but not across, family. For instance, for northern pikeminnow, the character "maxillary extends at least to anterior margin of eye" is unique within Cyprinids within the guide, but is also a character of salmonids, sandroller, some centrarchids, and the sculpins. In these cases, the families, or subsets of families, sharing the character are listed under *Note*. If species are known to hybridize, specifics and citations are listed under *Additional Information*. Distinguishing characteristics have been compiled from several sources (McAllister & Crossman, 1973; Scott & Crossman, 1973; Pollard et al, 197; Wydoski & Whitney, 2003) as well as laboratory observation.

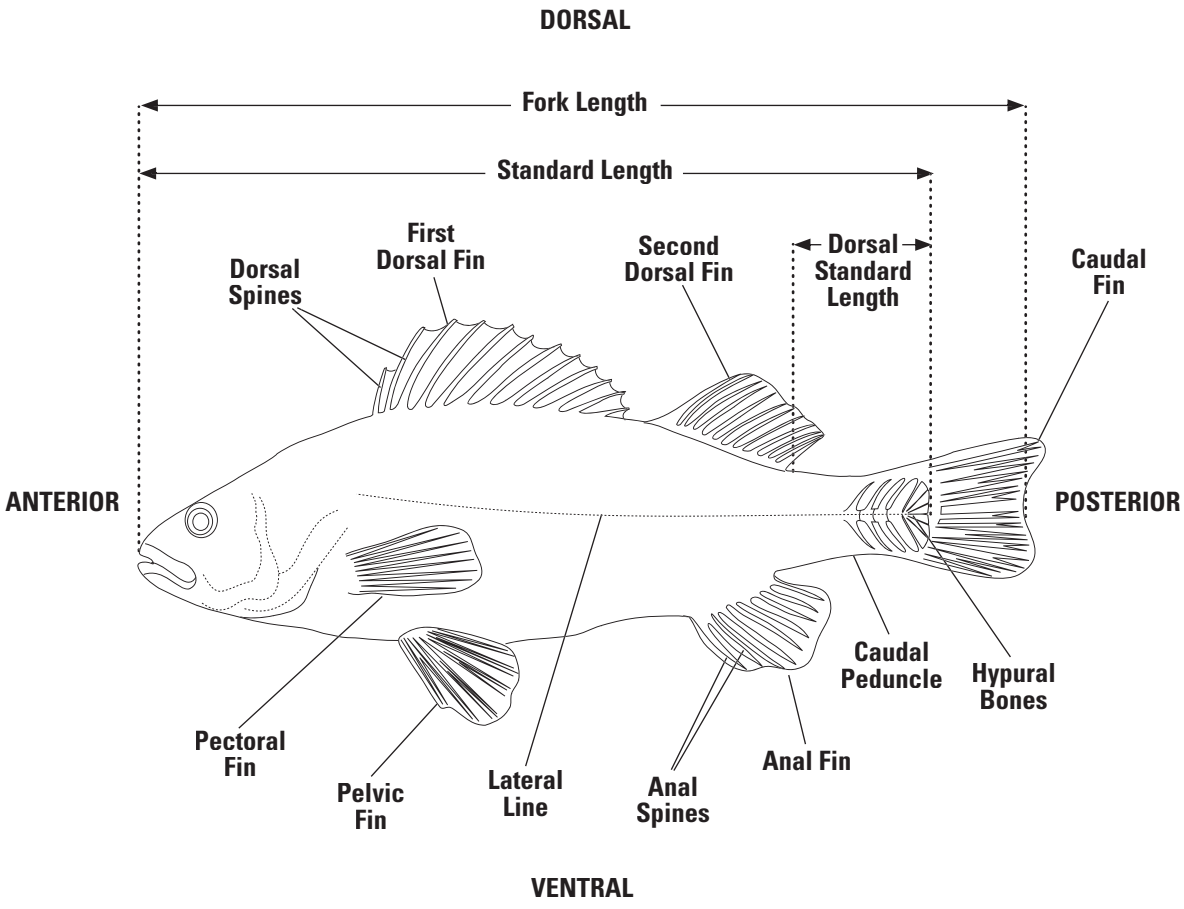


Figure 1. Fish structures and measurements used for identification of families and species in this guide.

Table 1. List of species and genera included in this guide. Under each bone type and otolith, fam(ily), gen(us), and sp(ecies) indicate the level of resolution of each species or genus. Bone types: Ph = lower pharyngeal; Cl = cleithrum; De = dentary; Hy = hyomandibular; Op = opercle; Oto = otolith. '-' indicates a species not included in a particular key.

Common Name	Scientific Name	Ph	Cl	De	Hy	Op	Oto
Lamprey Juvenile	*Lampetra spp.*	-	-	-	-	-	-
Mountain Whitefish	*Prosopium williamsoni*	-	sp	sp	sp	sp	sp
Coho	*Oncorhynchus kisutch*	-	gen	gen	gen	gen	sp
Steelhead (rainbow trout)	*Oncorhynchus mykiss*	-	gen	sp	gen	gen	sp
Sockeye (kokanee)	*Oncorhynchus nerka*	-	gen	sp	gen	gen	sp
Chinook	*Oncorhynchus tshawytscha*	-	gen	gen	gen	gen	sp
Westslope Cutthroat Trout	*Oncorhynchus clarki lewisi*	-	-	-	-	-	-
Brown Trout	*Salmo trutta*	-	-	-	-	-	-
Brook Trout	*Salvelinus fontinalis*	-	-	-	-	-	-
Chiselmouth	*Acrocheilus alutaceus*	sp	sp	sp	sp	sp	sp
Common Carp	*Cyprinus carpio*	sp	sp	sp	sp	sp	sp
Peamouth	*Mylocheilus caurinus*	sp	sp	sp	sp	sp	sp
Northern Pikeminnow	*Ptychocheilus oregonensis*	sp	sp	sp	sp	sp	sp
Speckled Dace	*Rhinichthys osculus*	-	sp	-	sp	sp	-
Redside Shiner	*Richardsonius balteatus*	sp	sp	sp	sp	sp	sp
Tench	*Tinca tinca*	sp	sp	sp	sp	sp	sp
Longnose Sucker	*Catostomus catostomus*	gen	gen	gen	gen	gen	sp
Largescale Sucker	*Catostomus macrocheilus*	gen	gen	gen	gen	gen	sp
Bullhead	*Ameiurus spp.*	-	gen	gen	gen	fam	gen
Channel Catfish	*Ictalurus punctatus*	-	sp	sp	sp	fam	sp
Three-spine Stickleback	*Gasterosteus aculeatus*	-	sp	sp	sp	sp	sp
Sand Roller	*Percopsis transmontana*	-	sp	sp	sp	sp	sp
Pumpkinseed	*Lepomis gibbosus*	-	gen	gen	gen	gen	sp
Bluegill	*Lepomis macrochirus*	-	gen	gen	gen	gen	sp
Smallmouth Bass	*Micropterus dolomieui*	-	gen	gen	sp	sp	sp
Largemouth Bass	*Micropterus salmoides*	-	gen	gen	sp	sp	sp
Black Crappie	*Pomoxis nigromaculatus*	-	sp	sp	sp	sp	sp
Yellow Perch	*Perca flavescens*	-	sp	sp	sp	sp	sp
Walleye	*Stizostedion vitreum vitreum*	-	sp	sp	sp	sp	sp
Sculpin	*Cottus spp.*	-	gen	gen	gen	gen	gen

Family Salmonidae

The salmon family consists of 66 species worldwide, with 20 in Washington State. They are distributed across the northern hemisphere, with the largest reaching a length of 1.5 m. Many species are anadromous.

Distinguishing Characteristics

1. Tiny, iridescent, blue, silver, or gold cycloid scales, with adipose fin (may be clipped in hatchery fish)
2. Large, iridescent, silver, cycloid scales, with an adipose fin

Unique identifiers
(1); (2)

Species included in the guide

Family Cyprinidae

The minnow or carp family is a diverse group with 2010 species worldwide, with 16 in Washington State. Globally they are distributed in North America, Eurasia, and Africa. The largest cyprinids reach 2.5–3 m in length, although many are less than 5 cm long.

Distinguishing Characteristics

1. Origin of pelvic fins anterior to or almost directly below dorsal fin origin
2. Single dorsal fin (entire fin from beginning to end) positioned in center of body, and dorsal fin insertion is anterior to anal fin origin
3. Scales not iridescent
4. Single dorsal fin (entire fin from beginning to end) positioned on posterior half of body, and dorsal fin insertion is posterior to anal fin origin
5. Caudal fin is deeply forked

Unique identifiers

(1,2,3); (1,4,5)

Additional information

Some species have overlapping scales that form a distinct diamond-shaped lattice pattern on body, particularly clear on posterior end of fish

Species included in the guide

Family Catostomidae

The sucker family consists of 68 species worldwide, five occur in Washington State. Globally they are in China, Siberia, and North America. The largest suckers can reach up to 100 cm in length, but are typically less than 60 cm. Their lips are usually thick with papillae and their mouths can protrude to find food or hold onto the substrate in fast moving water.

Distinguishing Characteristics

1. Mouth subterminal and lower lip has thick, fleshy pad with many papillae
2. Anal fin positioned so far posterior that when it is flattened next to body, it is touching or almost touching the origin of the caudal fin
3. Overlapping scales form a distinct diamond-shaped lattice pattern on body, particularly clear on posterior end of fish
4. Single dorsal fin (entire fin from beginning to end) positioned in center of body, and dorsal fin insertion is significantly anterior to anal fin origin, i.e., distance between dorsal fin insertion and anal fin origin is long
5. Scales cycloid (feels smooth when scales are stroked toward head)
6. Relatively wide caudal peduncle, and angle from body to caudal peduncle is shallow and almost flat on dorsal side, i.e. caudal peduncle depth about 1/3 the maximum body depth
7. Origin of pelvic fins clearly posterior to dorsal fin origin

Unique identifiers
(1); (2,3); (2,4); (2,5,6); (2,5,7)

Additional information
All local suckers are able to interbreed (Wydoski and Whitney, 2003)

Due to the amount of hybridization, sucker identification can be extremely difficult. The following table can serve as a guide to common characteristics for the four sucker species in the Columbia River.

Species	***Cleftness of Lower Lip***	***Papillae on Upper Lip***	***Lateral Line Scale Count***	***Dorsal Fin Ray Count***	***Maximum Length***
Largescale sucker	≤ 1 row of papillae	Present	62–80	13+	60 cm
Longnose sucker	≤ 1 row of papillae	Present	91–120	9–11	62 cm
Mountain sucker	≥ 2 rows of papillae	Absent	79–89	8–13	25 cm
Bridgelip sucker	≥ 2 rows of papillae	Present	88–124	11–14	53 cm

Species included in the guide

Sucker Diagnostic Cranial Bones

Dentary
No teeth or sensory pores. Ventral margin a C-shaped curve, with a sharply descending ventral leg (bone looks upside down).

Hyomandibular
Head positioned entirely to the anterior of the body.

Opercle
Dorsal ridge does not extend to posterior margin. Opercular arm creates a strong concavity in the dorsal margin.

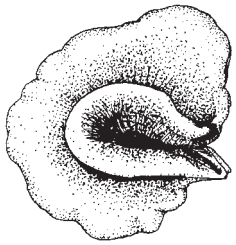
Cleithrum
Vertical limb ends in a single point. Horizontal limb with three points.

Lower Pharyngeal
Many regularly spaced teeth in a comb-like row.

Longnose Sucker Otoliths

Lagenar otolith characteristics

This otolith is oval shape with the anterior half of the dorsal area extended forward to give the otolith a raised "crested appearance." The entire margin of the otolith is weakly scalloped in appearance with rather regularly spaced rounded lobes. On the outer face, deep grooves radiating from the center outward to scalloped edges are evident. A ventral crista projection is present and typically extends beyond the anterior margin of the dorsal area.



Inner face

Ontogenetic variation

Undetermined

Utricular otolith characteristics

The posterior portion of the outer face is fan-shaped. The posterior–most margins are thin and sharp edged. The sulcus is prominently exposed on the dorsal edge of the inner face. The smooth, knob-like tubercle on the anterior of the inner face is very prominent and slightly cleft in the center, giving it a slightly bilobed appearance.

Inner face

Ontogenetic variation

Undetermined

Material examined

Description based on 2 pairs of lagenar otoliths (3.6 to 3.7 mm OH) and 2 pairs of utricular otoliths (3.2 to 3.3 OL). Top panel 3.7 mm OH; bottom panel 3.3 mm OL.

Family Ictaluridae

The catfish family consists of 45 species worldwide, six are found in Washington State. They are native to North and Central America. The largest specimens can reach up to 1.5 m in length.

Distinguishing Characteristics

1. 8 barbels around mouth
2. Adipose fin
3. Scales absent
4. Strong single spine on dorsal and each pectoral fin

Unique identifiers
(1); (2,3); (2,4)

Species included in the guide

Family Centrarchidae

The sunfish family consists of 28 species worldwide, nine occur in Washington State. They are native to North America. The largest specimens may reach 60 cm. They are nest builders, with the male usually guarding the nest.

Distinguishing Characteristics

1. Caudal peduncle depth is greater than 1/10 the standard length, i.e. relatively wide caudal peduncle
2. Single dorsal fin, but some species have a deep indentation in middle of fin, so could appear to be 2 fins
3. Dorsal fin (entire fin from beginning to end) positioned on posterior half of body, and insertion is either directly above or slightly anterior to anal fin insertion, but is not located at the caudal peduncle
4. Spines in anterior dorsal fin lobe, with membranes between all spines
5. Head is laterally compressed

Unique identifiers
(1,2); (1,3); (1,4); (2,3); (2,5)

Species included in the guide

Family Percidae

There are 159 members of the perch family globally, two are found in Washington State. They are distributed across the northern hemisphere. The largest recorded member of the family is 90 cm. All members of the Percidae are carnivorous, with the larger species being pisciverous. Percids have developed strong spines in the dorsal fin and gill covers which aid in predator avoidance.

Distinguishing Characteristics

1. Two dorsal fins that are clearly separated, so each fin has an obvious origin and insertion
2. Caudal peduncle depth is less than 1/10 the standard length, i.e. relatively narrow caudal peduncle
3. Second dorsal fin positioned on posterior half of body and insertion is either directly above or slightly anterior to anal fin insertion, but is not located at the caudal peduncle
4. Spines in anterior dorsal fin, with membranes between all spines

Unique identifiers
(1,2); (1,3); (1,4); (2,3)

Species included in the guide

Family Cottidae

There are 300 species of sculpins globally. Eleven are found in Washington state, with ten freshwater and one brackish species. They are distributed across the northern hemisphere and New Zealand, and can live in both freshwater and marine environments. The largest recorded specimen is 78cm. Sculpins are extremely difficult to identify to species due to their small size and varying morphological characteristics

Distinguishing Characteristics

1. Single long dorsal fin, with an indentation so it appears to be two fins
2. Dorsal fin insertion is either directly above or slightly anterior to anal fin insertion, and is located at the caudal peduncle
3. Long anal fin, almost a mirror-image of second dorsal fin
4. Spines in anterior lobe of dorsal fin, with membranes between all spines and rays
5. Head is dorso-ventrally flattened
6. Eyes close together near top of head
7. Caudal fin is straight-edged, or very slightly convex

Unique identifiers
(1,2); (1,5); (1,6); (1,7); (2,5); (2,6); (4,5); (4,6); (4,7)

Size range
Up to 25 cm; Examined range: 4.2 to 15.9 cm

Caloric data

Location	n	kJ/g	SD
All	12	5.056	0.97
River	6	4.384	0.66
Potholes	6	5.728	0.74

Sculpin Diagnostic Cranial Bones

Dentary
More than one row of similarly-sized teeth. Large sensory pores, with third pore filling almost the entire width of the ventral limb. Ratio of ventral leg width to dorsal leg width < 2.8. Ratio of fork depth to dorsal margin length > 0.30.

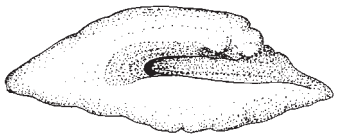
Hyomandibular
Anterior-ventrally oriented spike-like protrusion in center of lateral webbing.

Opercle
Dorsal ridge extends to posterior margin. Anterior ridge terminates at the edge of the webbing that lies between the dorsal and anterior ridges. Dorsal crest reduced, almost absent.

Cleithrum
Vertical limb with two processes.

Sculpin Otoliths

Saccular otolith
The otolith is long and slender in shape. The ostium is small with a poorly developed to absent antirostrum. The rostrum is decidedly pointed at the tip. The otolith margins are generally smooth. Crenellations, when present on the otolith margins, are rounded and barely evident. The posterior end of the otolith is decidedly attenuated and frequently terminates in an outwardly pointed projection. The outer face is distinctly concave. Generally, the otolith appears thick for its size.



Inner face

Dorsal view

Ontogenetic variation
Negligible within the size range examined.

Material examined
Description based on 7 pairs of otoliths (3.3 to 5.3 mm OL). Both panels 5.2 mm OL.

Note
Due to the difficulty in sculpin identification and hybridization, it is recommended to identify sculpin otoliths to the generic level only.

Pacific Lamprey (*Lampetra tridentata*)

Pacific lamprey are found in the lower and mid-Columbia River. They will remain in the river for four to seven years before migrating to the ocean. Larvae are filter feeders and adults feed on fish by suctioning to their sides, rasping their flesh, and feeding on blood and body fluids.

Distinguishing Characteristics

1. Lacks a jaw; has mostly unicuspid (single pointed) teeth
2. Cartilaginous skeleton
3. No paired fins, single dorsal fin, lacks scales
4. Seven gill openings on each side

Unique identifiers
(1); (2); (3); (4)

Size range
Up to 75 cm, landlocked up to 22 cm, larva up to 10 cm; Examined range: 11 to 15.3 cm

Allometry equation
$Wt = 0.00000002*TL^{3.85}$ n=25 R^2=0.59

Caloric data

Location	n	kJ/g	SD
River	6	5.572	1.08

Mountain Whitefish (*Prosopium williamsoni*)

The mountain whitefish is found throughout the Columbia River. They live in cool rivers and lakes, feeding on a variety of aquatic invertebrates and small fish.

Distinguishing Characteristics

1. Scales silver and iridescent, lateral line count <100
2. Slightly subterminal mouth
3. Posterior edge of maxillary does not reach beyond center of eye
4. Parr marks circular and present along dorsal surface
5. Back and sides light and iridescent; no dark spots (parr marks may be present on fish <12 cm)

Unique identifiers

(1); (2)*; (3)*; (4,5)

Note

(2)* see peamouth, chiselmouth, sandroller, Catostomidae

(3)* see bluegill, pumpkinseed, three-spine sticklebakc Cyprinidae, Catostomidae, Ictaluridae

Size range

Up to 30 cm; Examined range: 5.9 to 26.5 cm

Allometry equations

SL = 2.05*DS + 9.60	n=11	R^2=0.99
Wt = 0.000002*$SL^{3.34}$	n=11	R^2=0.99
Wt = 0.000002*$FL^{3.32}$	n=11	R^2=0.99

Caloric data

Location	n	kJ/g	SD
River	6	4.845	1.48

Mountain Whitefish Diagnostic Cranial Bones

Dentary

No teeth. Bone is boomerang-shaped, with long ventral leg.

Hyomandibular

Anterior webbing extends ventrally beyond the ventral process. The upper edge of the anterior webbing is smooth and convex.

Opercle

The dorsal ridge does not extend to the posterior margin. The dorsal-anterior corner is rounded and there is no opercular arm. The posterior margin has a concave scallop in line with the dorsal ridge.

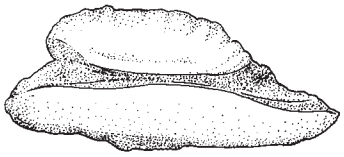
Cleithrum

The vertical and horizontal limbs end in a single point or lobe. Extensive membranous webbing extends out from the anterior margins of both limbs. Ratio of dorsal crest height to vertical limb length > 0.35.

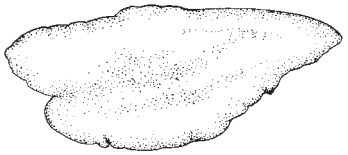
Mountain Whitefish Otoliths

Saccular Otolith

This otolith is elongate and proportionally thin in shape, particularly in large specimens. The rostrum is very elongate, wedge-shaped, and typically terminates in a sharp point. The sulcus is open at both ends and the posterior opening of the cauda is wide and funnel-shaped. The antirostrum is absent or weakly developed. The edge of the ventral area is generally smooth with a linear sharp step-like depression running parallel to the ventral edge; the dorsal area edge is typically irregular. The ventral crista is nearly linear in shape and curves downward only slightly at the ostium. The entire ventral margin of the otolith ranges from flat to concave giving the entire ventral area a shallow elongate appearance. The outer face is concave.



Inner face



Outer face

Dorsal view

Ontogenetic variation

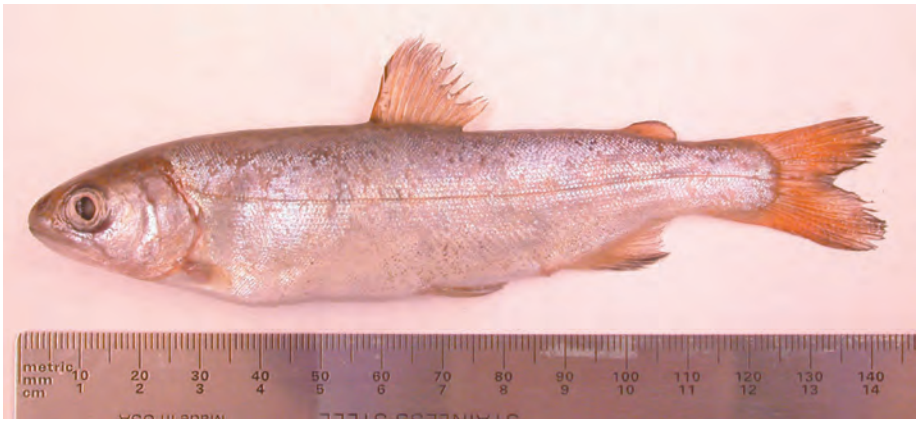
Appears to be negligible within the size range examined. The outer face is concave in small otoliths becoming weakly concave in those of larger individuals. In otoliths greater than 4 mm in length the posterior edge of the ventral area typically protrudes well beyond that of the dorsal area. The step-like depression along the ventral area edge becomes more developed with age.

Material examined

Description based on ten otoliths (1.4 to 6.2 mm OL). Illustrations 5.7 mm OL.

Coho (*Oncorhynchus kisutch*)

Coho occur throughout the lower and mid-Columbia River. They are anadromous and prefer pool and riffle habitats if available. They will feed on zooplankton and emerging insects.



Distinguishing Characteristics

(Fish < 12 cm)

1. Leading edge of anal fin is longer than anal fin base length; first several anal fin rays longer than others, giving fin a sickle-shaped appearance
2. Width of parr marks about equal to or usually less than width of light spaces between parr marks
3. Parr marks long, extending about as far below lateral line as above it

Unique identifiers

(1); (2,3)

(Fish > 12 cm)

1. Distinct black spots on back and upper lobe of caudal fin, no spots on lower caudal fin lobe
2. White gums around bases of teeth in lower jaw (specimens around 12 cm may be transitioning from black to white gums)
3. Caudal fin is deeply forked

Unique identifiers

(1); (1,2); (2,3)

Size range

Outmigrating coho are 12 to 20 cm long; Examined range: 7.3 to 17.0 cm

Allometry equations

SL = 2.20*DS +13.48	n=48	R^2=0.94
Wt = 0.00005*$SL^{2.76}$	n=44	R^2=0.94
Wt = 0.00004*$FL^{2.75}$	n=42	R^2=0.93

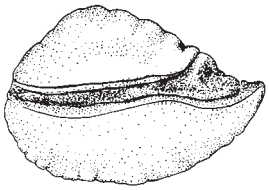
Caloric data

Location	n	kJ/g	SD
All	17	5.171	1.17
River	11	4.520	0.91
Hatchery	6	6.366	0.35

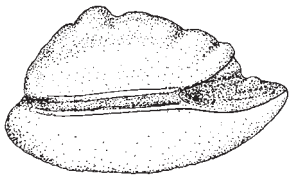
Coho Salmon Otoliths

Saccular Otoliths

The cauda is narrow and does not expand at the posterior opening. The ventral edge of the otolith is smooth and gently curved. The ventral crista of the sulcus is not straight but takes a decided downward curve at the ostial junction. The posterior margins of the dorsal and ventral areas are typically rounded in shape. The ventral area posterior margin, however, is variable in shape and may protrude noticeably beyond that of the dorsal area. The posterior edge of the outer face of the ventral area does not noticeably taper toward the inner face forming a thin edge. The dorsal area margin is also domed and irregular with several large lobes typically present at the anterior margin. Within the size range examined, the outer face is concave in shape.



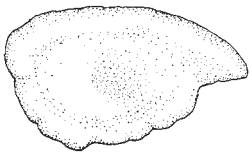
Inner face



Inner face

Ontogenetic variation

Undetermined due to high degree of intraspecific variation and the narrow size range of otoliths examined.



Outer face

Comments

Intraspecific variation in otolith morphology within this species is high and relates primarily to variability in the shape of the posterior otolith margins. This appears to be due, at least in part, to a high percentage of developmental pathology in the otoliths of this species. Typically, this takes the form of incomplete growth on the outer face of the otolith accompanied by crystalline vaterite mineral replacement. The rate of this developmental pathology can be high. Out of 33 pairs of otoliths examined in this study, 29 pairs (88.0%) demonstrated varying degrees of vateritic replacement. These conditions make identification of coho otoliths the most difficult of all the salmonids. Under some conditions otoliths of this species can be mistaken for those of steelhead salmon. Coho otoliths differ from those of steelhead in the following features: 1) In coho salmon otoliths, the dorsal area margin is more irregular, usually with one or two pronounced rounded knob-like structures on the anterior edge, and 2) The outer face of the ventral area does not taper rapidly to a thin edge at the posterior margin.

Dorsal view

Ventral view

Material examined

Description based on 33 otoliths (2.3 to 3.6 mm OL). Top panel 2.9 mm OL, bottom four 3.6 mm OL.

Steelhead (*Oncorhynchus mykiss*)

Steelhead are found throughout the Columbia River. They remain in the river up to seven years before migrating to the ocean. Juvenile steelhead feed primarily on aquatic invertebrates floating in the water column.

Distinguishing Characteristics

(Fish < 12cm)

1. Maxillary does not reach beyond eye socket; terminal mouth
2. Anal fin with 10–12 rays
3. Many distinct black spots on back, sides, and both lobes of caudal fin
4. Rounded caudal lobes and shallow fork in tail

Unique identifiers

(1,2)*; (1,3); (1,4)

Note

(1,2)* see Smallmouth bass, Three-spine stickleback, Pumpkinseed, Bluegill, Black crappie, Walleye

(Fish > 12cm)

1. Maxillary does not extend beyond eye socket except in specimens larger than 50 cm; terminal mouth
2. Anal fin with 10–12 rays
3. Many distinct black spots on back, sides, and both lobes of caudal fin

Unique identifiers

(1,2)*; (1,3)

Note

(1,2)* see Smallmouth bass, Three-spine stickleback, Pumpkinseed, Bluegill, Black crappie, Walleye

Additional Information

Can hybridize with cutthroat trout (Brown *et al.*, 2004; Rubidge and Taylor, 2004)

Size range

Up to 18 cm before migration; Examined range: 9.9 to 24.1 cm (Steelhead)
Up to 100 cm; Examined range: 13.7 to 24.5 cm (Rainbow trout)

Allometry equations

Steelhead		
SL = 2.314*DS + 16.67	n=52	R^2=0.95
Wt = 0.000006*SL $^{3.20}$	n=45	R^2=0.96
Wt = 0.000002*FL $^{3.39}$	n=52	R^2=0.96
Rainbow Trout		
SL = 2.4353*DS + 5.30	n=31	R^2=0.92
Wt = 0.00002*SL $^{2.95}$	n=31	R^2=0.92
Wt = 0.00002*FL $^{2.92}$	n=30	R^2=0.92

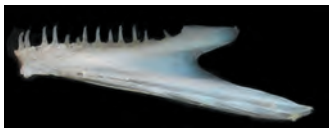
Caloric Data

Location	n	kJ/g	SD
All	17	5.700	0.72
River	10	5.515	0.66
Hatchery	7	5.716	0.73

Location	n	kJ/g	SD
Potholes	6	6.144	0.70

Steelhead Diagnostic Cranial Bone

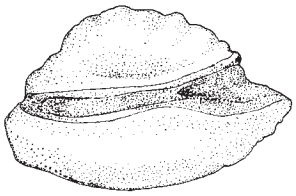
Dentary



A single row of teeth similar in shape and size. Ratio of ventral margin length to ventral leg length < 3.4 and ratio of body length to ventral leg length < 2.4. Ratio of body length to dorsal leg width $\leq$ 5.5

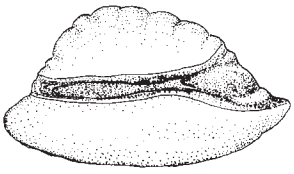
Steelhead Otoliths

Saccular Otolith



Inner face

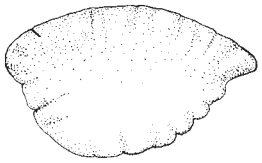
The cauda is narrow and does not expand at the posterior opening. An antirostrum is present and typically takes the form of a rounded lobe. The edge of the ventral area is smooth and gently curved. The ventral crista of the sulcus is not straight but takes a downward curve at the ostial junction. The posterior margins of the dorsal and ventral areas of steelhead otoliths are not parallel, with the ventral area noticeably extending beyond that of the dorsal area. The posterior margin of the dorsal area typically slopes forward at an acute angle. The posterior edge of the ventral area outer face tapers rapidly toward the inner face forming a thin ventral area edge. This feature gives the ventral posterior margin of the otolith a posteriorly "pinched" appearance when viewed on edge. Within the size range examined, the outer face ranged from weakly concave at around 2 mm OL to concave at around 3 mm OL.



Inner face

Ontogenetic variation

The dorsal area is thicker and smoother in smaller otoliths. As a result, the dorsal crista is typically very faint to absent in otoliths under 2.7 mm OL. In larger otoliths (up to 3.3 mm), the dorsal crista, when present, is poorly developed and never reaches the defined rounded crest found in sockeye otoliths of comparable size. Age–related changes in steelhead otolith morphology are very similar to those of sockeye salmon: the rostrum is short and typically blunt in shape in otoliths 1.5 to 2.0 mm OL, becoming sharper and more elongate in otoliths greater than 2.0 mm. The degree of concavity of the outer face increases with age.



Outer face

Material examined

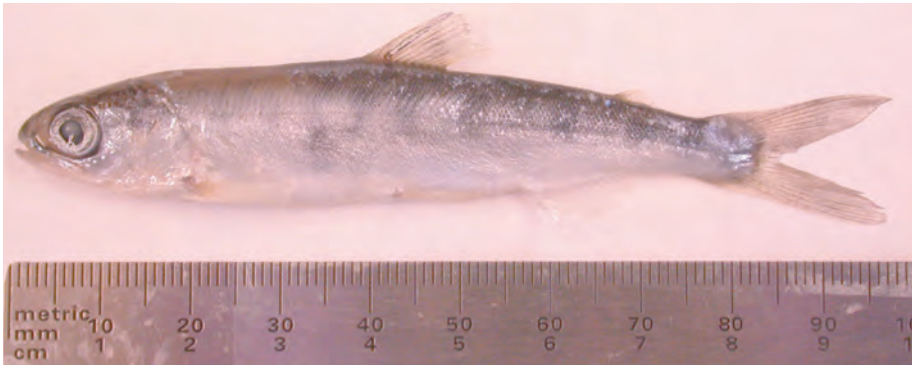
Description based on 26 otoliths (1.8 to 3.6 mm OL). Top panel 2.2 mm, lower four panels 3.6 mm OL.

Dorsal view

Ventral view

Sockeye (*Oncorhynchus nerka*)

Sockeye are found throughout the Columbia River. They are anadromous and juveniles feed largely on zooplankton. Kokanee are non-migratory sockeye, remaining in freshwater, feeding on zooplankton and aquatic insects.



Diagnostic Characteristics

(Fish < 12 cm)

1. Parr marks short and do not extend far, if at all, below lateral line
2. Width of parr marks is less than width of light spaces between parr marks
3. Length of parr marks irregular
4. Fine speckling may be present on back, but no distinct black spots on back, sides, or caudal fin

Unique identifiers

(1); (2,3); (2,4)

(Fish > 12 cm)

1. Fine speckling may be present on back, but no distinct black spots on back, sides, or caudal fin

Unique identifier

(1)

Size range

Up to 18 cm before migration; Examined range: 5.6 to 15.3 cm (Sockeye)
Up to 40 cm; Examined range: 4.8 to 5.0 cm (Kokanee)

Allometry equations

Sockeye		
$SL = 2.24*DS + 6.88$	n=142	R^2=0.99
$Wt = 0.000003*SL^{3.31}$	n=106	R^2=0.98
$Wt = 0.000002*FL^{3.37}$	n=105	R^2=0.98

Kokanee		
$SL = 1.98*DS + 9.55$	n=20	R^2=0.85
$Wt = 0.000005*SL^{3.28}$	n=19	R^2=0.90
$Wt = 0.000003*FL^{3.32}$	n=19	R^2=0.88

Caloric data

Location	n	kJ/g	SD
All	29	4.889	1.49
River	23	4.172	0.73
Hatchery	6	7.280	0.60

Location	n	kJ/g	SD
Hatchery	6	5.818	0.32

Sockeye Diagnostic Cranial Bone

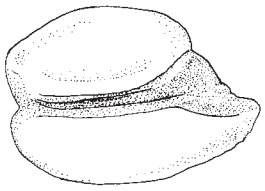
Dentary

A single row of teeth similar in shape and size. Ratio of ventral margin length to ventral leg length < 3.4 and ratio of body length to ventral leg length < 2.4. Ratio of body length to dorsal leg width > 5.5.

Sockeye Otoliths

Saccular Otoliths

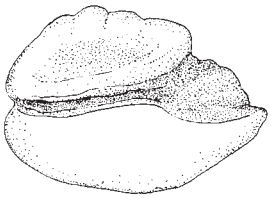
Due to the proportionally large dorsal area, otoliths of this species appear shortened with an almost square-shaped, centrally notched posterior margin. The posterior edges of the dorsal and ventral areas are typically near parallel. In some instances where they are not, the posterior edge of the ventral area protrudes only slightly beyond that of the dorsal area. The cauda is narrow and does not expand at the posterior opening. An antirostrum is present and typically takes the form of a blunt, rounded lobe. The ventral edge of the otolith is smooth and gently curved. The ventral crista of the sulcus is not straight but takes a decided downward curve at the ostial junction. The outer otolith face thins out at the central portion of the posterior edge giving the otolith a slightly tapered appearance when viewed on edge. The outer face ranges from flat in otoliths around 2 mm OL to slightly concave at around 3 mm OL.



Inner face

Ontogenetic variation

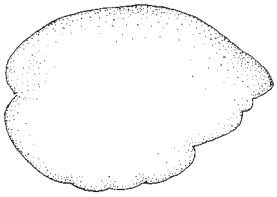
The rostrum becomes longer with age. Typically the rostrum is short and blunt in otoliths of 1.5 to 2.0 mm OL, becoming sharper and longer in otoliths greater than 2.0 mm. The dorsal crista is well developed and rounded in otoliths less than 1.8 mm OL, and flat to absent in those 1.8 to 3.1 mm OL. The degree of concavity of the outer face increases with age.



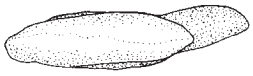
Inner face

Material examined

Description based on 81 otoliths (1.4 to 3.1 mm OL). Top panel 1.4 mm OL; bottom three panels 1.9 mm OL.



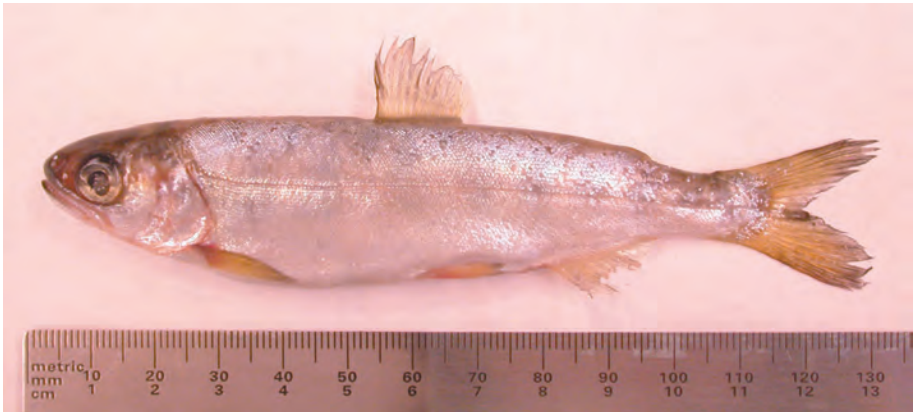
Outer face



Dorsal view

Chinook (*Oncorhynchus tshawytscha*)

Chinook are found in the mid and lower Columbia River. They require cool water and move from shallow to deeper water a few months after hatching. In the river, chinook feed on aquatic insects.



Distinguishing Characteristics

(Fish < 12 cm)

1. Width of parr marks usually greater than width of light spaces between parr marks
2. Parr marks long, extending about as far below lateral line as above it

Unique identifier

(1,2)

(Fish > 12 cm)

1. Black gums around bases of teeth in lower jaw; gums do not include outer lips (some salmonids <12 cm long may have black gums)
2. Distinct black spots on back and both lobes of caudal fin
3. Caudal fin is deeply forked

Unique identifiers

(1); (2,3)

Size range

Over 100 cm; Examined range: 4.8 to 18.8 cm

Allometry equations

$SL = 2.21*DS + 9.01$	n=114	R^2=0.99
$Wt = 0.00001*SL^{3.07}$	n=87	R^2=0.98
$Wt = 0.000006*FL^{3.15}$	n=87	R^2=0.98

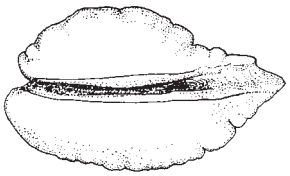
Caloric data

Location	n	kJ/g	SD
All	20	4.537	0.78
River	14	4.101	0.68
Hatchery	6	5.307	0.22

Chinook Otoliths

Saccular Otoliths

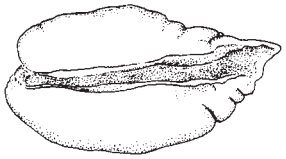
Due to the rounded posterior margins of the dorsal and ventral areas and the attenuated rostrum, otoliths from this species appear oval to teardrop in shape. The ventral crista of the sulcus is nearly linear in shape with only a slight depression at the ostium. The entire ventral edge of the otolith is gently curved. The sulcus is generally straight and narrow with little change in diameter between the ostium and cauda. The condition of the antirostrum ranges from absent to weakly developed and, when present, typically takes the form of a faint rounded lobe. The outer face is typically flat to weakly concave.



Inner face

Ontogenetic variation

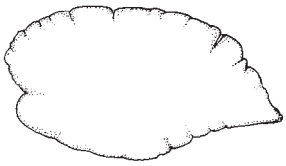
Due to an anterior extension of the ostium beyond the anterior tip of the ventral area, the rostrum is sharply pointed in otoliths of small juveniles becoming elongate and blunt in those of larger individuals. The ventral edge is sometimes faintly serrate in very small otoliths up to 2.0 mm OL, becoming smooth in those of larger specimens. The outer face is convex in otoliths ranging in size from 1.4 to 2.0 mm OL, becoming flat to only slightly concave in otolths ranging from 2.0 to 5.9 mm OL.



Inner face

Material examined

Description based on 86 otoliths (1.4 to 5.9 mm OL). Top panel 2.2 mm OL; bottom three panels 3.1 mm OL.



Outer face

Dorsal view

Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*)

Cutthroat trout historically occurred in the Lake Chelan and Methow River basins. They can be adfluvial or resident. They feed primarily on zooplankton and switch to aquatic invertebrates, rarely consuming fish.

Distinguishing Characteristics

1. Distinct orange or reddish slash marks below lower jaw in fish greater than 8 cm in length
2. Maxillary extends beyond eye
3. Many distinct black spots on back, sides, and both lobes of caudal fin; spots are primarily above the lateral line on the anterior half of the body and are most numerous on the caudal peduncle, where they are on both sides of the lateral line
4. Anal fin with 10–12 rays and anal fin base shorter than dorsal fin base

Unique identifiers

Fish < 12 cm: (1); (2,3); (2,4)
Fish > 12 cm: (1); (2,3,4)

Additional information

Can hybridize with rainbow trout (Brown *et al.*, 2004; Rubidge and Taylor, 2004)

Size range

Up to 40cm; Examined range: 8.1 to 18.8 cm

Allometry equations

SL = 2.33*DS + 12.52	n=34	R^2=0.98
Wt = 0.000008*$SL^{3.16}$	n=32	R^2=0.99
Wt = 0.000003*$FL^{3.31}$	n=27	R^2=0.97

Caloric data

Location	n	kJ/g	SD
Hatchery	6	6.255	0.24

Brown Trout (*Salmo trutta*)

Brown trout are an introduced salmonid in the mid and upper Columbia River. They can tolerate lower oxygen levels and higher degrees of turbidity than many other trout species. Fry feed on small invertebrates such as midge larvae, larger individuals eat aquatic invertebrates, and the largest trout feed almost exclusively on fish.

Distinguishing Characteristics

(Fish < 12 cm)

1. Darker orange spots along lateral line and lighter orange spots scattered irregularly below lateral line
2. Dorsal fin has orange spots
3. Outer edge of anal fin orange

Unique identifiers

(1); (2); (3)

(Fish > 12 cm)

1. Large dark spots with pale halos on sides of body
2. Caudal fin clear, may have a few spots on dorsal edge

Unique identifiers

(1,2)

Size range

Up to 140 cm; Examined range: 7.4 cm to 11.2 cm

Allometry equations

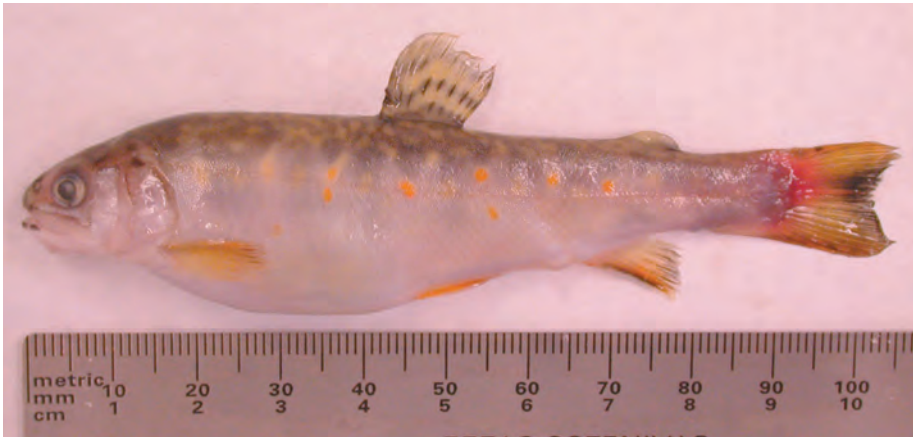
SL = 2.11*DS + 10.69	n=32	R^2=0.95
Wt = 0.00002*SL $^{2.95}$	n=31	R^2=0.97
Wt = 0.00001*FL $^{3.01}$	n=31	R^2=0.97

Caloric data

Location	n	kJ/g	SD
Hatchery	6	5.516	0.45

Brook Trout (*Salvelinus fontinalis*)

In Washington, the introduced brook trout are found in mountain lakes. They are also stocked for the sport fish industry in areas where they do not spawn. They require high oxygen levels and cool temperatures and prefer cool, clear headwater ponds and springs. The young eat zooplankton and midges, whereas larger fish eat aquatic and terrestrial insects. Fish larger than 15 cm will eat small fish.



Distinguishing Characteristics

(Fish < 12 cm)

1. Dorsal part of body has light markings resembling worm tracings
2. Sides of body have orange to crimson spots that are irregularly spaced above and below the lateral line
3. Pelvic and anal fins have a white leading edge that is bordered in black
4. Dorsal fin has alternating, light and dark horizontal stripes

Unique identifiers

(1); (2); (3); (4)

(Fish > 12 cm)

1. Conspicuous wavy markings on back and dorsal fin
2. Small crimson spots on darker background of sides of bodies

Unique identifiers

(1); (2)

Size range

Up to 30 cm; Examined range: 6.6 to 13.1 cm

Allometry equations

SL = 2.25*DS + 4.36	n=30	R^2=0.97
Wt = 0.00002*SL $^{3.03}$	n=28	R^2=0.98
Wt = 0.000005*FL $^{3.22}$	n=28	R^2=0.98

Caloric data

Location	n	kJ/g	SD
Hatchery	6	5.194	1.39

Chiselmouth (*Acrocheilus alutaceus*)

Chiselmouth are found throughout the Columbia River. They prefer large, wide, slow moving streams and lakes. Chiselmouth feed mostly on diatoms and algae, opportunistically consuming aquatic insects.

Distinguishing Characteristics

1. When viewed from below, lower jaw straight (in juveniles, plate may be slightly curved)
2. Caudal peduncle depth less than 1/3 the maximum body depth
3. Cross section of caudal peduncle almost square due to nearly flat dorsal surface
4. Subterminal mouth
5. Dorsal fin insertion almost directly above or slightly anterior to anal fin origin

Unique identifiers

(1); (2,3)*; (2,4); (2,5); (3,4); (3,5); (4,5)

Note

(2,3)* see three-spine stickleback

Additional Information

Can hybridize with northern pikeminnow (Wydoski and Whitney, 2003) and redside shiner (Smith, 1973)

Size range

Up to 30 cm; Examined range: 10.5 to 27.3 cm

Allometry equations

$SL = 2.84*DS + 4.33$	n=39	R^2=0.97
$Wt = 0.000007*SL^{3.19}$	n=37	R^2=0.98
$Wt = 0.000005*FL^{3.16}$	n=37	R^2=0.98

Caloric data

Location	n	kJ/g	SD
River	6	5.229	0.70

Chiselmouth Diagnostic Cranial Bones

Dentary

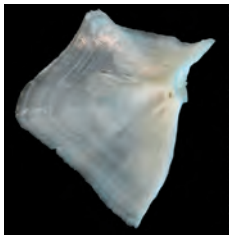
Teeth absent but sensory pores present. Dorsally pointing coronoid process. Ratio of symphyseal margin length to ventral margin length $\geq$ 0.30.

Hyomandibular

Lateral webbing flattened. Upper lateral webbing extends from opercular process to anterior process across most of the head. Opercular process embedded and oblong. Ratio of height of bone to width of head is between 2 and 2.75.

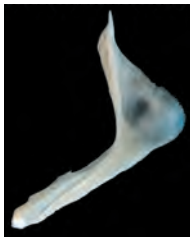
Opercle

Dorsal ridge less than half of opercle width. Length of the opercular arm is greater than the dorsal-ventral diameter of the articular fossa. The midpoint of the posterior margin is distinctly angular. Ratio of dorsal margin length to dorsal crest length < 0.70. Ratio of anterior margin length to dorsal crest length < 1.00.



Cleithrum

Vertical and horizontal limbs end in a single point or lobe. Distinct hook midway on medial process of horizontal limb.



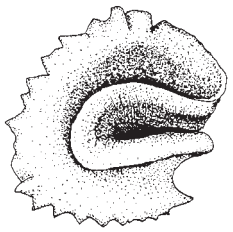
Lower Pharygeal

Only one row containing few (<10) teeth. No secondary teeth. The tip of the dorsal leg is pointed. The teeth are narrow, with an angled molar shape.

Chiselmouth Otoliths

Lagenar otolith

This otolith is generally circular in shape with a flattened, anterior edge. Otolith margins are lined with irregularly spaced heavy, rather blunt, long dentate projections. The dentate projections are thicker in the dorsal area. Typically the ventral crista extends beyond the ostium to form a blunt lobe-like projection. The otolith margins of the anterior face are smooth or nearly so. The anterior margin of the ventral area just below the projection of the ventral crista has a deep, c-shaped notch. The inner face of this otolith is flat or nearly so. Scalloping on the outer face radiating inward from the dentate margins is indistinct and irregular.



Inner face

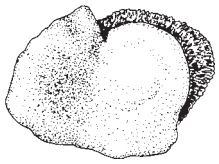
Dorsal view

Ontogenetic variation

The dentate projections on the otolith margins generally become thicker and more elaborate with age.

Utricular otolith

The anterior aspect of the inner face has a smoothly rounded knob-like tubercle on dorsal margin. The margins of this tubercle are somewhat asymmetrically bilobed in appearance. The concave, flared posterior edge of the inner face is smoothly rounded.



Inner face

Ontogenetic variation

The concave condition of the inner face of the posterior area increases with age.

Material examined

Description based on 21 pairs of lagenar otoliths (1.9 to 2.9 mm OH) and 22 pairs of utricular otoliths (1.9 to 2.6 mm OL). Top two panels 2.3 mm OH; bottom panel 2.3 mm OL.

Comment

Chiselmouth and pikeminnow are reported to hybridize (Wydoski and Whitney, 2003). The utricular otoliths of these two species are so similar it is not advisable, even under the best of conditions, to use them as the sole basis for discriminating between these two species. The lagenar otoliths, on the other hand, can, in most cases, be reliably identified to species. However, there are exceptions, where the diagnostic features are intermediate between the two. These cases typically relate to situations where it is difficult to discern whether the anterior edge of the otolith below the ventral crista has a c or v-shaped notch.

Common Carp (*Cyprinus carpio*)

Carp are an introduced fish found throughout the Columbia River. They prefer slow–moving water with vegetation and are tolerant of varying levels of temperature, oxygen, and pollution. Carp are bottom feeders, consuming a wide range of prey items.

Distinguishing Characteristics

1. First rays of dorsal and anal fin are distinct, heavy, and cartilaginous, with serrated posterior edge
2. Deep body; slope from body to caudal peduncle is steep on dorsal side (particularly in smaller fish)
3. Overlapping scales form a distinct diamond-shaped lattice pattern, particularly clear on posterior end of fish
4. Barbels on sides of upper jaw
5. Scales very large and thick

Unique identifiers

(1); (2,3)*; (2,4); (2,5); (3,4)

Note

(2,3)* see peamouth, Catostomidae

Size range

Up to 120 cm; Examined range: 6.0 to 16.1 cm

Allometry equations

SL = 7.75*DS – 11.81	n=9	R^2=0.98
Wt = 0.00001*$SL^{3.18}$	n=8	R^2=0.98
Wt = 0.00001*$FL^{3.16}$	n=8	R^2=0.99

Caloric data

Location	n	kJ/g	SD
All	8	3.743	0.34
River	3	4.000	0.43
Potholes	5	3.605	0.16

Common Carp Diagnostic Cranial Bones

Dentary

Teeth absent, but sensory pores present. Dorsally pointing coronoid process. Notch in posterior end of ventral leg. Ratio of symphyseal margin length to ventral margin length < 0.30. Ratio of dorsal margin length to posterior margin length $\leq$ 1.65.

Hyomandibular

Lateral webbing flattened. Ratio of height of bone to width of head > 2.75.

Opercle

Dorsal ridge less than half of opercle width. Length of the opercular arm is greater than the dorsal-ventral diameter of the articular fossa. The midpoint of the posterior margin is curved, not angular.

Cleithrum

The vertical limb ends in a single point, and the horizontal limb ends with two small lobes. No webbing on the anterior margin of the upper half of the vertical limb.

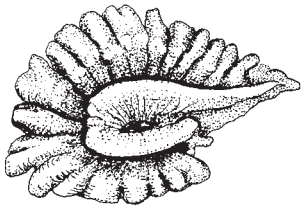
Lower Pharyngeal

Two secondary teeth running perpendicular to the primary teeth.

Common Carp Otoliths

Lagenar otolith

This otolith is oval to tear-drop in shape. The dorsal area anterior margin is wedge-shaped, taking the form of an angular, sharp projection extending well beyond the edge of the anterior margin of the ventral area. The edges of both the dorsal and ventral areas are lined with sharply defined, fine serrations. A small, shallow notch is typically present below the ventral crista. The inner face is slightly concave. The outer face is convex. Both the inner and outer faces are strongly sculpted with deep, finely spaced grooves radiating outward to the otolith margins.



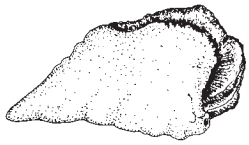
Inner face

Ontogenetic variation

Undetermined

Utricular otolith

The otolith is generally arrowhead shaped and is convex on both the inner and outer faces. The anterior aspect of the inner face does not have a smoothly rounded knob-like tubercle. The posterior margin of the inner face is weakly convex.



Inner face

Ontogenetic variation

Undetermined

Material examined

Description based on 6 pairs of lagenar otoliths (1.3 to 2.3 mm OH) and 7 pairs of utricular otoliths (1.1 to 1.9 OL). Top panel 2.2 mm OH; bottom panel 1.9 mm OL.

Peamouth (*Mylocheilus caurinus*)

Peamouth are common in Washington. They inhabit both lakes and streams, and are tolerant of salt water. Young fish feed on zooplankton and small aquatic insect larvae, while adults feed on a wide range of aquatic invertebrates.

Distinguishing Characteristics

1. Dorsal fin insertion is distinctly anterior to anal fin origin: the distance between dorsal fin insertion and anal fin origin is longer than 1–2 mm
2. Small, slightly subterminal mouth
3. May have a red to pink stripe on side of body
4. Caudal peduncle depth greater than 1/3 the maximum body depth
5. Cross section of caudal peduncle more oval-shaped than round

Unique identifiers

(1)*; (2)*; (3,4); (3,5)

Note

(1)* see Salmonidae, Catostomidae, Ictaluridae

(2)* see sandroller

Additional Information

Can hybridize with northern pikeminnow (Weisel, 1955a, b) and redside shiner (Weisel, 1954)

Size range

Up to 35 cm; Examined range: 4.8 to 26.3 cm

Allometry equations

SL = 2.47*DS + 5.44	n=45	R^2=0.98
Wt = 0.00001*$SL^{3.06}$	n=42	R^2=0.99
Wt = 0.000008*$FL^{3.07}$	n=41	R^2=0.99

Caloric data

Location	n	kJ/g	SD
River	6	5.152	0.74

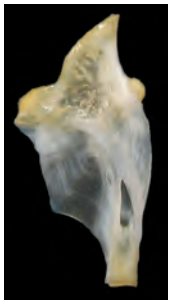
Peamouth Diagnostic Cranial Bones

Dentary

No teeth. Dorsally-pointing coronoid process. Ratio of symphyseal margin length to ventral margin length < 0.30. Ratio of dorsal margin length to posterior margin length $\leq$ 1.65.

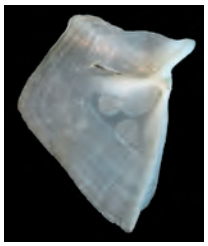
Hyomandibular

Lateral webbing is flattened. The upper lateral webbing is confined to a point on the posterior end of the head. Ratio of height of bone to width of head is between 2 and 2.75.



Opercle

Dorsal ridge less than half of opercle width. Length of the opercular arm is greater than the dorsal-ventral diameter of the articular fossa. The midpoint of the posterior margin is distinctly angular. Ratio of dorsal margin length to dorsal crest length < 0.70. Ratio of anterior margin length to dorsal crest length < 1.00. Ratio of anterior margin length to dorsal margin length $\leq$ 2.00.

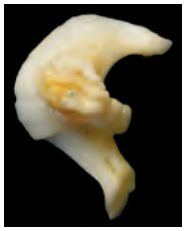


Cleithrum

The vertical and horizontal limbs end in a single point or lobe. The medial process at the end of the horizontal limb forms a small hook, with a square end at the ventral tip of the horizontal limb. When viewed laterally, the shelf formed by the horizontal limb is not visible.

Lower Pharyngeal

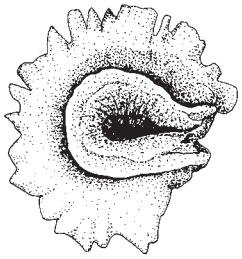
Pharyngeal very wide. Teeth molar like. One secondary tooth.



Peamouth Otoliths

Lagenar otolith

This otolith is generally circular in shape with a flattened anterior edge. The otolith margins are lined with irregularly spaced heavy, rather blunt, long dentate projections. Typically the ventral crista extends beyond the ostium to form a blunt lobe-like projection in large specimens, but can appear somewhat pointed in smaller ones. Due to the raised, thick cristae and the tapering of the dorsal and ventral areas outward toward the otolith margin the inner face of this otolith is convex in shape. The dorsal and ventral cristae are also comparatively thick and rounded on the outer edges. Scalloping on the outer face radiating inward from the crenellations on the margins is regular and clearly evident.



Inner face

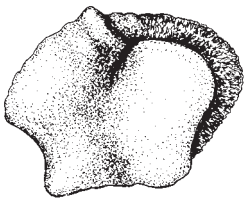
Dorsal view

Ontogenetic variation

The dentate projections on the otolith margins generally become thicker and more elaborate with age. In larger otoliths many of the projections become square tipped.

Utricular otolith

The anterior aspect of the inner face has a smoothly rounded knob-like tubercle on dorsal margin. The outer margins of the dorsal knob-like tubercle are rounded and have a faint symmetrically bilobed appearance. The concave, flared posterior margin of the inner face is generally rounded in shape but has a steep slope on the edge opposite the sulcus. Typically, there is a prominent lobe-like projection protruding at an obtuse angle at the dorsal insertion of the sulcus.



Inner face

Ontogenetic variation

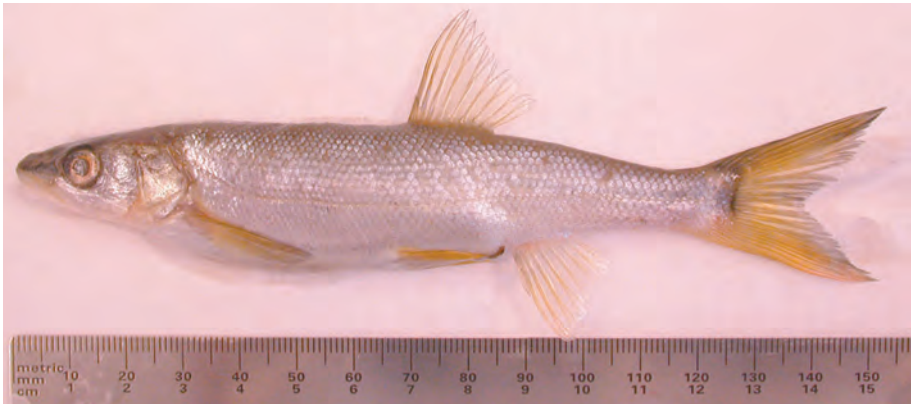
The concavity of the inner face of the posterior area increases with age to a degree that in some larger otoliths the posterior margin becomes cup-shaped.

Material examined

Description based on 9 pairs of lagenar otoliths (1.8 to 3.7 mm OH) and 10 pairs of utricular otoliths (1.7 to 3.9 OL). Top two panels 3.6 mm OH; bottom panel 3.4 mm OL.

Northern Pikeminnow (*Ptychocheilus oregonensis*)

Northern pikeminnow are abundant in the Columbia River. They prefer slow moving water, and will stay in relatively shallow areas. The young tend to eat aquatic invertebrates, feeding on crayfish and other fish as they grow.



Distinguishing Characteristics

1. Small, distinct black spot on base of caudal fin
2. Maxillary extends at least to anterior margin of eye
3. Terminal mouth
4. Dorsal fin insertion is almost directly above or slightly anterior to anal fin origin
5. Caudal peduncle depth greater than 1/3 maximum body depth
6. Cross section of caudal peduncle more oval-shaped than round

Unique identifiers

(1); (2)*; (3,4); (4,5); (4,6)

Note

(2)* see sandroller, Salmonidae, some Centrarchidae, Cottidae

Additional Information

Can hybridize with chiselmouth (Wydoski and Whitney, 2003), peamouth (Weisel, 1955a, b), and redside shiner (Scott and Crossman, 1973)

Size range

Up to 50 cm; Examined range: 3.3 to 31.7 cm

Allometry equations

SL = 3.02*DS + 0.96	n=110	R^2=0.99
Wt = 0.000006*$SL^{3.19}$	n=99	R^2=0.99
Wt = 0.000004*$FL^{3.20}$	n=98	R^2=0.99

Caloric data

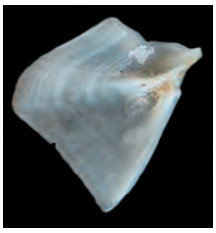
Location	n	kJ/g	SD
River	6	4.511	0.60

Northern Pikeminnow Diagnostic Cranial Bones

Dentary
No teeth. Nine or more sensory pores.

Hyomandibular
Anterior crest has a distinct dip near the anterior process. Ratio of height of bone to width of head < 2.

Opercle
Opercle is opaque. Dorsal ridge less than half of the opercle width. Anterior margin may be greater than 15 mm. Length of opercular arm is greater than the dorsal-ventral diameter of the articular fossa.



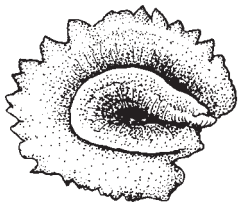
Cleithrum
Vertical and horizontal limbs end in a single point or lobe. Medial process at end of horizontal limb forms a short shelf or hook, tapering at the ventral tip of the horizontal limb. Edge of dorso-posterior lobe is a smooth curve.

Lower Pharyngeal
The pharyngeal is narrow. Teeth are canine-like, with two secondary teeth running parallel to the primary row.

Northern Pikeminnow Otoliths

Lagenar otolith

This otolith is slightly oval with a blunt anterior edge. The otolith margins are lined with rather regularly spaced delicate, dentate, spine-like projections. Typically the ventral crista extends beyond the ostium to form a blunt lobe-like projection in large specimens but can appear somewhat pointed in smaller ones. There is a deep v-shaped notch on the anterior edge below the ventral crista. The inner face of this otolith is flat or nearly so. Scalloping on the outer face radiating inward from the crenellations on the margins is regular and clearly evident.



Inner face

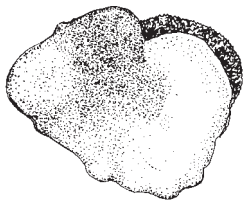
Dorsal view

Ontogenetic variation

The dentate projections on the otolith margins generally become thicker and more elaborate with age.

Utricular otolith

The anterior aspect of the inner face has a smoothly rounded knob-like tubercle on dorsal margin. The outer margins of the dorsal knob-like tubercle are rounded and somewhat bilobed in appearance. The concave flared posterior edge of the inner face is smoothly rounded. The flared ventral margin of the inner face is generally rounded and has a distinct slope toward the lateral termination of the sulcus.



Inner face

Ontogenetic variation

The concave condition of the inner face of the posterior area increases with age.

Material examined

Description based on 45 pairs of lagenar otoliths (0.9 to 3.9 mm OH) and 45 pairs of utricular otoliths (0.9 to 3.7 OL). Top two panels 2.2 mm OH; bottom panel 2.1 mm OL.

Comment

Pikeminnow and chiselmouth are reported to hybridize (Wydoski and Whitney, 2003). The utricular otoliths of these two species are so similar it is not advisable, even under the best of conditions, to use them as the sole basis for discriminating between these two species. The lagenar otoliths, on the other hand, can in most cases be reliably identified to species. However, there are exceptions, where the diagnostic features are intermediate between the two. These cases typically relate to situations where it is difficult to discern whether the anterior edge of the otolith below the ventral crista has a c or v-shaped notch.

Speckled Dace (*Rhinichthys osculus*)

Speckled dace are found throughout the Columbia River Basin. They inhabit cold streams and lakes and feed on small benthic invertebrates and plant material.

Distinguishing Characteristics

1. Outer margin of anal fin convex or straight; fin contains 6–7 rays
2. Dorsal fin insertion is posterior to anal fin origin
3. Forked caudal fin

Unique identifiers
(1,2,3)

Size range
Up to 10 cm; Examined range: 5.0 to 7.0 cm

Allometry equations
Insufficient sample size for allometry

Caloric data

Location	n	kJ/g	SD
River	2	4.558	0.60

Speckled Dace Diagnostic Cranial Bones

Hyomandibular

Ratio of height of bone to width of head < 2. Anterior webbing with convex edge. The opercular process is convex.

Opercle

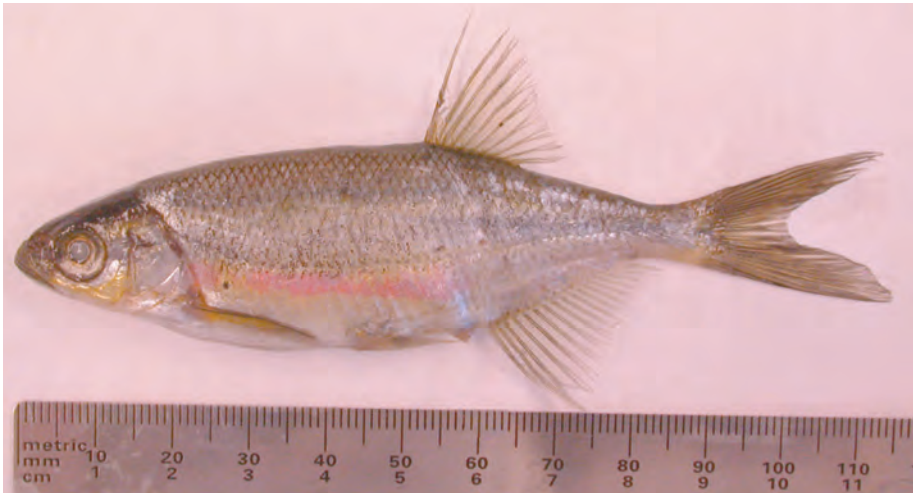
Dorsal ridge less than half of opercle width. Length of opercular arm is greater than the dorsal-ventral diameter of the articular fossa. The midpoint of the posterior margin protrudes and is distinctly angular. Ratio of dorsal margin length to dorsal crest length $\geq$ 0.70.

Cleithrum

Vertical and horizontal limbs end in a single point or lobe. The medial process at the end of the horizontal limb forms a short shelf or hook, tapering at the ventral tip of the horizontal limb. The edge of dorso-posterior lobe comes to a distinct point.

Redside Shiner (*Richardsonius balteatus*)

The redside shiner is found throughout Washington in lakes and ponds, as well as rivers and streams with slow currents. The young feed on zooplankton and algae and the adults feed on aquatic insects and snails as well as zooplankton when they are in pelagic areas.



Distinguishing Characteristics

1. Long anal fin that inserts near caudal peduncle
2. Often with a thick, bright red or yellow stripe on side of body
3. Caudal peduncle depth much less than 1/3 the maximum body depth

Unique identifiers

(1); (2,3)

Additional information

Can hybridize with peamouth (Weisel, 1954), northern pikeminnow (Scott and Crossman, 1973), and chiselmouth (Smith, 1973)

Size range

Up to 15 cm; Examined range: 2.6 to 12.0 cm

Allometry equations

SL = 3.56*DS - 0.53	n=103	R^2=0.98
Wt = 0.000002*$SL^{3.51}$	n=72	R^2=0.99
Wt = 0.000001*$FL^{3.53}$	n=69	R^2=0.99

Caloric data

Location	n	kJ/g	SD
River	6	4.067	0.71

Redside Shiner Diagnostic Cranial Bones

Dentary

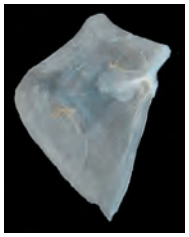
No teeth. Dorsally pointing coronoid process. Ratio of sympyseal margin length to ventral margin length < 0.30. Ratio of dorsal margin length to posterior margin length > 1.65.

Hyomandibular

Lateral webbing is flattened. The upper lateral webbing is confined to a lobe on the posterior end of the head. Ratio of height of bone to width of head between 2 and 2.75.

Opercle

Opercle is transluscent. Dorsal ridge less than half of opercle width. Length of opercular arm less than dorsal-ventral diameter of articular fossa. Anterior margin less than 15 mm.



Cleithrum

The vertical and horizontal limbs end in a single point or lobe. The medial process at the end of the horizontal limb forms a short shelf or hook, with a square end at the ventral tip of the horizontal limb. When viewed laterally, the shelf formed by the horizontal limb is visible.

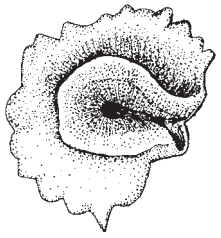
Lower Pharyngeal

Two secondary teeth running parallel to primary teeth. Distinct protrusion on lateral margin.

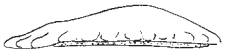
Redside Shiner Otoliths

Lagenar otolith

This otolith is generally circular in shape. The ostial side is decidedly flattened and the anterior margins of the dorsal and ventral areas are near parallel. There is no pronounced notch or concavity on the ventral margin below the ventral crista. The otolith margins are lined with numerous, rather regularly spaced, comparatively short dentate projections, which are generally more pronounced in the dorsal area. In some otoliths the ventral portion of the crista extends anteriorly beyond the ostium to form a sharp spike-like projection. The inner face is flat or nearly so. The outer face is convex. Scalloping on the outer face radiating inward from the margins is regular but shallow and difficult to discern, particularly in the ventral area.



Inner face



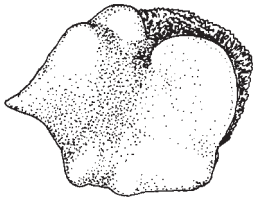
Dorsal view

Ontogenetic variation

The dentate projections on the otolith margins generally become thicker and more elaborate with age.

Utricular otolith

The anterior aspect of the inner face has a smoothly rounded knob-like tubercle on the dorsal margin. The concave, flared posterior portion of the inner face is short and terminates in a raised, sharp projection. This sharp–edged projection typically curves slightly inward.



Inner face

Ontogenetic variation

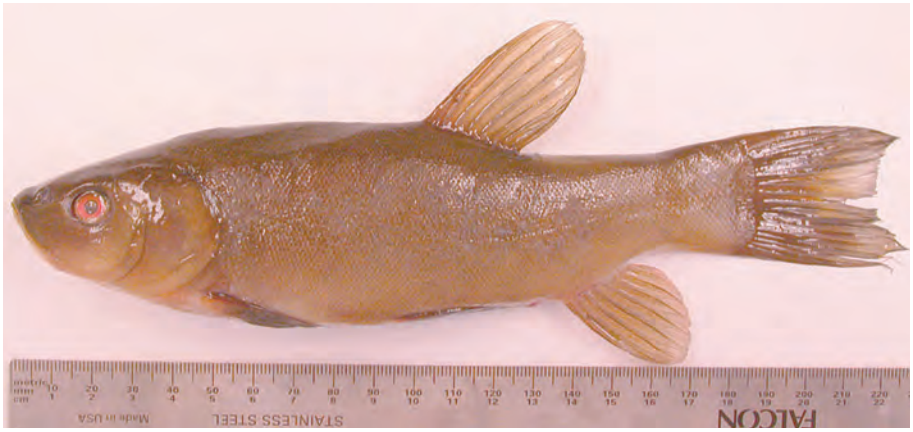
The degree of concavity of the inner face of the posterior area increases with age.

Material examined

Description based on 17 pairs of lagenar otoliths (1.5 to 2.6 mm OH) and 23 pairs of utricular otoliths (1.0 to 2.1 mm OL). Top two panels 2.2 mm OH; bottom panel 1.9 mm OL.

Tench (*Tinca tinca*)

Tench are an introduced species found sporadically throughout the Columbia River. They prefer shallow areas of lakes and ponds with dense aquatic vegetation. They eat zooplankton and algae when young, graduating to aquatic insects and other invertebrates.



Distinguishing Characteristics

1. Body and fins almost uniformly dark olive-brown
2. Caudal fin with square, blunt end; not forked
3. Caudal peduncle depth almost half the maximum body depth
4. Barbels shorter than snout

Unique identifiers

(1)*; (2,3)*; (2,4); (3,4)*

Note

(1)* see bullhead, walleye, Salmonidae, some Catostomidae
(2,3)* see bullhead
(3,4)* see bullhead

Size range Up to 45 cm; Examined range: 12.8 to 32.6 cm

Allometry equations

SL = 2.86*DS + 26.39	n=28	R^2=0.90
Wt = 0.00003*$SL^{2.97}$	n=26	R^2=0.94
Wt = 0.0013*$FL^{2.16}$	n=25	R^2=0.69

Caloric data

Location	n	kJ/g	SD
River	6	3.411	0.47

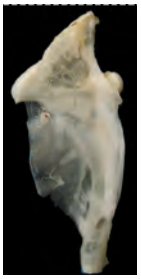
Tench Diagnostic Cranial Bones

Dentary

No teeth or sensory pores. Relatively straight ventral margin and a pronounced dorsally pointing coronoid process.

Hyomandibular

Anterior webbing does not extend beyond opercular process. Lateral webbing oriented posteriorly, or posterio-laterally to surface of head and body. Upper lateral webbing extends from posterior process across most of the head. Opercular process protrudes and is round. Ratio of height of bone to width of head is between 2 and 2.75.



Opercle

Dorsal ridge does not extend to posterior margin. Length of opercular arm greater than dorsal-ventral diameter of articular fossa. Midpoint of posterior margin protrudes and is distinctly angular. Ratio of dorsal margin length to dorsal crest length ≥ 1. Ratio of anterior margin length to dorsal margin length > 2.

Cleithrum

Vertical limb ends in a single point, horizontal limb with two points. Slight but distinct webbing on the upper half of the vertical limb extending out from anterior margin.

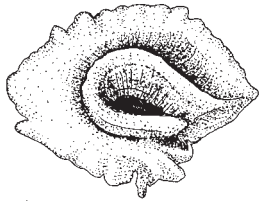
Lower Pharyngeal

Teeth are broad and molar-like. No secondary teeth. Tip of dorsal leg flattened.

Tench Otoliths

Lagenar otolith

This otolith is generally oval in shape. The dorsal area anterior edge is wedge-shaped, taking the form of an angular, sharp projection extending well beyond the edge of the anterior margin of the ventral area. Regular, low profile scalloping is present almost exclusively on the dorsal area edges. The ventral area edge is typically smooth. Scalloping on the outer face is clearly evident and radiates outward from the otolith base to dorsal area margin. A blunt, finger-like projection is typically present below the ventral crista on the anterior margin of the ventral area.



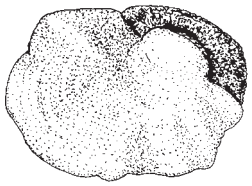
Inner face

Ontogenetic variation

Negligible

Utricular otolith

The inner face is generally fan-shaped. The anterior aspect of the inner face has a single, pronounced smoothly rounded knob-like tubercle on the dorsal margin. The posterior margin of the inner face ranges from flat to slightly concave with broadly rounded edges.



Inner face

Ontogenetic variation

Negligible

Material examined

Description based on 13 pairs of lagenar otoliths (1.9 to 3.2 mm OH) and 13 pairs of utricular otoliths (2.1 to 2.9 OL). Top panel 2.7 mm OH; bottom panel 2.8 mm OL.

Largescale Sucker (*Catostomus macrocheilus*)

Largescale suckers are the most common sucker in Washington State. They inhabit lakes and streams prefering cooler water. All suckers have protrusible mouths which they use to search the substrate for food.

Distinguishing Characteristics

Due to the amount of hybridization, sucker identification can be extremely difficult. Refer to the family page for a guide to common sucker characteristics.

Size range

Up to 60 cm; Examined range: 8.4 to 41.6 cm

Allometry equations

SL = 3.00*DS + 7.17 n=54
Wt = 0.00004*$SL^{2.84}$ n=9
Wt = 0.00002*$FL^{2.90}$ n=9

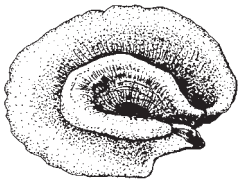
Caloric data

R^2=0.99	Location	n	kJ/g	SD
R^2=0.98	River	6	4.583	0.76
R^2=0.98				

Largescale Sucker Otoliths

Lagenar otolith

This otolith is oval in shape. The entire margin of the otolith is scalloped in appearance with rather regularly spaced low profile, rounded lobe-like projections. On the outer face, deep grooves radiating from the center outward to scalloped edges are evident. The anterior edge of the ventral crista typically forms a sharp projection that does not extend beyond the anterior edge of the dorsal area.



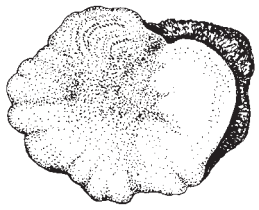
Inner face

Ontogenetic variation

Negligible

Utricular otolith

Posterior area of the inner face ranges from flat to weakly concave. The posterior half of the inner face is fan-shaped with faint grooves radiating out to thick, smoothly rounded edges. The edges of the posterior margin are irregularly lobed.



Inner face

Ontogenetic variation

Negligible

Material examined

Description based on 22 pairs of lagenar otoliths (1.1 to 2.7 mm OH) and 32 pairs of utricular otoliths (1.3 to 2.8 OL). Top panel 2.7 mm OH; bottom panel 2.8 mm OL.

Bullhead (*Ameiurus spp.*)

Black and yellow bullhead are rare in Washington, found sporadically through the lower and mid Columbia River. The brown bullhead is more common on the Columbia. They are opportunistic feeders consuming a variety of aquatic invertebrates and plant material. Bullhead have been introduced to Washington State.

Distinguishing Characteristics

1. Body uniformly dark with no distinct spots
2. Caudal fin slightly indented to straight-edged
3. Adipose fin

Unique identifiers
(1,2,3)

Yellow bullhead (Ameiurus natalis)
Brown bullhead (Ameiurus nebulosus) (photo)
Black bullhead (Ameiurus melas)

Due to small sample size of all bullhead species, size range and calorimetry are a combination of all three species.

Species	*Chin Barbels*	*Fin Membranes*	*Anal Fin Ray Count*	*Caudal Fin Shape*	*Barbs on Pectoral Spine*	*Maximum Length*
Black bullhead	Grey to black	Jet black	16–22	Indented	Strong	66 cm
Brown bullhead	Grey to black	Seldom black	21–24	Indented	Weak to absent	55 cm
Yellow bullhead	White to yellow		23–28	Rounded		47 cm

Size range

Up to 66cm; Examined range: 4.5 to 25.4 cm

Caloric data

Location	n	kJ/g	SD
All	9	4.442	0.66
River	4	4.556	0.87
Potholes	5	4.351	0.52

Bullhead Diagnostic Cranial Bones

Dentary

Multiple rows of similarly shaped teeth. Sensory pores create obvious pits. The body gradually tapers as it reaches the symphyseal margin, making anterior third of the dentary wide. Ratio of ventral leg width to dorsal leg width < 2.8. Ratio of fork depth to dorsal margin length $\leq$ 0.30.

Hyomandibular

The anterior webbing is jagged and extends ventrally beyond the ventral process.

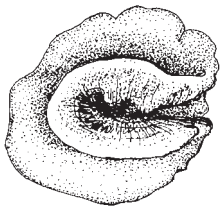
Cleithrum

The vertical limb has three processes, with the middle process extending beyond a line drawn between the tips of the first and third processes.

Brown Bullhead Otoliths

Lagenar otolith

This otolith has a circular shape with a flattened anterior edge. The otolith margins are generally smooth with no evidence of dentate projections. The scalloping of the margins is very subtle with only faintly rounded lobes evident on the dorsal edge. Typically, blunt, lobe-like extensions of the dorsal and the ventral cristae protrude slightly beyond the anterior edge giving the flat face of the otolith a bilobed appearance. The surface of the outer face is generally without grooves radiating inward from the margins.



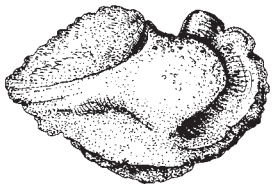
Inner face

Ontogenetic variation

Undetermined

Utricular otolith

Only the posterior half of the inner and outer face is convex. The outer face is concave. Typically there is a pronounced notch at the dorsal insertion of the sulcus. On the inner face, a faintly raised ridge extending from the anterior thickening to the posterior margin is also commonly present.



Inner face

Ontogenetic variation

Undetermined

Material examined

Description based on 4 pairs of lagenar otoliths (1.8 to 2.0 mm OH) and 4 pairs of utricular otoliths (2.7 to 3.0 OL). Top panel 1.8 mm OH; bottom panel 3.0 mm OL.

Channel Catfish (*Ictalurus punctatus*)

Channel catfish have been introduced in Washington and are inhabit the mid and lower Columbia River. They are most often found in clear lakes, reservoirs, and streams, but can also tolerate turbid conditions. Smaller catfish eat aquatic insects and small fish, and catfish greater than 30 cm are primarily piscivorous.

Distinguishing Characteristics

1. Caudal fin deeply forked
2. Sides of body have distinct dark spots on light background

Unique identifiers

(1)*; (2)*

Note

(1)* see walleye, some Salmonidae, some Cyprinidae, Catostomidae

(2)* see black crappie, some Salmonidae

Size range

Up to 100 cm; Examined range: 21.6 to 33.0 cm

Allometry equations

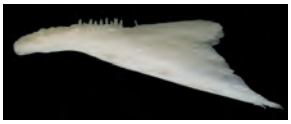
SL = 21.61*DS + 11.6	n=4	R^2=0.99
Wt = 0.0001*$SL^{2.65}$	n=7	R^2=0.95
Wt = 0.0002*$FL^{2.54}$	n=7	R^2=0.97

Caloric data

Location	n	kJ/g	SD
River	3	6.522	0.74

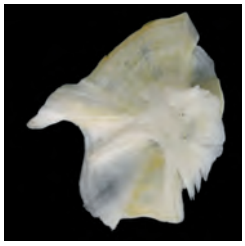
Channel Catfish Diagnostic Cranial Bones

Dentary



Multiple rows of similarly shaped teeth. Sensory pores create subtle pits. The body tapers quickly, making the anterior third of the dentary narrow. Ratio of ventral leg width to dorsal leg width < 2.8. Ratio of fork depth to dorsal margin length $\leq$ 0.3.

Hyomandibular



The anterior webbing extends ventrally beyond the opercular process. The upper edge of the anterior webbing is smooth edged and concave; the lower edge of the webbing is jagged.

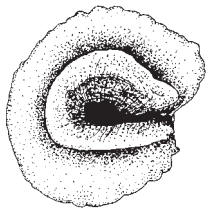
Cleithrum

Vertical limb with three processes. The middle process does not extend beyond a line drawn between the tips of the first and third processes.

Channel Catfish Otoliths

Lagenar otolith

Very similar, probably indistinguishable, to that of the brown bullhead described previously (p. 56).



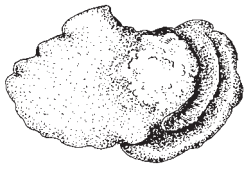
Inner face

Ontogenetic variation

Undetermined

Utricular otolith

The posterior half of both the inner and outer face is convex. Typically, there is a pronounced notch at the dorsal insertion of the sulcus. On the inner face, there is no trace of a faintly raised ridge extending from the anterior thickening to the posterior margin.



Inner face

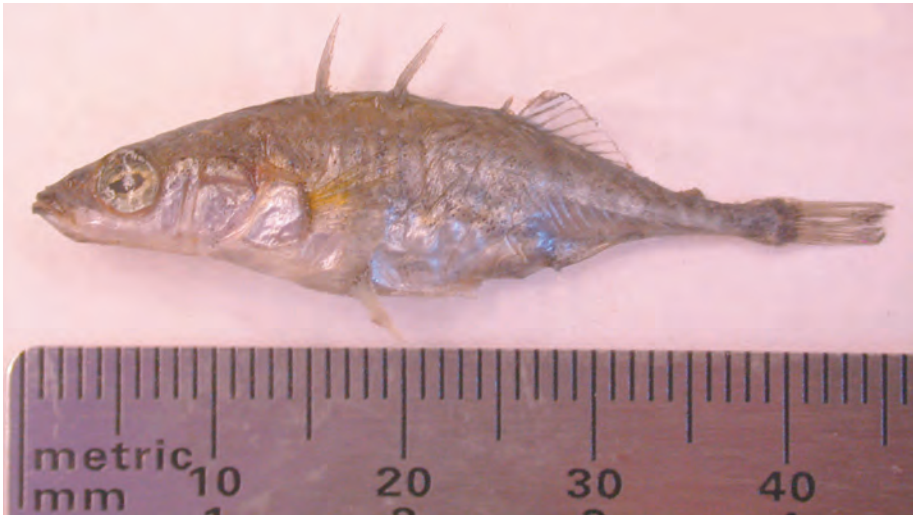
Ontogenetic variation

Undetermined

Material examined

Description based on 2 pairs of lagenar otoliths (1.8 to 2.2 mm OH) and 6 pairs of utricular otoliths (3.0 to 4.0 OL). Top panel 2.2 mm OH; bottom panel 3.4 mm OL.

Three-spine Stickleback (*Gasterosteus aculeatus*)



Three-spine sticklebacks are found in the lower and mid Columbia River. They inhabit slow–moving water and lakes, and are tolerant of saltwater. Sticklebacks will eat anything from algae to small invertebrates.

Distinguishing Characteristics

1. 3–5 prominent spines in anterior part of dorsal fin, with no membranes between the spines
2. Pelvic fins modified into prominent spines on sides of body

Unique Identifiers
(1); (2)

Size range
Up to 10 cm; Examined range: 2.4 to 7.7 cm

Allometry equations

SL = 2.45*DS + 1.74	n=277	R^2=0.94
Wt = 0.000002*$SL^{3.55}$	n=216	R^2=0.91
Wt = 0.000001*$TL^{3.53}$	n=215	R^2=0.92

Caloric data

Location	n	kJ/g	SD
River	6	4.803	0.80

Dorsal standard measurement taken from base of third spine to end of hypural bones

Three-spine Stickleback Diagnostic Cranial Bones

Dentary

More than one row of similarly shaped teeth present. Coronoid process flattened into a spatulate shape.

Hyomandibular

Lateral webbing oriented perpendicular to lateral surface of head and body. Anterior crest is thin and membranous. Ratio of height of bone to width of head < 2.

Opercle

Radial striations present throughout opercle.

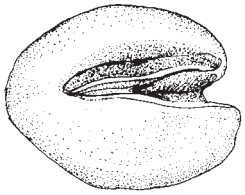
Cleithrum

Vertical and horizontal limbs end in a single point or lobe. Dorso-posterior lobe is a distinct triangular shape, giving the cleithrum a distinct T-shape.

Three-spine Stickleback Otoliths

Saccular otolith

Otoliths from this species are very small, typically less than 1 mm OL. The otolith shape is round to square in shape. The rostrum is very short with a bluntly rounded tip and frequently difficult to distinguish from the antirostrum which is similar in size and shape. The sulcus is very narrow, deep, and closed at the posterior end. Above the sulcus is a flat area that frequently demonstrates tiny radial striations. The otolith margins are generally smooth, without crenulations or scalloping. The outer face is strongly convex. The otolith appears thick for its size.



Inner face

Dorsal view

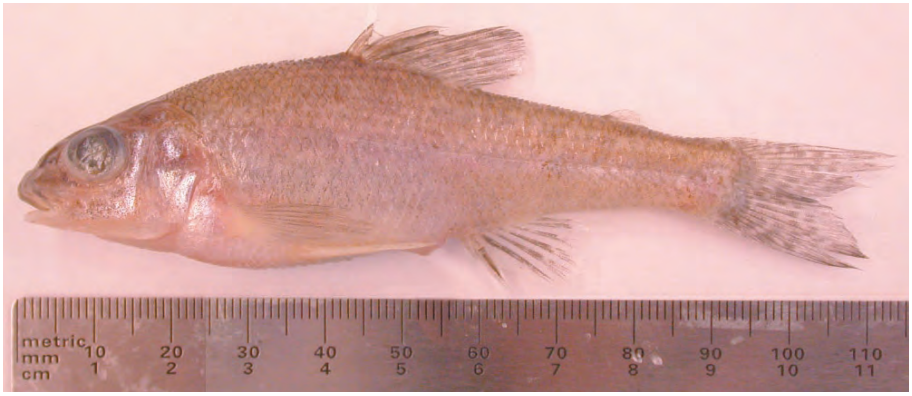
Ontogenetic variation

Negligible

Material examined

Description based on 16 pairs of otoliths (0.4 to 0.9 mm OL). Both panels 0.8 mm OL.

Sandroller (*Percopsis transmontana*)



Sandrollers are found in the lower and mid Columbia River. They live in quiet backwaters and in streams with cover. Sandrollers feed primarily on zooplankton and small aquatic insects.

Distinguishing Characteristics

1. Adipose fin
2. Scales ctenoid (feels rough when scales are stroked toward the head)
3. Two spines in both the dorsal and anal fins, one spine present in each pelvic fin, with membranes between all spines and rays
4. Caudal fin has vertical brown stripes
5. Body has distinct brown mottled pattern

Unique identifiers

(1,2); (1,3); (1,4); (1,5); (4,5)

Size range

Up to 12 cm; Examined range: 4.1 to 10.8 cm

Allometry equations

SL = 2.95*DS - 1.37	n=64	R^2=0.98
Wt = 0.00002*$SL^{3.08}$	n=64	R^2=0.99
Wt = 0.000009*$FL^{3.12}$	n=61	R^2=0.99

Caloric data

Location	n	kJ/g	SD
River	7	4.441	0.51

Sandroller Diagnostic Cranial Bones

Dentary

Multiple rows of similarly shaped teeth. Ratio of ventral leg width to dorsal leg width ≥ 2.8.

Hyomandibular

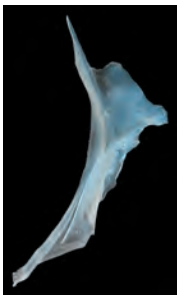
Anterior webbing smooth edged and gradually tapers into ventral process. Ratio of height of bone to width of head < 2.

Opercle

Dorsal ridge extends to posterior margin. Anterior ridge extends ventrally beyond the webbing that lies between the dorsal and anterior ridges.

Cleithrum

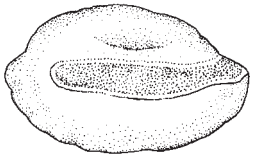
Vertical and horizontal limbs end in a single point or lobe. Medial process at end of horizontal limb is smooth and angles into ventral tip. Heel caudally projecting. Notch at base of dorsal spine.



Sandroller Otoliths

Saccular otolith

The otolith is oval in shape. The ostium is moderate in size with a very weakly developed–to–absent antirostrum. The rostrum is broad with a rounded tip. The otolith edges are typically smooth. Sculpturing of otolith edges, when present, are broadly lobate and very subtle. The sulcus is very shallow with poorly delineated edges. Dorsal and ventral cristae are absent. The outer face is slightly concave to almost flat in configuration. Generally, otoliths from this species appear thick for their size.



Inner face

Dorsal view

Ontogenetic variation

Negligible, faint, fine serrations are seen on the ventral area margins on otoliths of some juveniles.

Material examined

Description based on 16 otoliths (2.2 to 5.1 mm OL). Both panels 4.1 mm OL.

Pumpkinseed (*Lepomis gibbosus*)

Pumpkinseed are a common introduced species found in the Columbia River. They prefer warm, shallow water with dense vegetation and are not typically found in open water. Pumpkinseed feed on aquatic invertebrates.

Distinguishing Characteristics

1. Opercular flap mostly black, but dorsal and ventral margins are white and posterior margin is red in fresh specimens
2. Small brown spots on lighter-colored membranes of caudal fin and posterior half of dorsal fin
3. Posterior portion of opercle bone stiff
4. Very compressed and deep body

Unique identifiers
(1); (2,3); (2,4); (3,4)

Additional information
Can hybridize with bluegill (Konkle and Philipp, 1992; Schwartz, 1981)

Size range
Up to 20 cm; Examined range: 6.0 to 16.6 cm

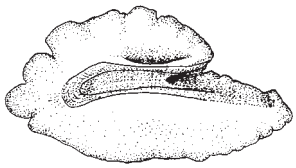
Allometry equations

SL = 4.94*DS + 4.22	n=36	R^2=0.91
Wt = 0.00002*$SL^{3.15}$	n=33	R^2=0.97
Wt = 0.00001*$FL^{3.15}$	n=31	R^2=0.97

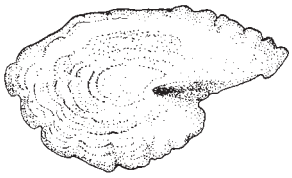
Caloric data

Location	n	kJ/g	SD
River	6	3.950	0.34

Pumpkinseed Otoliths



Inner face



Outer face

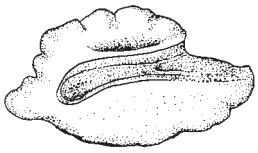
Dorsal view

Saccular otoliths

The otolith is oval in shape. The ostium is narrow with a weakly developed antirostrum. The rostrum is slender and generally tapers rapidly to a point at the tip, which frequently curves outward. The dorsal crista of the sulcus takes the form of a sharply defined ridge. The posterior end of the cauda projects downward. Irregular lobate sculpturing is typically confined to the margins of the dorsal area but also can occur to a lesser extent on the ventral area of the rostrum. In some, the ventral area sculpturing takes the form of fine crenellations on rostrum. The posterior margin of the otolith frequently has a single, somewhat pointed lobe–like extension that tends to curve outward. The outer face of the otolith is decidedly concave. A unique feature of the outer otolith face of this species is that the seasonal growth zones are typically clearly evident, particularly on the posterior half. These take the form of uniformly spaced concentric, raised, circular laminations that persist even in specimens heavily eroded by digestion.

Ontogenetic variation

The degree of concavity of the outer face and lobate sculpturing of the otolith margins generally increases with age. The rostrum also becomes more robust and elongate in otoliths at around 3.5 mm OL.



Inner face

Dorsal view

Material examined

Description based on 9 otoliths (2.9 to 5.6 mm OL). Top three panels 5.3 mm OL; bottom two panels 4.0 mm OL.

Comments

Due to the age–related changes in the shape of the rostrum, large pumpkinseed otoliths (3.5 mm OL or greater) can be difficult to distinguish from those of equivalent sized bluegill. Under these conditions the prominent growth zone laminations on the otolith outer face found in pumpkinseed usually serve to distinguish these two species of *Lepomis*.

Bluegill (*Lepomis macrochirus*)

Bluegill are a common introduced species in the Columbia River. They prefer warm, shallow water with vegetation and will seek out cover. Fry feed on zooplankton, and larger fish feed on aquatic invertebrates with small fish and terrestrial insects occasionally becoming important food sources.

Distinguishing Characteristics

1. Opercular flap black or blue-black
2. Dark spot present on posterior end of dorsal fin (may be indistinct or faint)
3. Posterior portion of opercle bone flexible
4. Very compressed and deep body

Unique identifiers

(1); (2); (3,4)

Additional Information

Can hybridize with pumpkinseed (Konkle and Philipp, 1992; Schwartz, 1981)

Size range

Up to 40 cm; Examined range: 7.1 to 19 cm

Allometry equations

$SL = 5.04*DS + 8.22$	n=50	R^2=0.92
$Wt = 0.00001*SL^{3.29}$	n=49	R^2=0.97
$Wt = 0.000007*FL^{3.27}$	n=48	R^2=0.97

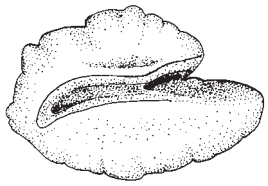
Caloric data

Location	n	kJ/g	SD
All	12	4.430	0.30
River	6	4.357	0.25
Potholes	6	4.503	0.34

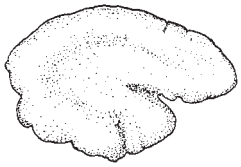
Bluegill Otoliths

Saccular otoliths

This otolith is oval. The ostium is deep with a pronounced, well-developed, robust, rounded antirostrum. Both dorsal and ventral cristae are prominent. The posterior end of the cauda projects downward. The rostrum is broad, typically blunt at the tip, with a slight twist outward at the anterior end. The lobate sculpturing takes the form of extensive shallow crenellations around the margins of both the ventral and dorsal areas but is more predominant dorsally. The shape of the posterior margin of the otolith is generally rounded. The outer face of the otolith ranges from flat to weakly concave in otoliths from small individuals (2.0 to 3.0 mm OL) to concave in otoliths greater than 3.5 mm OL. Otoliths from this species also appear relatively thin for their size.



Inner face



Outer face

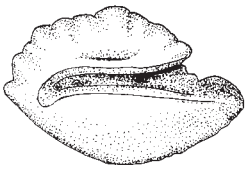
Dorsal view

Ontogenetic variation

Other than the degree of concavity of the outer face increasing with age, there are small changes in otolith shape. Generally, the lobate condition of the dorsal and ventral area margins increases with age.

Material examined

Description based on 28 otoliths (2.1 to 6.9 mm OL). Top three panels 4.8 mm OL; bottom two panels 4.0 mm OL.



Inner face

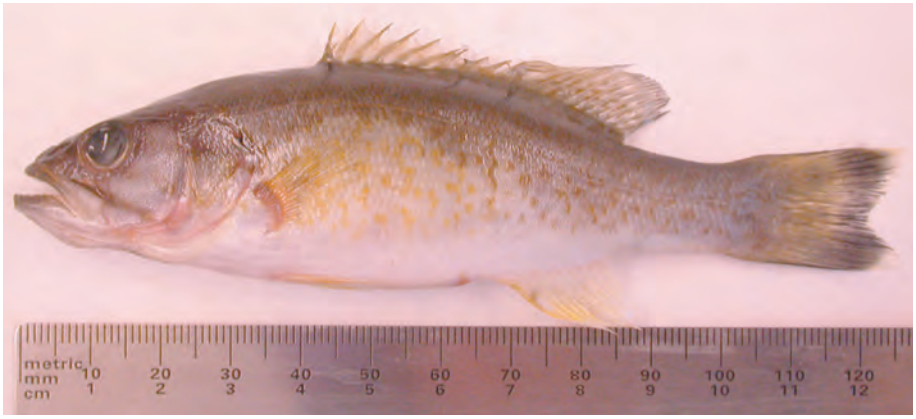
Dorsal view

Comments

Due to the age–related changes in the shape of the rostrum, large bluegill otoliths (3.5 mm OL or greater) can be difficult to distinguish from those of equivalent sized pumpkinseed. Under these conditions the prominent growth zone laminations on the otolith outer face found in pumpkinseed usually serve to distinguish these two species of *Lepomis*.

Smallmouth Bass (*Micropterus dolomieui*)

Smallmouth bass are an introduced species found throughout the Columbia River. They inhabit cool, clear streams and lakes. Like many freshwater piscivores, smallmouth bass begin feeding on zooplankton, moving to aquatic insects and then to fish as they grow.



Distinguishing Characteristics

1. In the anterior dorsal fin lobe, the posterior-most spine (should be the shortest) is more than one-half the length of longest spine
2. Maxillary does not extend past the posterior margin of the eye
3. Fish smaller than 20 cm have three vertical bands on caudal fin, which are orange and yellow at the caudal fin base with a white tip
4. Faint to dark vertical bars on sides of body, but no dark lateral line
5. Dark lines radiate back from eyes

Unique identifiers

(1)*; (3); (2,4)*; (2,5); (4,5)

Note

(1)* see Cottidae

(2,4)* see yellow perch

Additional Information

Can hybridize with largemouth bass (Gomelsky *et al.*, 2004; Schwartz, 1981)

Size range

Up to 45 cm; Examined range: 7.2 to 29.9 cm.

Allometry equations

SL = 6.06*DS - 30.39	n=100	R^2=0.96
Wt = 0.00002*$SL^{3.09}$	n=33	R^2=0.85
Wt = 0.000006*$FL^{3.20}$	n=83	R^2=0.97

Caloric data

Location	n	kJ/g	SD
All	12	5.099	0.74
River	6	4.973	1.03
Potholes	6	5.224	0.17

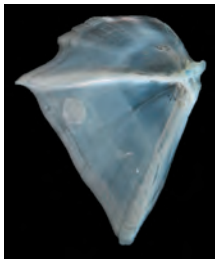
Smallmouth Bass Diagnostic Cranial Bones

Hyomandibular

Anterior webbing extends to ventral end of body and forms a point midway. When viewed from the medial side, the lateral webbing is visible and significantly extends ventrally from the body. Ventral end of lateral webbing forms a sharp notch where it meets the ventral process in most individuals. Ratio of height of bone to width of head < 2.

Opercle

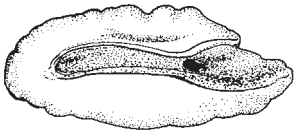
Prominent dorsal crest. Dorsal ridge extends to posterior margin. Anterior ridge terminates at the edge of the webbing that lies between the dorsal and anterior ridges. Posterior margin curved away from junction with posterior end of dorsal ridge. Ratio of dorsal crest height to ridge length $\geq$ 0.30.



Smallmouth Bass Otoliths

Saccular otolith

The otolith is very long and slender in shape. The ostium is shallow with a weakly developed rounded antirostrum. The dorsal crista is sharply defined. The posterior end of the cauda is proportionally very long and terminates in a distinct downward curve. The irregular, lobate sculpturing is typically poorly defined and predominantly confined to the edges of the dorsal area. The shape of the posterior margin of the otolith ranges from weakly rounded to squarish in shape. The outer face of the otolith is concave throughout the indicated size range.



Inner face

Dorsal view

Ontogenetic variation

Negligible change in general shape within the indicated size range. The lobate dorsal area margin is typically irregular in otoliths of juveniles, becoming more organized and broadly rounded in larger specimens. The lobate condition may extend to the posterior margin of the ventral area in otoliths greater than 6.5 mm OL.

Material examined

Description based on 31 otoliths (3.3 to 7.9 mm OL). Both panels 5.3 mm OL.

Largemouth Bass (*Micropterus salmoides*)

Largemouth bass are an introduced species found throughout the Columbia River. They do best in shallow, warm, clear water in weed beds with substrates of mud and organic material. Smaller fish feed primarily on aquatic insects, and larger fish are extensively piscivorous.

Distinguishing Characteristics

1. In the anterior dorsal fin lobe, the posterior-most spine (should be the shortest) is less than one-half the length of longest spine
2. Maxillary extends past the posterior margin of the eye
3. Fish smaller than 25 cm have a thick, irregular, dark lateral stripe along lateral line (broken, inconspicuous, or absent in fish larger than 25 cm)

Unique identifiers

(1)*; (2)*; (3)

Note

(1)* see Cottidae

(2)* see Salmonidae

Additional Information

Can hybridize with smallmouth bass (Gomelsky *et al.*, 2004; Schwartz, 1981)

Size range

Up to 95 cm; Examined range: 6.8 to 28.2 cm.

Allometry equations

SL = 5.30*DS – 5.76	n=40	R^2=0.93
Wt = 0.00001*$SL^{3.21}$	n=37	R^2=0.99
Wt = 0.000005*$FL^{3.23}$	n=37	R^2=0.99

*C*aloric data

Location	n	kJ/g	SD
All	12	4.472	0.76
River	6	4.595	0.68
Hatchery	6	4.986	0.66

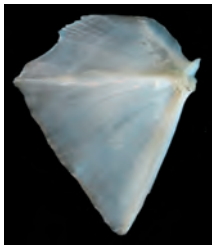
Largemouth Bass Diagnostic Cranial Bones

Hyomandibular

Anterior webbing extends to ventral end of body and forms a point midway. When viewed medially, the lateral webbing extends only slightly posterior, if at all, from the body. Ventral end of lateral webbing tapers as it approaches the opercular process. Ratio of height of bone to width of head < 2.

Opercle

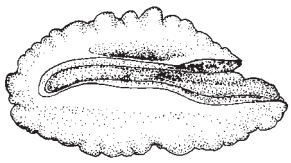
Prominent dorsal crest. The dorsal ridge extends to the posterior margin. Posterior margin near junction with dorsal ridge is straight (may have small curves or shape irregularities). Ratio of dorsal crest height to ridge length $\geq$ 0.30.



Largemouth Bass Otoliths

Saccular otolith

Otoliths from this species are generally oval in outline with an almost teardrop-like shape. The ostium is shallow with a weakly developed but sharp antirostrum. The dorsal crista is sharply defined and the posterior end of the cauda projects downward. The finely lobate sculpturing is extensive around the margins of both the ventral and dorsal areas. The posterior margin is generally rounded. The outer face is concave in otoliths greater than 3.5 mm OL.



Inner face

Dorsal view

Ontogenetic variation

Other than the degree of concavity of the outer face increasing with age mentioned above, there are negligible changes in general shape within the indicated size range.

Material examined

Description based on 9 otoliths (2.4 to 7.7 mm OL). Both panels 5.6 mm OL.

Black Crappie (*Pomoxis nigromaculatus*)

Black crappie are an introduced species found in the reservoirs of the Columbia River, as well as in many lakes in Washington. Smaller black crappie feed on zooplankton, and larger individuals feed on aquatic invertebrates and small fish.

Distinguishing Characteristics

1. Dorsal fin base length approximately equal to the distance from dorsal fin origin to eye
2. 6–9 spines in dorsal fin
3. Sides of body heavily mottled with black, but not striped
4. Very compressed and deep body

Unique identifiers

(1); (2,3); (2,4)

Additional Information

Can hybridize with white crappie (Spier and Ackerson, 2004; Schwartz, 1981)

Size range

Up to 45cm; Examined range: 4.8 to 24.1cm

Allometry equations

$SL = 5.41*DS + 2.11$	n=35	R^2=0.93
$Wt = 0.00001*SL^{3.24}$	n=35	R^2=0.99
$Wt = 0.000006*FL^{3.24}$	n=30	R^2=0.99

Caloric data

Location	n	kJ/g	SD
Potholes	6	5.097	0.34

Black Crappie Diagnostic Cranial Bones

Dentary

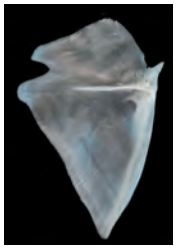
Multiple rows of similarly shaped teeth. The majority of the large cavity just below the dental plate is posterior to the third sensory pore. Ratio of symphyseal margin length to dorsal margin length $\leq$ 0.23.

Hyomandibular

The lateral webbing is oriented perpendicular to the lateral surface of head and body. The tip of the dorsal process forms a sharply pointed protrusion. Ratio of height of bone to width of head $\geq$2.

Opercle

The dorsal ridge extends more than half of the opercle width but does not reach the posterior margin. Opercular arm present. Notch at posterior end of dorsal crest.



Cleithrum

Vertical and horizontal limbs end in a single point or lobe. The medial process at the end of the horizontal limb is smooth and angles into the ventral tip. The heel is ventrally oriented. Ratio of horizontal limb length to dorso-posterior lobe length < 2.2. Angle created by posterior edge of dorsal spine and edge of dorso-posterior lobe > 140 degrees.

Black Crappie Otoliths

Saccular otoliths

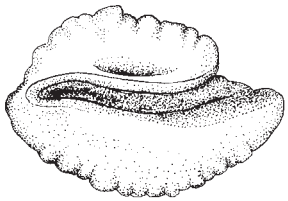
These otoliths are oval. The ostium is large with a well-developed, rounded antirostrum. The rostrum is broad and tapers rapidly upward to a rounded point that curves outward at the tip. A very sharply defined dorsal crista is present almost along the entire sulcus. The posterior end of the cauda extends almost to the posterior edge of the otolith and curves slightly downward. The edges of both the dorsal and ventral areas are elaborately sculptured. The dorsal area edge is covered with large, irregular lobes. The entire edge the ventral area is covered with small, regularly rounded crenellations. The posterior margin of the otolith is generally rounded. The outer face of the otolith is flat to only slightly concave in otoliths around 3.9 mm OL, becoming concave in otoliths over 5.0 mm.

Ontogenetic Variation

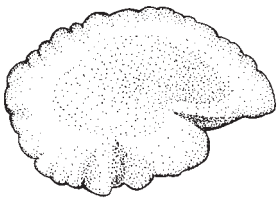
With the exception of the degree of outer face concavity discussed above, there is little change in otolith shape. Generally, the lobed and crenellated condition of the otolith margins becomes more elaborate with age.

Material examined

Description based on 12 otoliths (3.8 to 7.8 mm OL). Top three panels 5.7 mm OL; bottom two panels 3.8 mm OL.

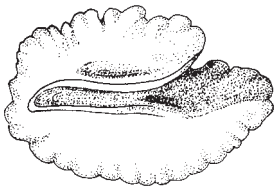


Inner face

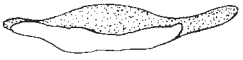


Outer face

Dorsal view



Inner face



Dorsal view

Yellow Perch (*Perca flavescens*)

Yellow perch are an introduced species found throughout the Columbia River. They prefer clear, warm water with rooted vegetation and will stay in shallower depths. Young will feed on zooplankton, moving to aquatic insect larvae, crayfish, and small fish as their size increases.

Distinguishing Characteristics

1. Prominent vertical dark bars on sides of body
2. Anal fin has two spines and 6–8 soft rays
3. Distance between pelvic fins is much less than the length of the base of the pelvic fin (origin to insertion)
4. Dorsal fins are separate, each with an obvious origin and insertion
5. Caudal fin has a shallow fork and rounded lobes

Unique identifiers
(1)*; (2); (3); (4,5)

Note
(1)* see smallmouth bass

Size range
Up to 30 cm; Examined range: 3.7 to 26.1 cm.

Allometry equations

SL = 6.03*DS - 4.49	n=89	R^2=0.98
Wt = 0.00001*$SL^{3.14}$	n=84	R^2=0.99
Wt = 0.000007*$FL^{3.14}$	n=83	R^2=0.99

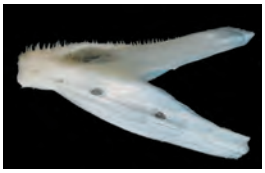
Caloric data

Location	n	kJ/g	SD
All	12	5.087	0.93
River	6	4.362	0.33
Potholes	6	5.813	0.74

Yellow Perch Diagnostic Cranial Bones

Dentary

Multiple rows of similarly shaped teeth present. The majority of the large cavity just below the dental plate is anterior to the third sensory pore. Ratio of symphyseal margin length to dorsal margin length $\leq$ 0.23.



Hyomandibular

Anterior webbing forms an approximate right angle midway down opercular process before terminating prior to ventral process. Ratio of height of bone to width of head < 2.

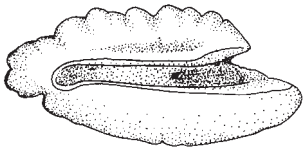
Opercle

Prominant dorsal crest with smooth anterior end. Dorsal ridge extends to posterior margin. Ratio of dorsal crest height to dorsal ridge length < 0.30.

Cleithrum

Vertical and horizontal limbs end in a single point or lobe. Medial process at end of horizontal limb is smooth and angles into ventral tip. Anterior edge of dorsal spine tapers concavely towards the tip. Serrate heel caudally projecting. Ratio of dorsal spine length to vertical limb length < 0.34.

Yellow Perch Otoliths



Inner face

Dorsal view

Saccular otoliths

The otolith is moderately slender in shape. The ostial opening is deep with a distinct antirostrum. The pronounced broadly lobate sculpturing (typically 5 to 8 lobes) is elaborate and almost exclusively confined to the edges of the dorsal area. The posterior end of the otolith typically has a prominent knob-like projection, which frequently has a small indentation near the center, giving it a dimpled or bilobed appearance. The dorsal crista is sharply defined. The terminal portion of the cauda curves downward. The outer face of the otolith is concave throughout the size range examined.

Ontogenetic variation

Negligible change in general shape. The lobate dorsal area margin is typically irregular in otoliths of juveniles, becoming more organized and broadly rounded in larger specimens. The downward curve of the posterior end of the cauda is very slight in juveniles (1.4 to 2.0 mm OL) becoming more pronounced in otoliths of larger individuals. The concave condition of the outer face increases with age. Otoliths 1.4 to 2.0 mm OL are slightly concave while those greater than 4.4 mm OL are decidedly so.

Material examined

Description based on 49 otoliths (1.4 to 5.8 mm OL). Both panels 5.4 mm OL.

Walleye (*Stizostedion vitreum vitreum*)

Walleye are an introduced species found throughout the Columbia River. They inhabit large lakes and rivers in loose schools in open water. Young feed on zooplankton and aquatic insects and will feed almost exclusively on fish by the time they reach 15 cm.

Distinguishing Characteristics

1. Numerous strong, large, often recurved teeth on jaws and premaxillaries
2. Anal fin and lower lobe of caudal fin have white tips
3. Anal fin has two spines and 12–13 soft rays
4. Distance between pelvic fins is about equal to the length of the base of the pelvic fin (origin to insertion)
5. Dorsal fins are separate, each with an obvious origin and insertion
6. Caudal fin forked with pointed lobes

Unique identifiers

(1); (2)*; (3); (4); (5,6)

Note

(2)* see smallmouth bass

Size range

Up to 100 cm; Examined range: 11.4 to 30.6 cm.

Allometry equations

SL = 7.00*DS - 11.35	n=34	R^2=0.91
Wt = 0.000004*$SL^{3.28}$	n=28	R^2=0.99
Wt = 0.000002*$FL^{3.31}$	n=28	R^2=0.99

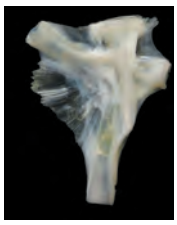
Caloric data

Location	n	kJ/g	SD
Potholes	6	4.658	0.23

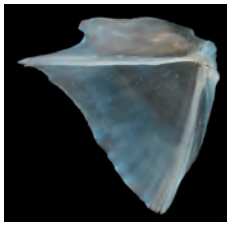
Walleye Diagnostic Cranial Bones

Dentary
Teeth of varying shape and size.

Hyomandibular
Anterior webbing has a jagged edge, and terminates prior to ventral end of ventral process. Ratio of height of bone to width of head < 2.



Opercle
Dorsal ridge extends to posterior margin. Dorsal crest prominent with notch on anterior end. Ratio of dorsal crest height to dorsal ridge length < 0.30.

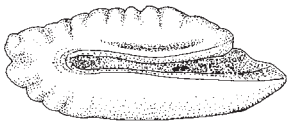


Cleithrum
Vertical and horizontal limbs end in a single point or lobe. Medial process at end of horizontal limb is smooth and angles into ventral tip. Heel caudally-projecting; usually serrate. Dorsal spine gradually tapers toward the tip. Ratio of dorsal spine length to vertical limb length $\geq$ 0.34.

Walleye Otoliths

Saccular otolith

The otolith is long and slender in shape. The ostial opening is deep with a pronounced antirostrum. The posterior end of the cauda may expand slightly but is generally straight in configuration and does not curve downward. The small, poorly defined, irregularly spaced lobate sculpturing is predominantly confined to the dorsal area margins. The posterior edge of the otolith frequently terminates in a prominent lobed knob-like structure. In otoliths from smaller individuals (~ 4.5 mm OL), the outer face of the otolith ranges from weakly concave to almost flat, becoming moderately concave in larger specimens.



Inner face

Dorsal view

Ontogenetic variation

Other than the degree of outer face concavity mentioned above, the lobate dorsal area margin is typically irregular in otoliths of juveniles becoming more organized and sharply defined in those of larger specimens. The lobate condition may extend to the posterior margin of the ventral area in otoliths greater than 5.5 mm OL.

Material examined

Description based on 11 otoliths (4.3 to 6.6 mm OL). Both panels 5.3 mm OL.

Comments

The general otolith shape of walleye otoliths can, on occasion, appear very similar to those of the yellow perch. The diagnostic feature separating the two species is the lack of a downward projection of the posterior end of the cauda in walleye otoliths. The otoliths of walleye are also proportionally thinner than those of yellow perch.

Otolith Introduction

The auditory-equilibrium organ of fishes is made up of three chambers, the sacculus, utriculus and lagena. Each of these chambers contains an otolith: the saggita, lapillus and asteriscus, respectively (Hildebrand 1984). In most teleosts, the saggital otolith is larger than the utricular or lagenar otoliths. As a result, the morphology of the saggital otolith is relied upon to discriminate species, and most descriptive otolith guides deal almost exclusively with the morphology of the saccular or saggital otolith. However, in the Columbia River system, the siluriform (catfishes) and cypriniform (minnows and suckers) fishes are also well represented. These two fish groups differ from the typical plan in that the lapillus and asteriscus otoliths are larger than the saggital otolith. In these fish groups, the saggital otolith typically takes the form of a small, delicate needle-like structure that is rarely found intact in predator stomach contents. Species identification of otoliths from these two orders of fishes relies on the morphology of the asteriscus and / or the lapillus. Due to the need to refer to all three of these otolith types in this study, we use the anatomical rather than the structural terminology for these otoliths and use the terms saccular, lagenar and utricular in the text.

Many of the fish species known to occur in the aquatic bird stomach samples from this region are closely related. As a result, the otolith morphology exhibited is similar and species determination from isolated otoliths can be very difficult in some of the fish families represented. The otolith descriptions in the species pages are based on otoliths removed from intact fish within the size ranges indicated and therefore represent specimens in ideal condition. However, the distinguishing morphologic features of otoliths encountered in stomach samples are compromised to varying degrees by exposure to the digestive process. As a result, it is recommended that the species page descriptions and key should be used primarily as an instructional aid when attempting to identify otoliths in stomach samples from this region. The dichotomous key is designed primarily to highlight the main features distinguishing the species and, consequently, is confined to utilizing only one or two diagnostic characteristics. Because of these limitations, the key should not be used for as the sole source of identification. Rather, it is designed to be used with the species page descriptions in conjunction with actual comparative specimens in an otolith reference collection. The reference otolith series used in this study, including those individual otolith specimens used to prepare the original illustrations, are available at the University of Washington Fish Collection.

Varying degrees of intraspecific and / or ontogenetic variation in otolith morphology is typical in all fish species. As a result, the species page descriptions and key are useful only within the otolith size ranges indicated in the text. Similarly, when evaluating individual otoliths from stomach samples, care must be taken to compare reference otoliths that are of comparable size. To facilitate comparison, standard otolith measurements in millimeters are referred to throughout the text under the *Material Examined* heading. These are otolith

length (OL) and otolith height (OH). With some modification, otolith structure terminology (Fig. 2) used in the text is generally modified from Harkonen (1986) and Hecht and Hecht (1981).

Otoliths of the family Salmonidae

Otolith morphology of many of the closely related salmon species is very similar and, as a result, considerable care must be taken when attempting to distinguish members of this family. Identification problems are compounded by the high degree of inherent ontogenetic and intraspecific variation exhibited in some species. In addition, varying degrees of developmental otolith pathology commonly termed vateritic replacement have been reported to be common in some salmonid species (Casteel 1974, Gauldie 1986). This condition, in which the normal argonite crystalline structure of the otolith is at least partially replaced by vaterite, typically results in varying degrees of otolith malformation. The occurrence of this condition, which Gauldie (1986) has suggested to be both under genetic control as well as influenced by environmental conditions, is also documented to vary regionally (Pearson et al. 1993). In the examined salmonid reference otoliths used for the preparation of the study, vateritic replacement occurred in all four species of *Oncorhynchus* represented. The frequency ranged from uncommon in chinook and sockeye to as high as 88% in coho.

Otoliths of the cypriniform and siluriform fishes

Otoliths in the Cyprinidae, Catostomidae and Ictaluridae are unique. In these families, the saccular otolith is needle-shaped and too small and delicate to be of diagnostic value. The lagenar and utricular otoliths are the largest of the three otolith types and for most species they demonstrate sufficient morphologic detail for species identification. The orientation of lagenar and utricular otoliths can also be readily determined allowing for separation of left and right otoliths for use in determining minimum prey number. In the cypriniform families, Cyprinidae and Catostomidae, the lagenar otoliths exhibit the most useful morphologic detail. However, they can be difficult to identify in stomach content samples because many of their distinguishing features are delicate and are easily compromised by the digestive process. To date, the application of lagenar otoliths in species identification in the siluriform family Ictaluridae remains unresolved and is in need of further investigation.

Utricular otoliths, on the other hand, are more limited in detailed morphological structure. However, the general shape of utricular otoliths appears to differ enough to be useful in distinguishing between most of the common prey species. This is particularly true for the catfishes (Ictaluridae) where, to date, only the utricular otoliths are employed in species identification. Utricular otoliths are also a useful aid in confirming tentative damaged lagenar otolith identifications. In instances where lagenar otoliths have been severely damaged or are absent, they can be reliably used as the sole source of identification and enumeration for some species. Due to the more limited amount of morphologic detail, it is difficult

to convey the subtle species-level differences through written descriptions and single view illustrations. As a result, it is highly recommended when using utricular otoliths for the sole source of species identification that direct side-by-side comparisons with confirmed reference specimens of comparable size be conducted.

Otoliths of the family Ictaluridae

In this family, the utricular otoliths are larger than the lagenar. The lagenar otoliths are small and typically devoid of morphologic detail. As a result, morphology of the utricular otolith seems to be the most reliable for species identification, while that of the lagenar does not seem to be useful even on a generic level. Due to the lack of comparative specimens, only two of the six species of the bullhead catfishes in the study area are presented. As a result, the reader should treat the following descriptions and diagnostic species differences with some caution until additional samples from the other species can be examined and compared.

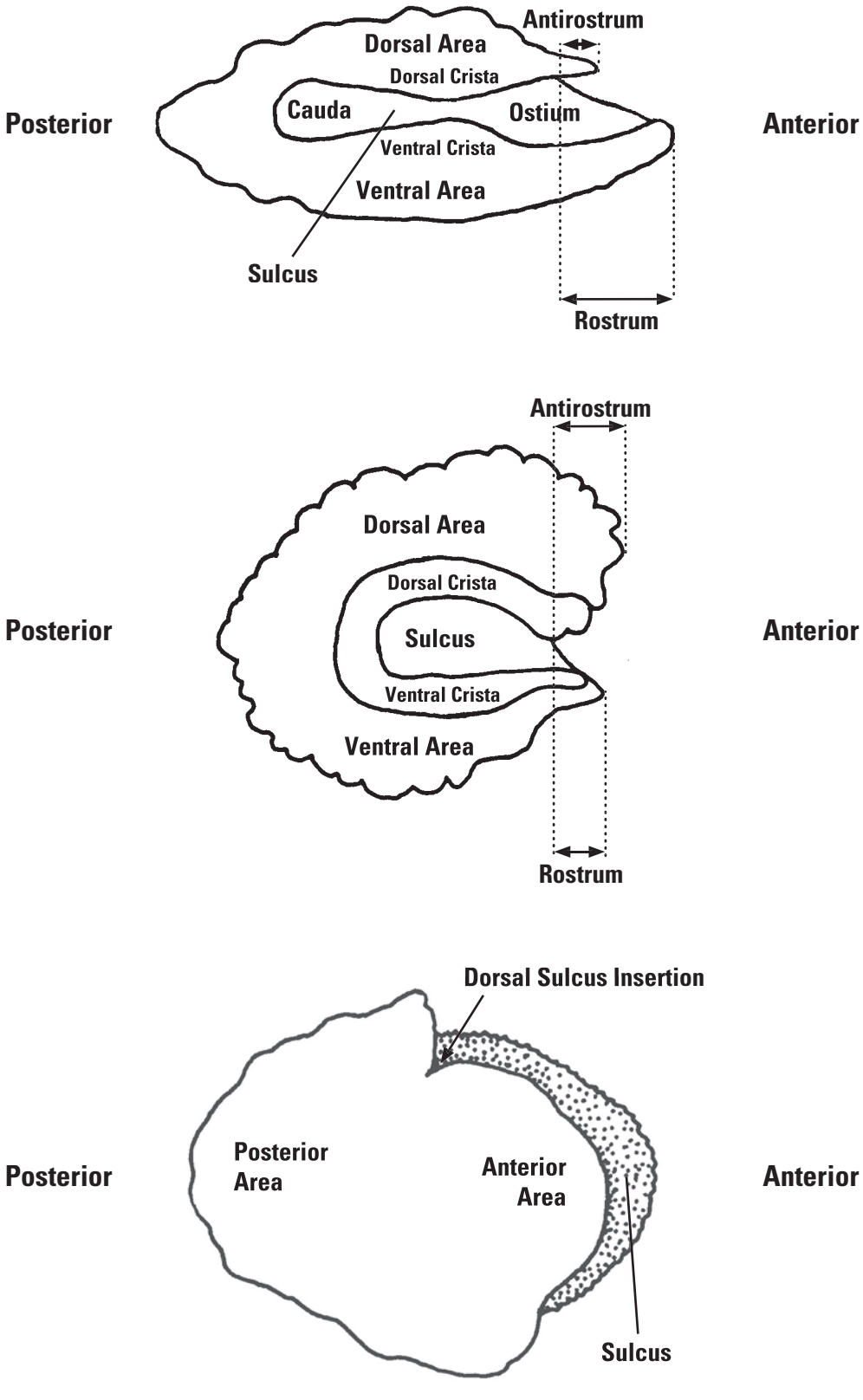


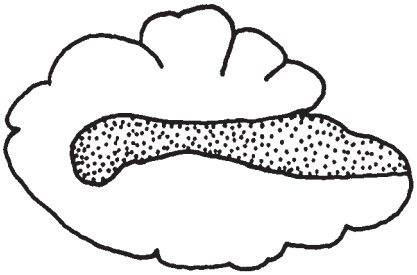
Figure 2. Diagrams of the inner face of the left saccular (top), lagenar (middle), and utricular (bottom) otoliths illustrating various morphologic features used in the text descriptions.

Otolith Type

Saccular Otoliths

Sulcus generally linear in shape

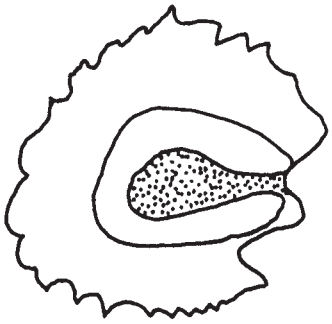
Salmonidae
Gasterosteidae
Percopsidae
Centrarchidae
Percidae
Cottidae



Lagenar Otoliths

Sulcus circular to oval in shape

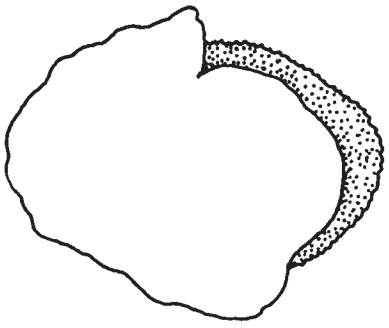
Cyprinidae
Catostomidae
Ictaluridae



Utricular Otoliths

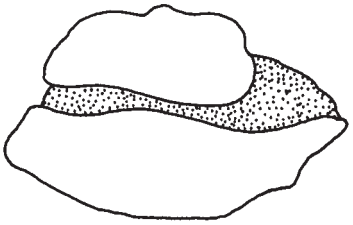
Otolith thickened at the anterior end and circular to oval in shape. The sulcus is small, taking the form of a narrow groove curving around the anterior-dorsal edge

Cyprinidae
Catostomidae
Ictaluridae



Saccular Otoliths

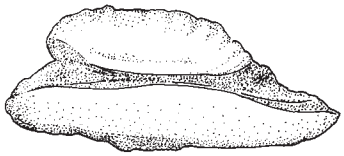
1. a. Sulcus open at the posterior end. (*family Salmonidae*)



go to 2

b. Sulcus closed at the posterior end. **go to 6**

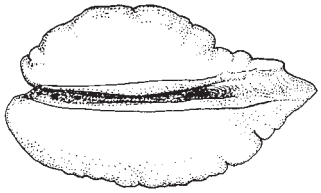
2. a. Posterior opening of the cauda expanded dorsally.



Mountain whitefish

b. Posterior opening of the cauda not expanded dorsally. **go to 3**

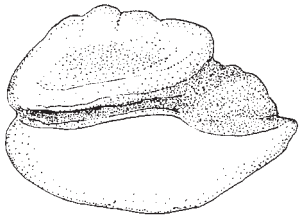
3. a. General otolith shape elongate with gently rounded posterior end (almost tear-drop shaped). The anterior end is attenuated. The ostium typically extends beyond the anterior margin of the ventral area.



Chinook salmon

b. General otolith shape compact rather than elongate. The ostium does not extend beyond the anterior margin of the ventral area. **go to 4**

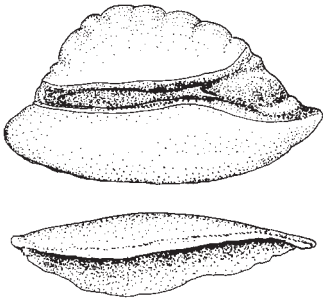
4. a. Posterior margins of dorsal and ventral areas are typically parallel, or nearly so, giving the posterior end a generally squared-off appearance.



Sockeye salmon

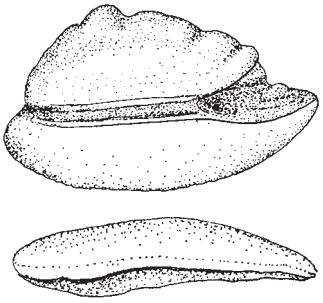
b. Posterior margins of dorsal and ventral areas not parallel. Instead, the posterior margin of the ventral area typically extends beyond that of the dorsal. **go to 5**

5. a. Posterior edge of the outer otolith face of the ventral area margin thins out abruptly giving the otolith an angular, chipped appearance when viewed from the ventral edge.



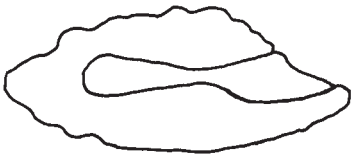
Steelhead

b. Posterior edge of the outer otolith face of the ventral area margin does not thin out abruptly, but remains rounded.



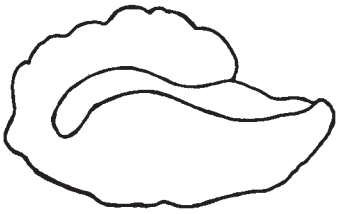
Coho salmon

6. a. Otolith generally elongate or fusiform in shape.



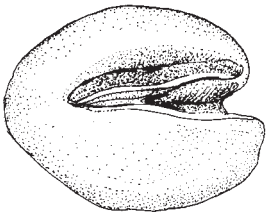
go to 7

b. Otolith generally oval in shape, not elongate or fusiform.



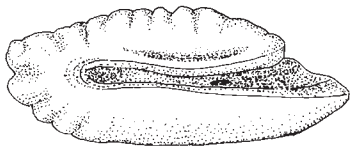
go to 9

c. General otolith shape rounded to somewhat squarish, not elongate or ovate. Otolith typically very small, usually less than 1.0 mm in length, never exceeding 1.2 mm. Outer face is convex.



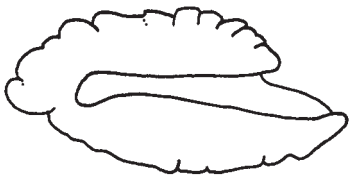
Three-spine stickleback

7. a. Sulcus straight. Posterior portion of the cauda may expand somewhat but does not curve downward.



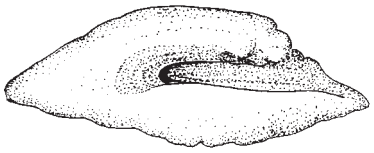
Walleye

b. Sulcus curved. Posterior end of cauda curves downward.



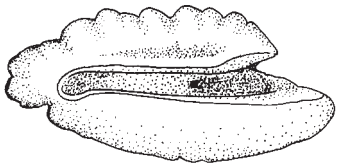
go to 8

8. a. Lobate sculpturing very weakly developed to absent on dorsal area margins. Antirostrum poorly developed to absent. The cauda and rostrum both project, giving a football appearance.



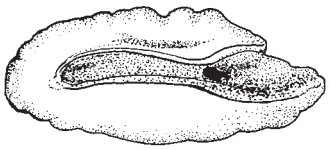
Sculpin

b. Sculpturing of dorsal area margin takes the form of approximately 8-9 well-defined, rounded knob-like lobes.



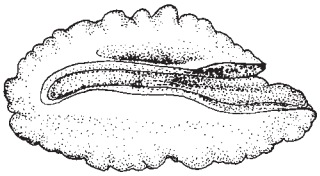
Yellow perch

c. Lobes of dorsal area margin poorly defined taking the form of approximately 6-7 rather irregular, low profile lobes.



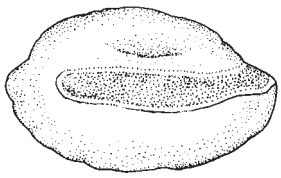
Smallmouth bass

d. Numerous (10+) well-defined, small lobes on both the dorsal and ventral area margins.



Largemouth bass

9. a. Sulcus shallow and weakly defined. Dorsal and ventral cristae very weakly developed.

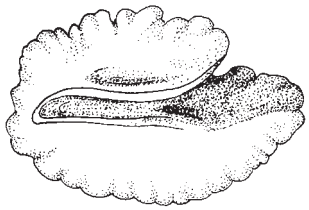


Sandroller

b. Sulcus well defined. Dorsal and/or ventral cristae clearly present.

go to 10

10. a. Lobate sculpturing prominent on the margins of both the dorsal and ventral areas.

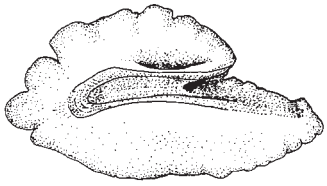


Black crappie

b. Lobate sculpturing largely confined to the dorsal margins. When present on the margins of the ventral area, the lobes are weakly defined and confined to the area of the rostrum.

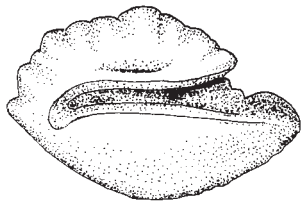
go to 11

11. a. Rostral shape typically slender with an attenuated, upturned tip. The outer face is concave with regular, clearly evident, concentric growth zone laminations that dominate the interior surface.



Pumpkinseed

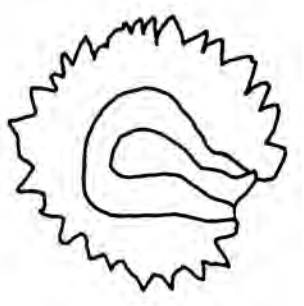
b. Rostral shape typically stout and rounded at the tip. Outer face concave but concentric growth zone laminations are not a prominent surface feature.



Bluegill

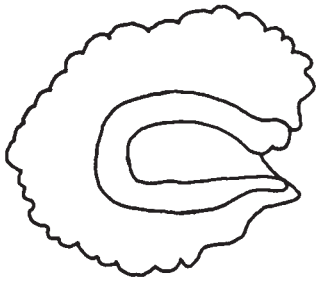
Lagenar Otoliths

1. a. Otolith circular to oval in shape. Condition of otolith margin ranges from numerous long spine-like to low profile, sharp-edged dentate projections. (*family Cyprinidae*)



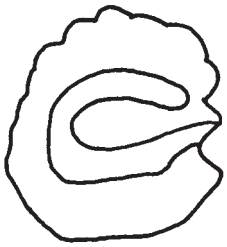
go to 2

b. Otolith always oval in shape. Otolith margins not spine-like or dentate, but with numerous, regulary spaced low profile lobe-like or scalloped edges. (*family Catostomidae*)



go to 7

c. Otolith shape generally circular. Otolith margins generally smooth without spine-like or dentate edges. Scalloped edges, when present, take the form of only 8-10 weakly defined, broad lobes that are typically confined to the margins of the dorsal area. Identification lower than family level not currently possible. (*family Ictaluridae*)



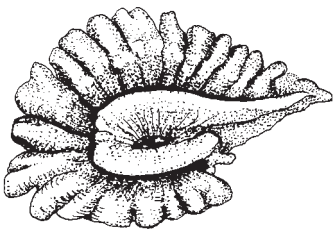
2. a. Otolith is oval to teardrop shaped with wedge shaped dorsal area that projects beyond the anterior edge of the ventral area.

go to 3

b. Otolith is circular and dorsal crista does not extend significantly beyond ventral crista.

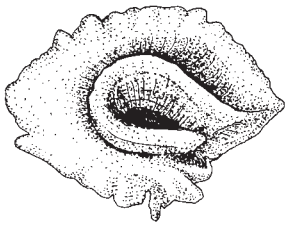
go to 4

3. a. Otolith is teardrop shaped, with dorsal area greatly extending beyond ventral area. Both inner and outer faces strongly sculpted with grooves radiating to the otolith margins.



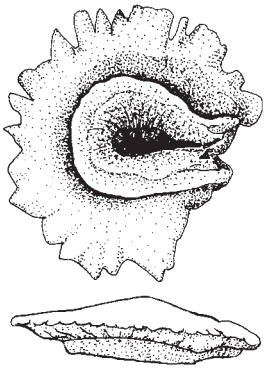
Common carp

b. Otolith oval in shape, with dorsal area slightly extending beyond ventral area. Low scallops present on dorsal edges.



Tench

4. a. Dorsal and ventral cristae thickened and raised above the dorsal and ventral areas which generally slope toward the outer edges giving the inner face of the otolith a convex shape.

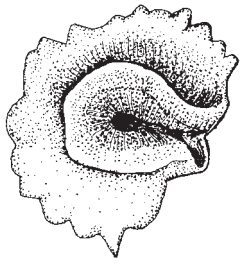


Peamouth

b. Dorsal and ventral cristae generally not rising above the level of the dorsal and ventral areas. The inner face of the otolith is flatened.

go to 5

5. a. No pronounced notch below the anterior end of the ventral crista.

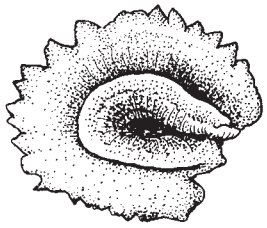


Redside shiner

b. V-shaped or c-shaped notch below the anterior end of the ventral crista.

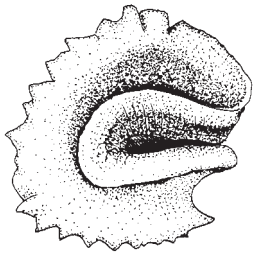
go to 6

6. a. Extension of the ventral crista is slight, typically not extending beyond the anterior edges of the dorsal and ventral areas. Ventral area has a deep v-shaped notch directly below the anterior extension of the ventral crista.



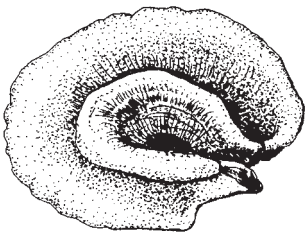
Northern pikeminnow

b. Anterior margin of the ventral area below the anterior extension of the ventral crista has a wide c-shaped notch that gently tapers anteriorly to a point.



Chiselmouth

7. a. Otolith uniformly oval in shape. Anterior extension of the ventral crista typically forms a sharp point which extends beyond the anterior edge of the antirostrum.



Largescale sucker

Utricular Otoliths

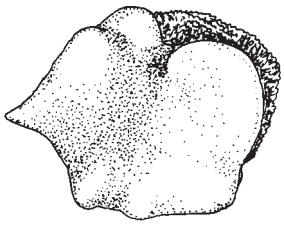
1 a. Inner face of otolith has a smooth, thickened, knob-like prominence at the anterior end. **go to 2**

b. Smooth, knob-like prominence on inner face absent. **go to 6**

2. a. Posterior end with sharp edge. **go to 3**

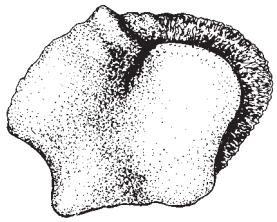
b. Posterior end rounded, lacks sharp edge. **go to 4**

3. a. Posterior half of inner face weakly concave with a single sharp point at the terminal edge.



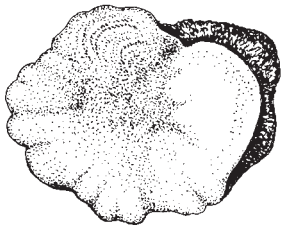
Redside shiner

b. Posterior half of the inner face concave with an expanded, sharp posterior margin.



Peamouth

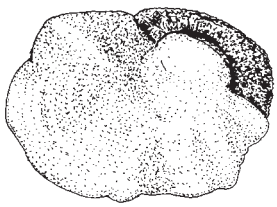
4. a. Posterior half of the inner face flat to weakly concave. The inner face of the posterior half is fan-shaped with 3-4 faint grooves radiating out to the posterior margin.



Largescale sucker

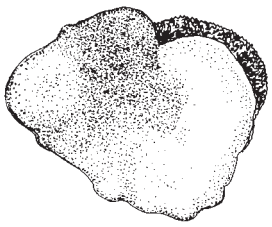
b. Posterior half of inner face smooth, grooves absent. **go to 5**

5. a. Inner face generally fan-shaped. Posterior half of the inner face flat or nearly so. The posterior-most margins are broadly rounded with no sharp edges.

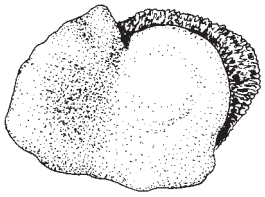


Tench

b. Posterior half of the inner face weakly concave with the posterior-most margins broadly rounded with no sharp edges.

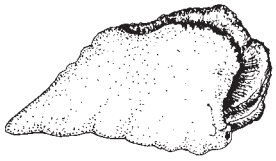


Northern pikeminnow



Chiselmouth

6. a. Posterior half of both the inner and outer face convex and angular in shape giving the entire otolith an arrowhead shape. There is no notch at the dorsal sulcus insertion.

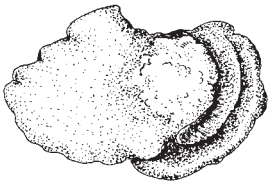


Common carp

b. Otolith not arrowhead shaped.

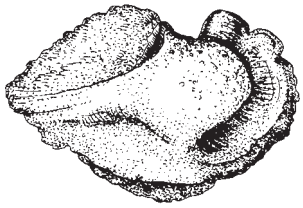
go to 7

7. a. Posterior half of both the inner and outer face convex. There is a pronounced notch at the dorsal sulcus insertion.



Channel catfish

b. Only the posterior half of the inner face convex. The outer face is concave. A pronounced notch at the dorsal sulcus insertion is present.



Brown bullhead

Lower Pharyngeal

Identification

The lower pharyngeal is the term applied to the modified 5th ceratobranchial. It is a paired bone located in the throat that acts as a grinding mechanism. In the Cyprinidae and Catostomidae families, the lower pharyngeals are diagnostic. They are large and C-shaped, with distinct teeth. Pharyngeals are present in other families, but are not diagnostic.

Orientation

All photographs and illustrations in this key are of the right lower pharyngeal. To orient a pharyngeal to match this key, point the dorsal and ventral legs left with the teeth up towards the viewer. The scale bar in all photographs is five millimeters.

Note

The teeth on the lower pharyngeal can easily fall out during a dissection or digestion. When looking for sockets (especially for secondary teeth) be sure not to confuse them with fossa, which can also occur within the curve of the primary row of teeth.

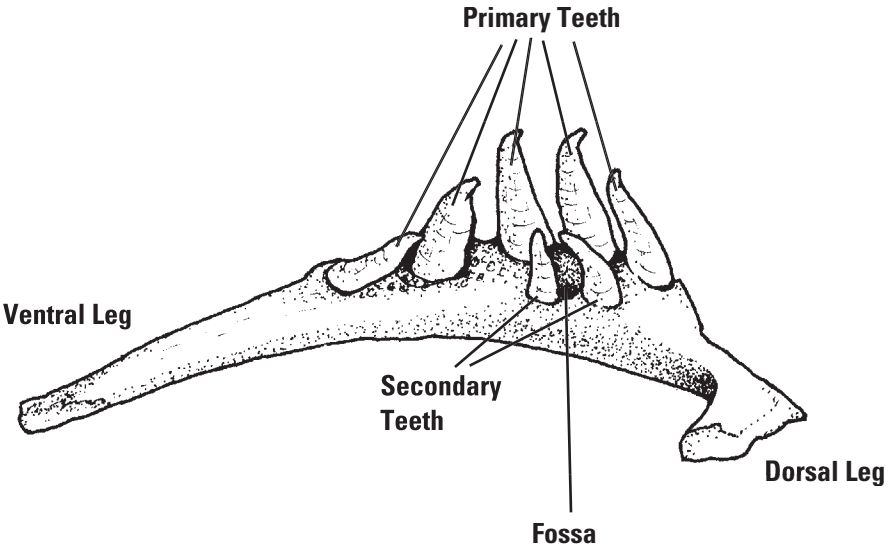


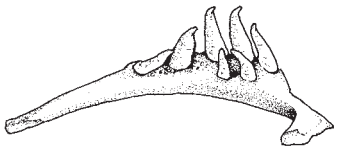
Figure 3. Left lower pharyngeal of a northern pikeminnow depicting major features used in the key.

1. Pharyngeal Teeth

a. Many regularly spaced teeth in a comb-like row

Sucker spp.

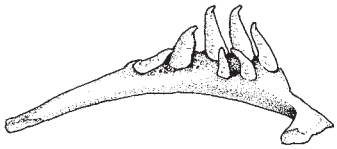
b. Few teeth (<10) in one or more short rows, not comb-like, may be molar or canine-like



go to 2

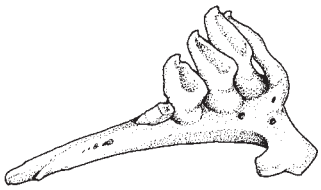
2. Secondary Teeth

a. Secondary teeth present



go to 3

b. Secondary teeth absent



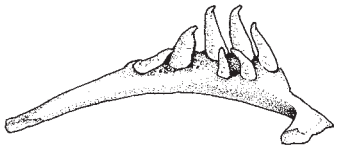
go to 6

3. Number and Position of Secondary Teeth

a. Two secondary teeth running perpendicular to primary teeth

Common carp

b. Single secondary tooth, or two teeth running parallel to primary teeth



go to 4

4. Protrusion on Outside Margin

a. Protrusion present

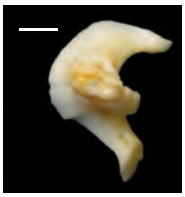
Redside shiner

b. Protrusion absent

go to 5

5. Number of Secondary Teeth; Tooth and Pharyngeal Shape

a. One secondary tooth; teeth molar-like; pharyngeal very wide



Peamouth

b. Two secondary teeth; teeth canine-like; pharyngeal slender

Northern pikeminnow

6. Shape of Dorsal Tip and Teeth

a. Tip of dorsal leg flattened; teeth are broad and molar-like

Tench

b. Tip of dorsal leg pointed; teeth narrower, tipped molar shape

Chiselmouth

Cleithrum

Identification

The cleithrum is the major bone of the pectoral girdle in bony fishes. The cleithra meet ventrally, forming the posterior edge of the gill chamber.

Orientation

All photographs in this key are of the lateral side (outside) of the left cleithrum. To orient a bone to match this key, the dorsal spine should be oriented to the upper-right, pointing up. The scale bar on all photographs is five millimeters.

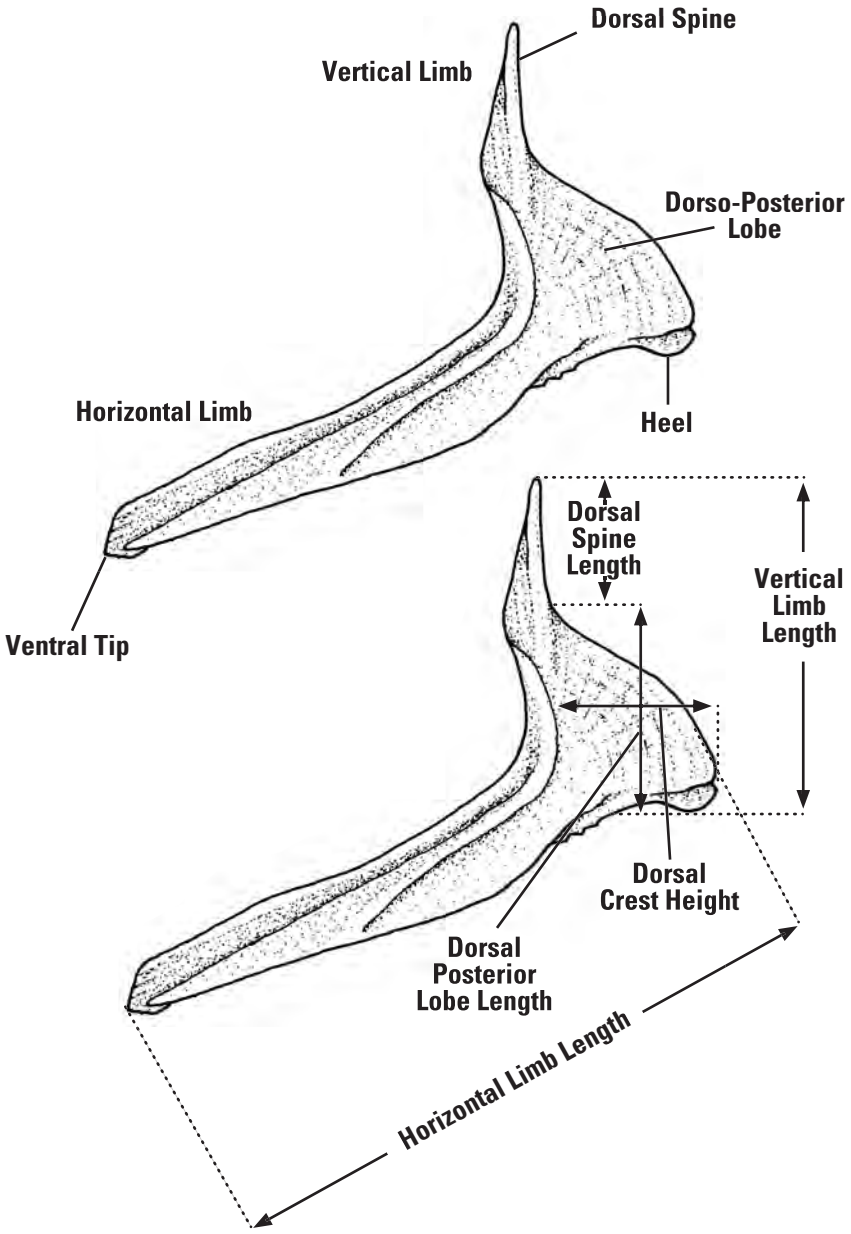
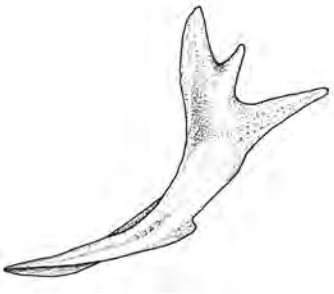


Figure 4. Left cleithrum of a walleye depicting features and measurements used in the key.

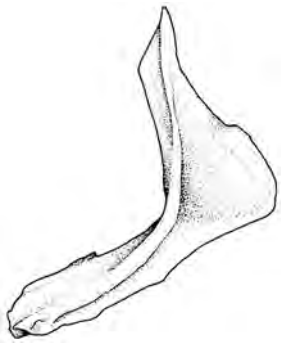
1. Points on Vertical Limb

a. Vertical limb with two or more points



go to 2

b. Vertical limb ends in a single point or lobe



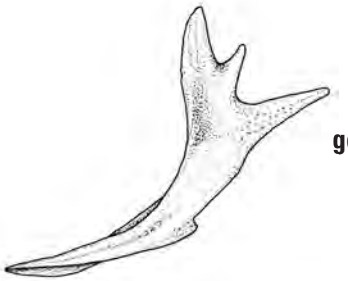
go to 4

2. Number of Points on Vertical Limb

a. Vertical limb with two points

Sculpin spp.

b. Vertical limb with three points



go to 3

3. Length of Middle Point on Vertical Limb

a. Middle point does not cross line drawn between tips of first and third points

Channel catfish

b. Middle point crosses line drawn between tips of first and third points

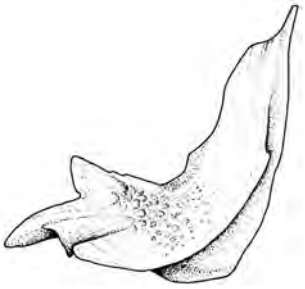
Black bullhead

Brown bullhead

Yellow bullhead

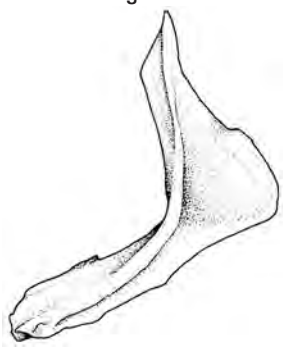
4. Horizontal Limb Shape

a. Horizontal limb with multiple points



go to 5

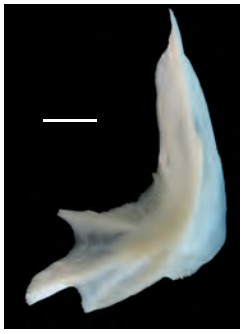
b. Horizontal limb with single point, lobe, or flat-line edge



go to 7

5. Number of Points on Horizontal Limb

a. Horizontal limb with three points



Sucker spp.

b. Horizontal limb with two points

go to 6

6. Webbing on Vertical Limb

a. Slight but distinct webbing on the upper half of the vertical limb, extending out from anterior margin

Tench

b. No webbing on the upper half of the vertical limb extending out from the anterior margin

Common carp

7. Dorso-posterior Lobe Thickness and Texture

a. Dorso-posterior lobe thickened and wrinkled; distinct triangular shape

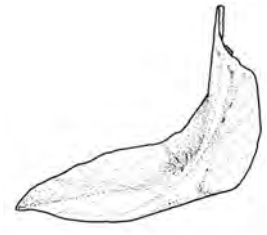
Three-spine stickleback

b. Dorso-posterior lobe smooth and may have webbing

go to 8

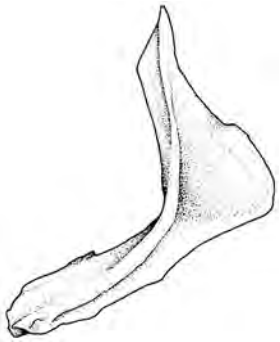
8. Webbing Between Limbs

a. Extensive membranous webbing extending out from anterior margins of both limbs



go to 9

b. Webbing minor or absent



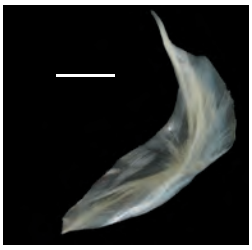
go to 10

9. Ratio: Dorsal Crest Height to Vertical Limb Length

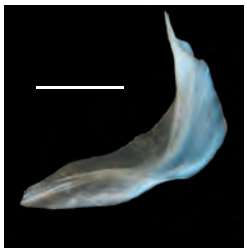
a. Dorsal crest height : vertical limb length ≤ 0.35

Sockeye

Chinook

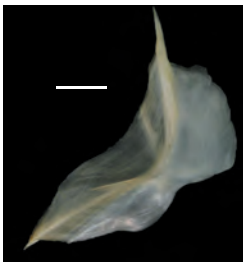


Coho



Steelhead

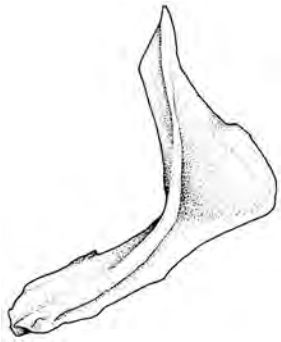
b. Dorso-posterior lobe smooth and may have webbing



Mountain whitefish

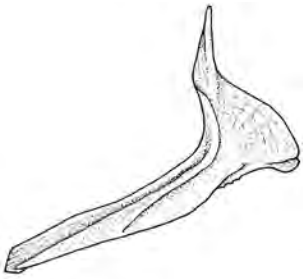
10. Shape of Medial Process at End of Horizontal Limb

a. Medial process at end of horizontal limb forms a short shelf or hook



go to 11

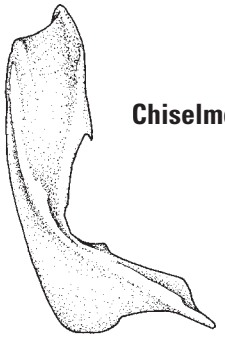
b. Medial process at end of horizontal limb is smooth and angles into ventral tip



go to 15

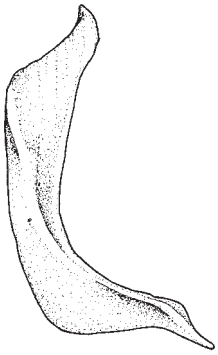
11. Hook on Horizontal Limb (medial or dorsal view)

a. Hook midway on medial process of horizontal limb present



Chiselmouth

b. Hook midway on medial process of horizontal limb absent



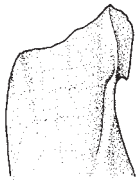
go to 12

12. Shape of Ventral Tip of Horizontal Limb (dorsal view)

a. Webbing tapers as it approaches the ventral tip of the horizontal limb

go to 13

b. Webbing does not taper, forming a square end at the ventral tip of the horizontal limb



go to 14

13. Edge of Dorso-posterior Lobe Shape (lateral view)

a. Edge of dorso-posterior lobe comes to a distinct point

Speckled dace

b. Edge of dorso-posterior lobe is curved

Northern pikeminnow

14. Visibility of Horizontal Limb Shelf

a. Horizontal limb twisted so shelf not visible

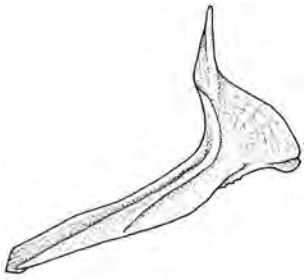
Peamouth

b. Horizontal limb twisted so shelf visible

Redside shiner

15. Heel Orientation

a. Heel caudally-projecting



go to 16

b. Heel shallow, ventrally-oriented

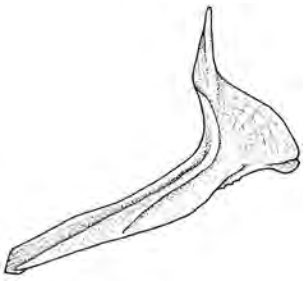
go to 18

16. Notch at Base of Dorsal Spine

a. Notch present

Sandroller

b. Notch absent



go to 17

17. Ratio: Dorsal Spine Length to Vertical Limb Length; Dorsal Spine Shape

a. Dorsal spine length: vertical limb length < 0.34; anterior edge of dorsal spine tapers concavely towards the tip; heel serrate

Yellow perch

b. Dorsal spine length : vertical limb length ≥ 0.34; dorsal spine does not taper concavely to a tip; heel usually serrate

Walleye

18. Ratio: Horizontal Limb Length to Dorso-posterior Lobe Length

a. Horizontal limb length: dorso-posterior lobe length ≥ 2.20

Smallmouth bass

Largemouth bass

b. Horizontal limb length: dorso-posterior lobe length < 2.20

go to 19

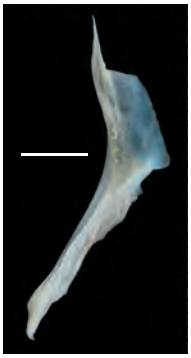
19. Angle Created by Dorsal Spine and Dorso-posterior Lobe

a. Angle > 140°

Black crappie

b. Angle ≤ 140°

Bluegill



Pumpkinseed

Dentary

Identification

The dentary is a paired bone located on the lower jaw that bears teeth in most bony fishes. It has a Y-shape with the stem (body) pointing anteriorly towards the tip of the mouth and the two legs pointing posteriorly. The left and right dentaries meet at the symphyseal (anterior) margin.

Orientation

All photographs and illustrations in this key are of the lateral side (outside) of the left dentary. To match this key, orient the symphyseal margin to the left and the dorsal and ventral legs to the right, with the dental plate to the top. The scale bar on all photographs is five millimeters.

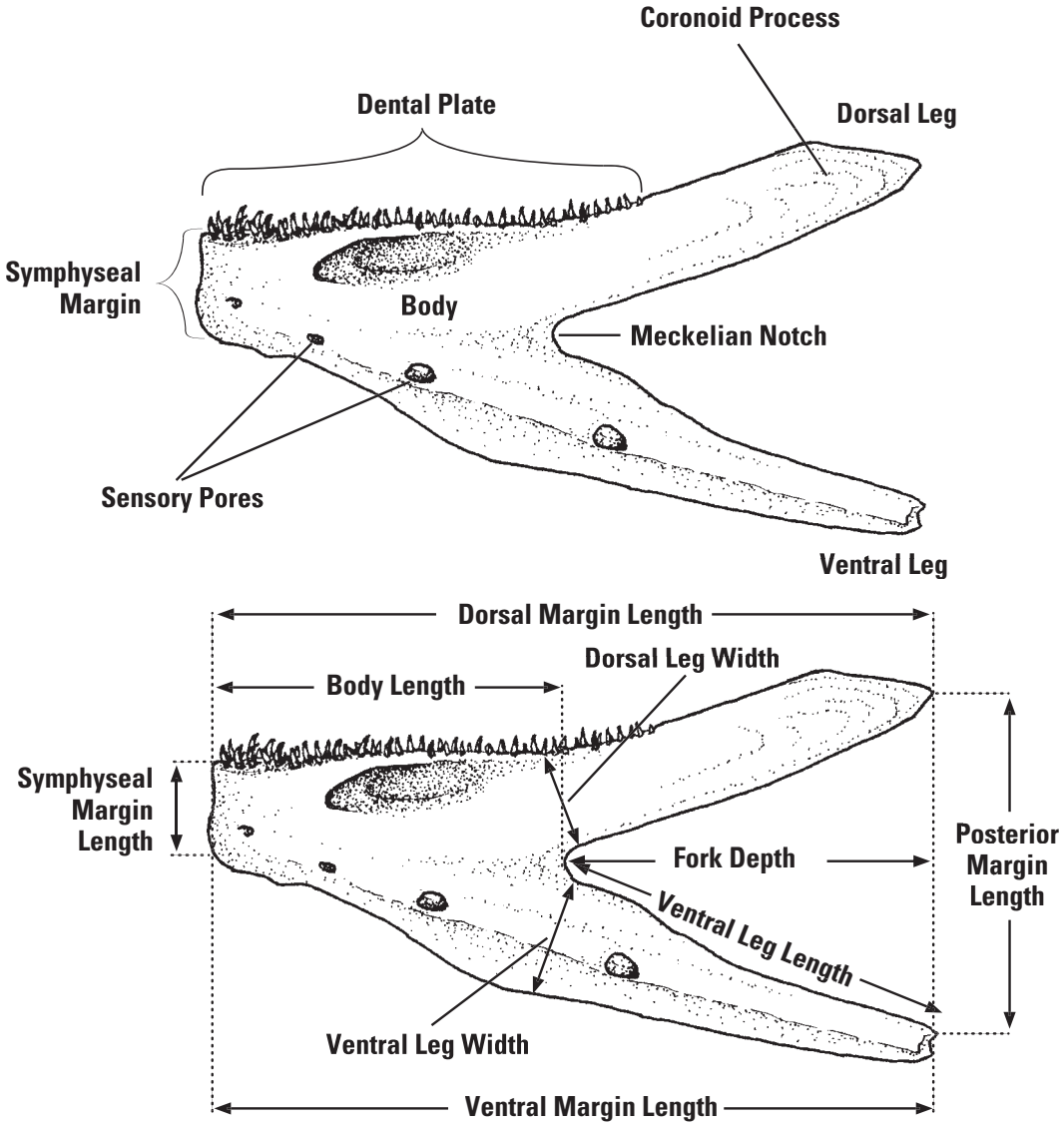
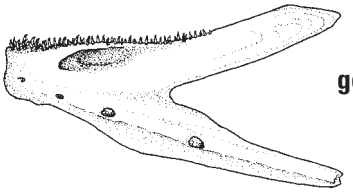


Figure 5. Left dentary of a yellow perch depicting features and measurements used in the key.

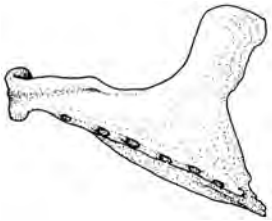
1. Teeth

a. Teeth or tooth sockets on dental plate present



go to 2

b. Teeth or tooth sockets on dental plate absent; dental plate smooth



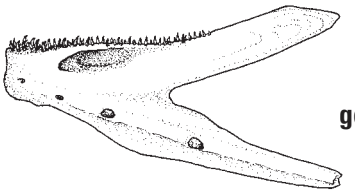
go to 14

2. Tooth Shape

a. Teeth of varying shapes and sizes (Teeth rarely fall out. If missing, sockets will be widely varying in size)

Walleye

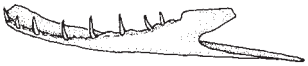
b. Teeth of similar shape and size (If teeth missing, sockets will be of approximately equal size)



go to 3

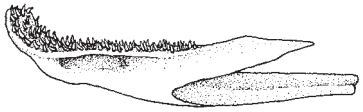
3. Number of Rows of Teeth

a. One row of teeth



go to 4

b. More than one row of teeth

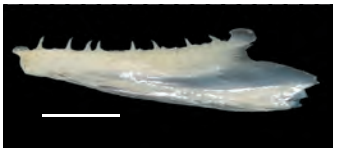


go to 6

4. Ratio: Ventral Margin Length to Ventral Leg Length; Ratio: Body Length to Ventral Leg Length

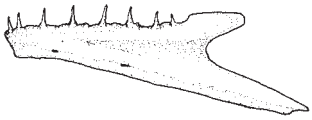
a. Ventral margin length: ventral leg length ≥ 3.7; Body length: ventral leg length ≥ 2.6

Coho



Chinook

b. Ventral margin length : ventral leg length < 3.4; Body length : ventral leg length < 2.4



go to 5

5. Ratio: Body Length to Dorsal Leg Width

a. Body length : dorsal leg width > 5.5

Sockeye

b. Body length : dorsal leg width ≤ 5.5

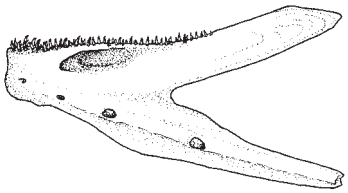
Steelhead

6. Coronoid Process Shape

a. Coronoid process wide, flat, and curves dorsally well above tooth line

Three-spine stickleback

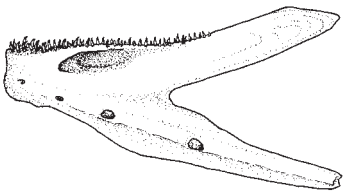
b. Coronoid process remains straight, at or slightly above tooth line



go to 7

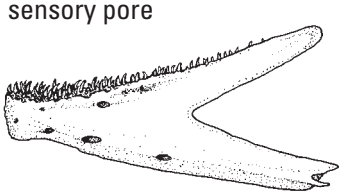
7. Large Cavity in Body (lateral view)

a. Large cavity present in body just below the dental plate



go to 8

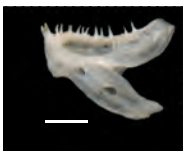
b. If cavity present, it is not much larger than a sensory pore



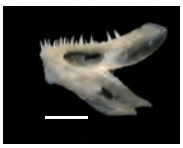
go to 10

8. Ratio: Symphyseal Margin Length to Dorsal Margin Length

a. Symphyseal margin length : dorsal margin length > 0.23

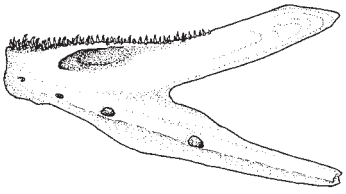


Bluegill



Pumpkinseed

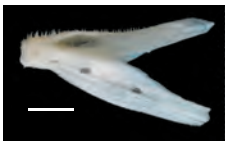
b. Symphyseal margin length : dorsal margin length ≤ 0.23



go to 9

9. Cavity Location

a. Majority of large cavity located in the body just below the dental plate is anterior to the third sensory pore



Yellow perch

b. Majority of large cavity located in the body just below the dental plate is posterior to the third sensory pore

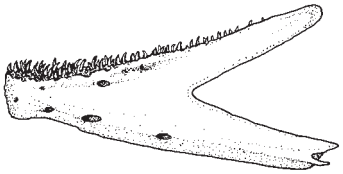
Black crappie

10. Ratio: Ventral Leg Width to Dorsal Leg Width

a. Ventral leg width : dorsal leg width ≥ 2.8

Sandroller

b. Ventral leg width : dorsal leg width < 2.8



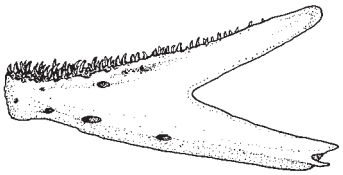
go to 11

11. Ratio: Fork Depth to Dorsal Margin Length

a. Fork depth : dorsal margin length ≤ 0.30

go to 12

b. Fork depth : dorsal margin length > 0.30



go to 13

12. Sensory Pore Size and Body Shape

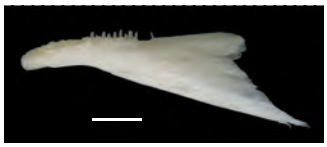
a. Sensory pores create obvious pits; body gradually tapers as it reaches the symphyseal margin, making anterior third of dentary wide

Black bullhead

Brown bullhead

Yellow bullhead

b. Sensory pores create subtle pits; body tapers quickly making anterior third of dentary narrow



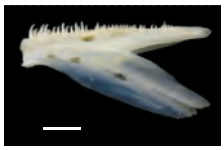
Channel catfish

13. Sensory Pore Size

a. Sensory pores large, with third pore filling almost entire width of ventral limb

Sculpin spp.

b. Sensory pores much smaller than width of ventral limb

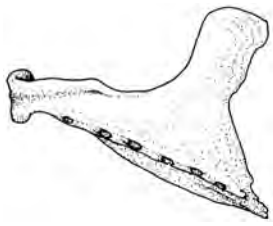


Smallmouth bass

Largemouth bass

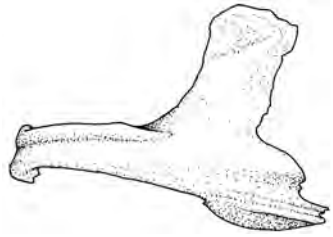
14. Sensory Pores on Lateral Surface

a. Sensory pores present



go to 15

b. Sensory pores absent



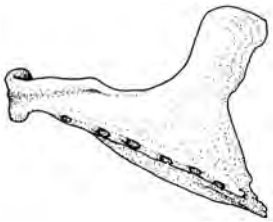
go to 16

15. Number of Sensory Pores

a. Nine or more sensory pores

Northern pikeminnow

b. Less than nine sensory pores



go to 17

16. Shape of Ventral Margin

a. Ventral margin a C-shaped curve, with sharply descending ventral leg (bone looks upside down)

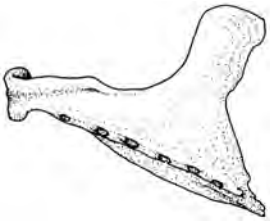
Sucker spp.

b. Ventral margin relatively straight; pronounced dorsally-pointing coronoid process

Tench

17. Coronoid Process

a. Elongated, dorsally-pointing coronoid process present



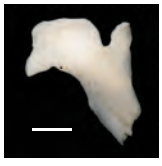
go to 18

b. Coronoid process flat; bone is boomerang-shaped

Mountain whitefish

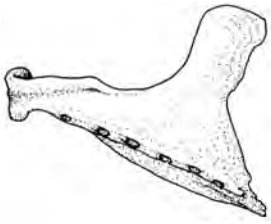
18. Ratio: Symphyseal Margin Length to Ventral Margin Length

a. Symphyseal margin length : ventral lmargin ength ≥ 0.30



Chiselmouth

b. Symphyseal margin length : ventral margin length < 0.30



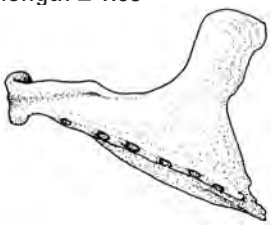
go to 19

19. Ratio: Dorsal Margin Length to Posterior Margin Length

a. Dorsal margin length : posterior margin length > 1.65

Redside shiner

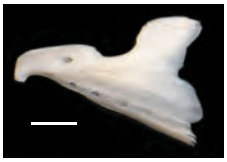
b. Dorsal margin length : posterior margin length ≤ 1.65



go to 20

20. End Shape of Ventral Leg

a. End of ventral leg with notch



Common carp

b. End of ventral leg without notch; comes to a single point

Peamouth

Hyomandibular

Identification

The hyomandibular is a paired bone that connects the lower jaw to the cranium. It is shaped like a cross, with varied amounts of webbing, or membranous bone, extending from or in between the arms (processes). The upper part of the bone (the head) contains the dorsal (up), anterior (towards the mouth), and opercular (towards the tail) processes. The lower portion of the bone (the body) contains the ventral (down) process and associated membranes.

Orientation

All photographs and illustrations in this key are of the lateral side (outside) of the left hyomandibular. The lateral side always has more texturing than the medial side. To orient a hyomandibular to match this key, have the lateral side facing out, with the head at the top. If lateral webbing is present, it should point toward the viewer. The scale bar on all photographs is five millimeters.

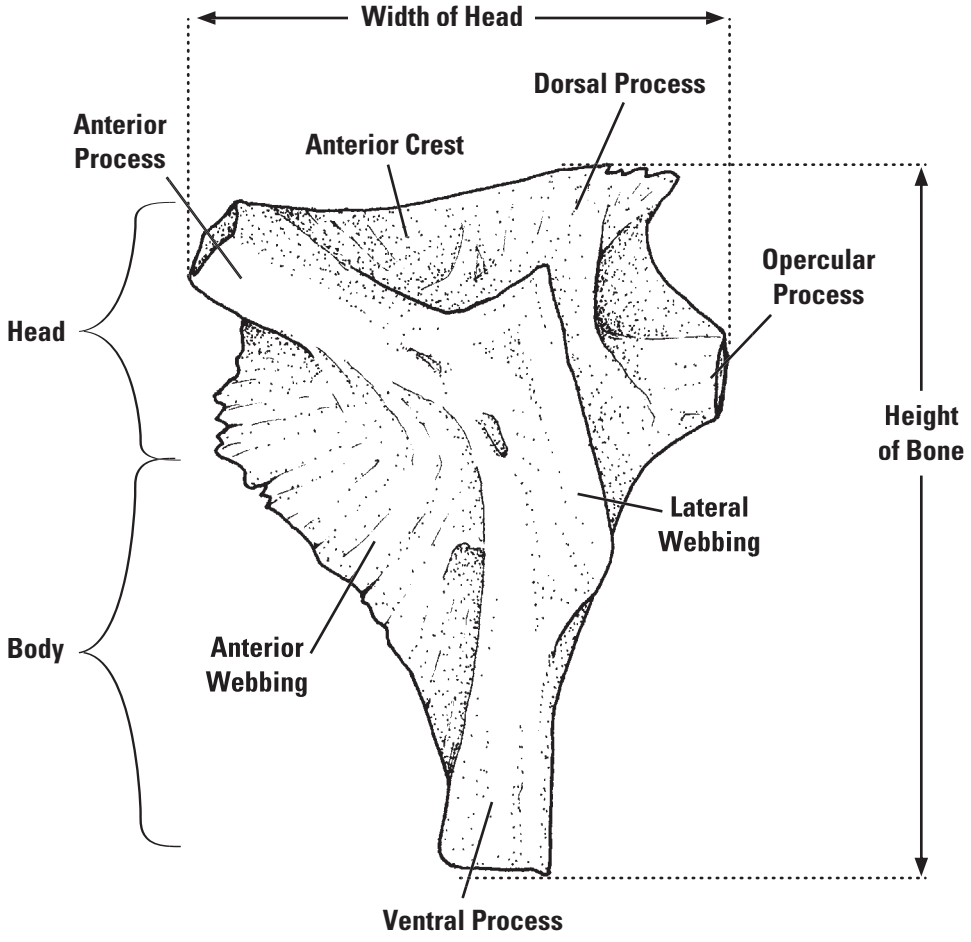


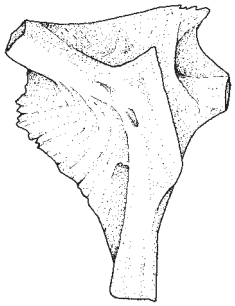
Figure 6. Left hyomandibular of a walleye depicting features and measurements used in the key.

1. Head Position

a. Head positioned entirely anterior to the body

Sucker spp.

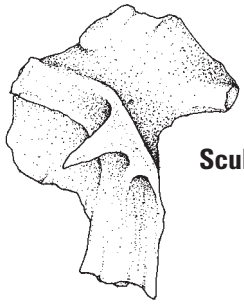
b. Head positioned partially or entirely over body



go to 2

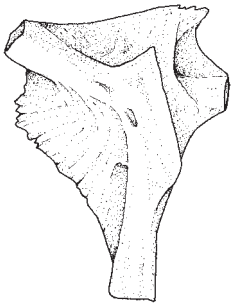
2. Spike at Base of Head

a. Spike-like protrusion in center of lateral webbing, oriented anterio-ventrally



Sculpin spp.

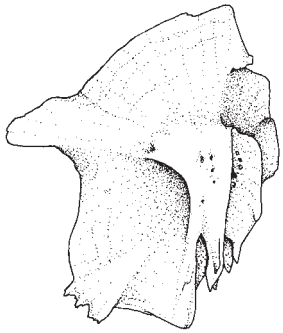
b. Lateral webbing without spike



go to 3

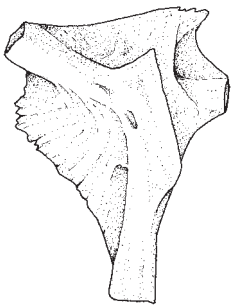
3. Extension of Anterior Webbing

a. Anterior webbing extends beyond the ventral process



go to 4

b. Anterior webbing does not extend beyond ventral process



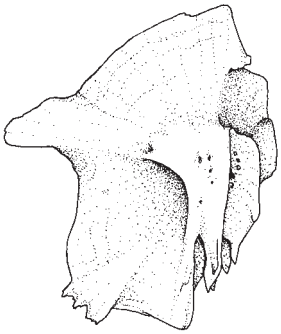
go to 6

4. Anterior Webbing Shape

a. Upper edge of anterior webbing is smooth and convex

Mountain whitefish

b. Upper half of edge of anterior webbing is jagged and/or concave

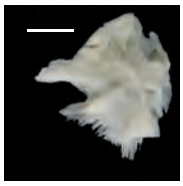


go to 5

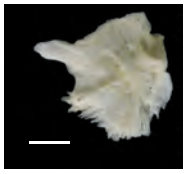
5. Anterior Webbing Shape

a. Jagged edges extend throughout majority of anterior webbing

Black bullhead

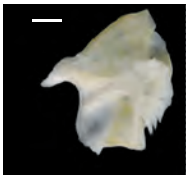


Brown bullhead



Yellow bullhead

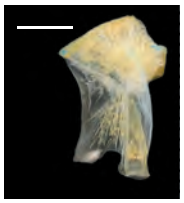
b. Upper edge of anterior webbing smooth and concave, with jagged edge confined to lower edge



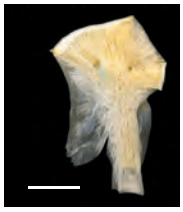
Channel catfish

6. Anterior Webbing Shape

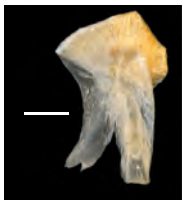
a. Anterior webbing with anterio-ventrally extending lobe



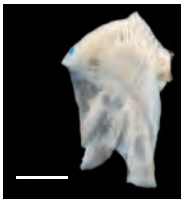
Sockeye



Chinook

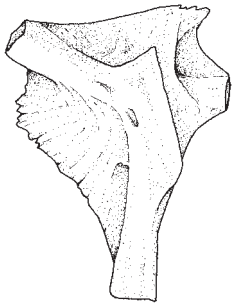


Coho



Steelhead

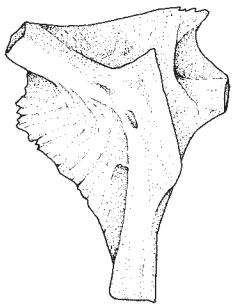
b. Anterior webbing without lobe



go to 7

7. Head width

a. Height of bone : width of head < 2.00



go to 8

b. Height of bone : width of head ≥ 2.00

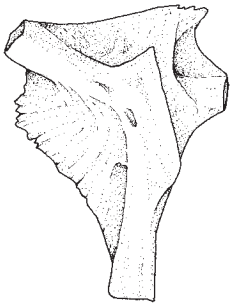
go to 14

8. Curvature of Anterior Crest

a. Anterior crest has a large, distinct dip near anterior process

Northern pikeminnow

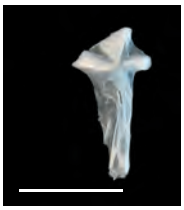
b. Anterior crest is straight or slightly curved



go to 9

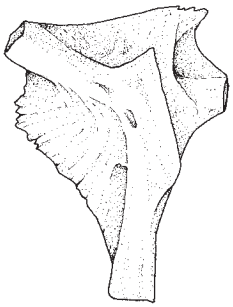
9. Anterior Webbing Texture

a. Anterior webbing with a smooth edge



Sandroller

b. Anterior webbing with a pointed or jagged edge



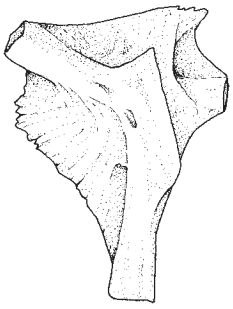
go to 10

10. Shape of Opercular Process

a. End of opercular process is convex

Speckled dace

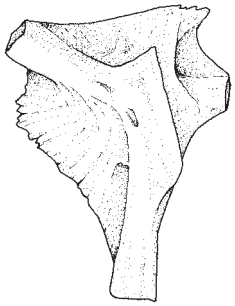
b. End of opercular process is concave



go to 11

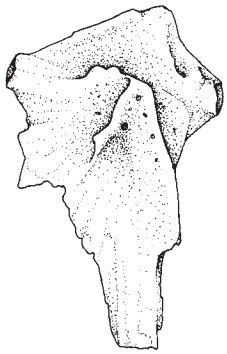
11. Extension of Anterior Webbing

a. Anterior webbing terminates above end of ventral process



go to 12

b. Anterior webbing extends to end of ventral process



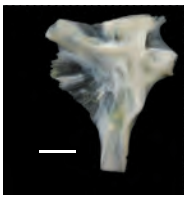
go to 13

12. Anterior Webbing Shape

a. Anterior webbing forms an approximate right angle midway down the body

Yellow perch

b. Anterior webbing tapers towards ventral process



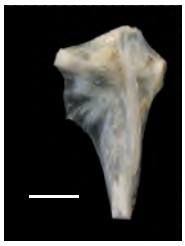
Walleye

13. Position and Shape of Lateral Webbing

a. Lateral webbing extends beyond posterior of the body; ventral end of lateral webbing forms a sharp notch where it meets the body in most individuals

Smallmouth bass

b. Lateral webbing extends only slightly posterior of the body if at all; ventral end of lateral webbing tapers as it approaches the body



Largemouth bass

14. Lateral Webbing Orientation

a. Lateral webbing oriented perpendicular to surface of head and body

go to 15

b. Lateral webbing oriented posteriorly, or posterio-laterally, not perpendicular to surface of head and body

go to 17

15. Dorsal Process Shape

a. Tip of dorsal process forms a sharply pointed protrusion

Black crappie

b. Tip of dorsal process is blunt or cornered; not pointed

go to 16

16. Anterior Crest Thickness

a. Anterior crest is thin and membranous

Three-spine stickleback

b. Anterior crest is equal in thickness to the anterior and dorsal processes

Bluegill

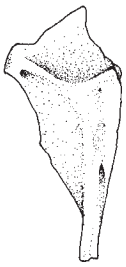
Pumpkinseed

17. Head Width

a. Height of bone : width of head > 2.75

Common carp

b. Height of bone : width of head ≤ 2.75



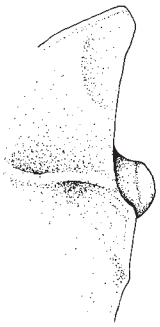
go to 18

18. Length of Upper End of Lateral Webbing

a. Upper lateral webbing is confined to a point or lobe on the posterior end of the head over opercular process

go to 19

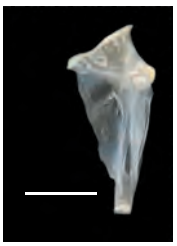
b. Upper lateral webbing extends from opercular process to anterior process across most of the head



go to 20

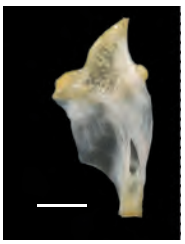
19. Lateral Webbing Shape

a. Upper lateral webbing forms a lobe over the opercular process



Redside shiner

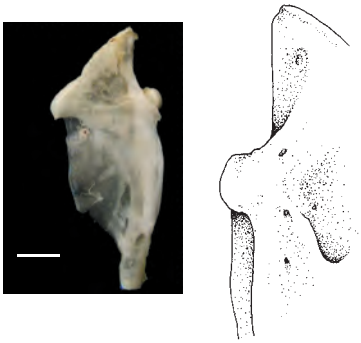
b. Upper lateral webbing forms a point over the opercular process



Peamouth

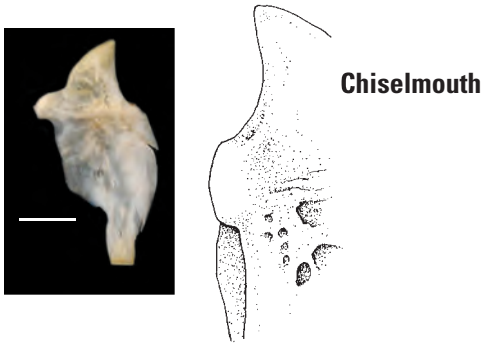
20. Shape of Opercular Process (medial view)

a. Sticks out and is round



Tench

b. Embedded and oblong



Chiselmouth

Opercle

Identification

The opercle is a three or four-sided, paired bone, located in the dorsal part of the opercular membrane. As the largest bone in the opercular series, it acts as a structure to reinforce the gill clefts.

Orientation

All photographs and illustrations in this key are of the medial side (inside) of the left opercle. The medial side has more texturing, and the dorsal ridge protrudes along the medial side. To orient an opercle to match this key, the articular fossa should be in the upper-right, with the anterior margin on the right, and the dorsal margin at the top. The medial side (inside) should be facing the viewer. The scale bar in all photographs is five millimeters.

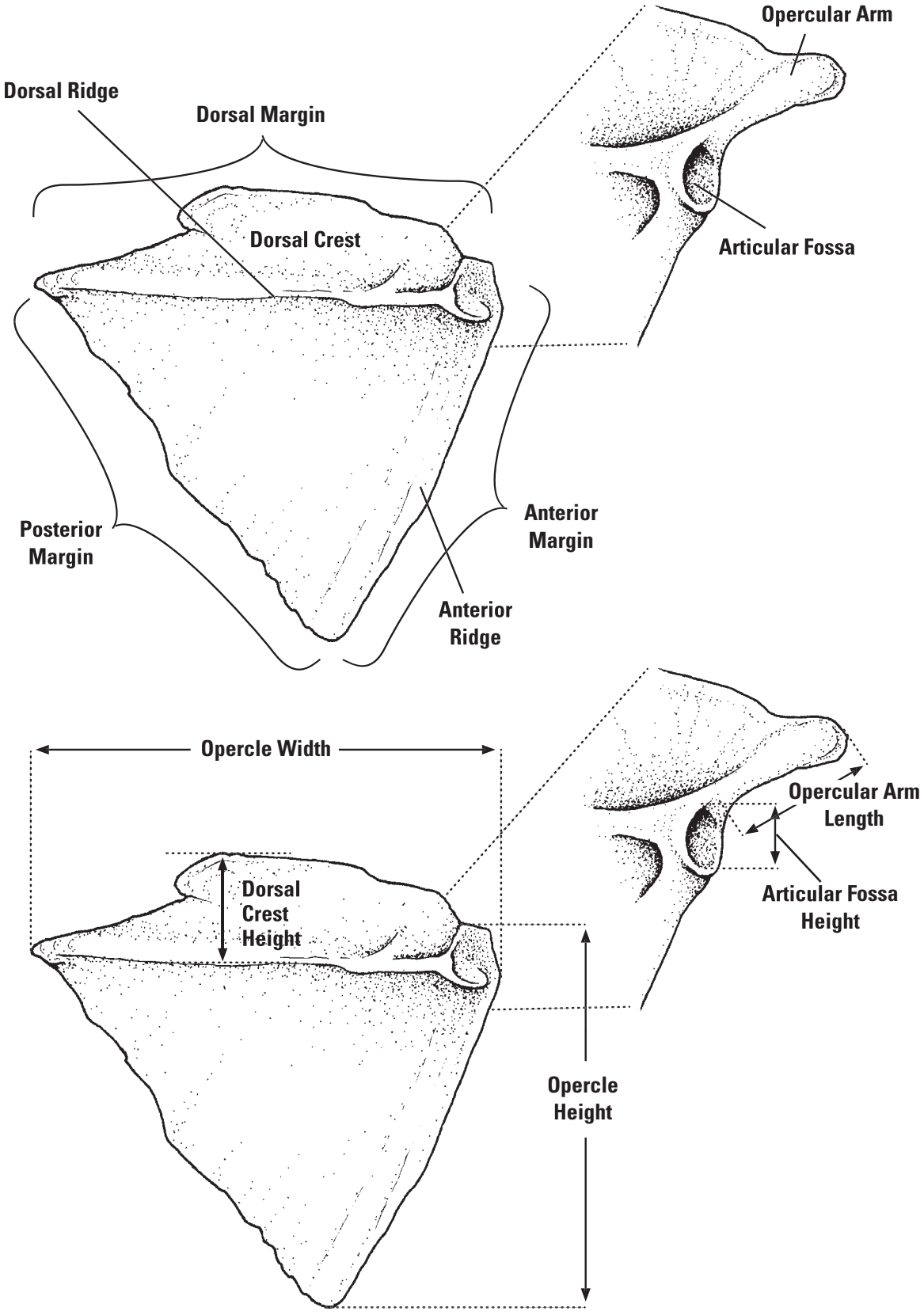


Figure 7. Left opercle of yellow perch and peamouth (inset illustrating opercular arm) depicting features and ratios used in the key.

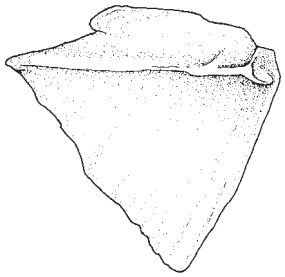
1. Elongation of Articular Fossa

a. Articular fossa is elongated and protrudes ventrally

Channel catfish

Bullhead spp.

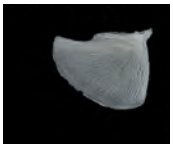
b. Articular fossa is round or oval and does not protrude ventrally



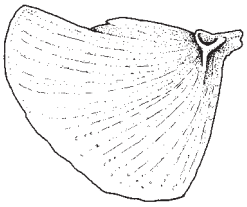
go to 2

2. Surface Texture

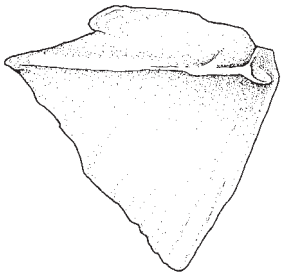
a. Radial ridges present throughout opercle



Three-spine stickleback



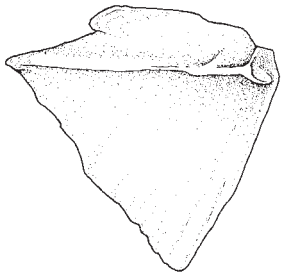
b. Radial ridges absent



go to 3

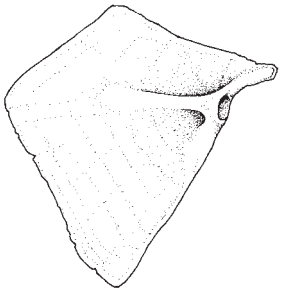
3. Extension of Dorsal Ridge

a. Dorsal ridge extends to posterior margin (may be actual ridge, or thickened, more opaque bone that extends to posterior margin)



go to 4

b. Dorsal ridge does not extend to posterior margin



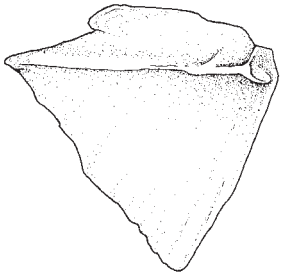
go to 9

4. Extension of Anterior Ridge

a. Anterior ridge extends ventrally beyond the webbing that lies between the dorsal and anterior ridges

Sandroller

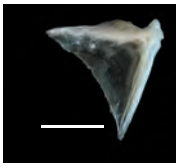
b. Anterior ridge terminates at the edge of the webbing that lies between the dorsal and anterior ridges



go to 5

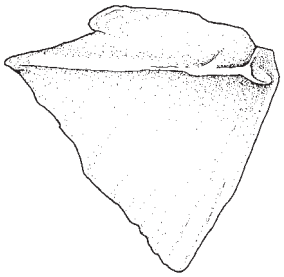
5. Size of Dorsal Crest

a. Dorsal crest very small, almost absent



Sculpin spp.

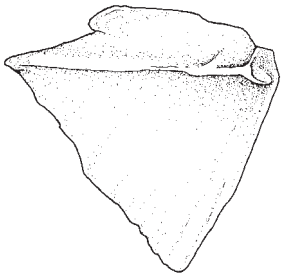
b. Dorsal crest large and prominent



go to 6

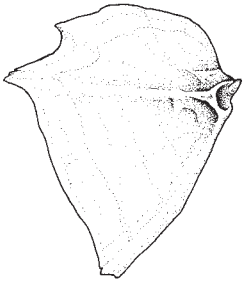
6. Ratio: Dorsal Crest Height to Dorsal Ridge Length

a. Dorsal crest height : dorsal ridge length < 0.30



go to 7

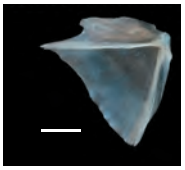
b. Dorsal crest height : dorsal ridge length ≥ 0.30



go to 8

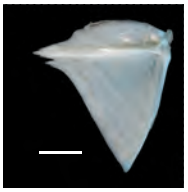
7. Shape of Dorsal Crest

a. Notch on posterior end of dorsal crest



Walleye

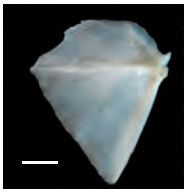
b. Posterior end of dorsal crest smooth or wavy



Yellow perch

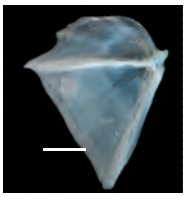
8. Shape of Posterior Margin at Dorsal Ridge

a. Dorsal ridge and posterior margin meet at same point



Largemouth bass

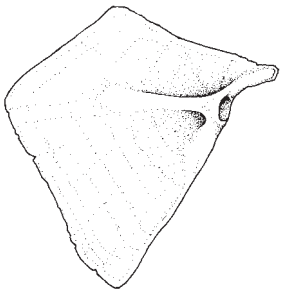
b. Dorsal ridge extends past junction with posterior margin



Smallmouth bass

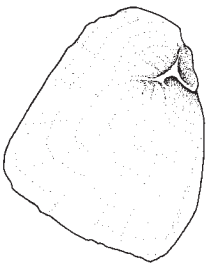
9. Opercular Arm

a. Dorso-anterior corner pointed ir opercular arm present



go to 10

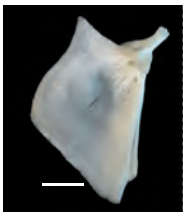
b. Opercular arm absent; dorso-anterior corner rounded



go to 19

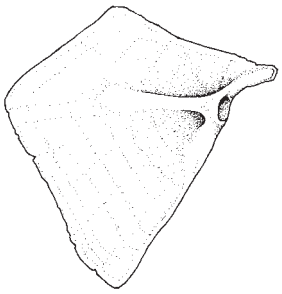
10. Shape of Dorsal Margin

a. Opercular arm creates a strong concavity in dorsal margin



Sucker spp.

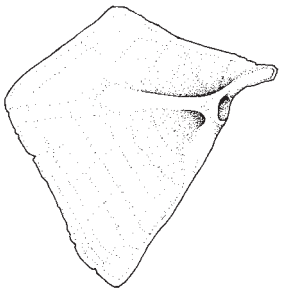
b. Opercular arm does not contribute to a concavity; dorsal margin approximately straight, or slightly curved



go to 11

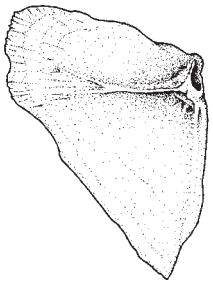
11. Extension of Dorsal Ridge

a. Dorsal ridge, if present, extends < 50% of opercle width



go to 12

b. Dorsal ridge extends along ≥ 50% of opercle width



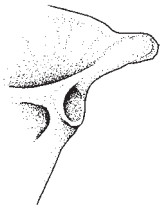
go to 18

12. Opercular Arm Length

a. Opercular arm length < articular fossa height

go to 13

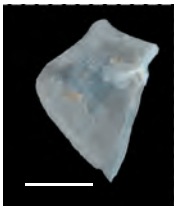
b. Opercular arm length > articular fossa height



go to 14

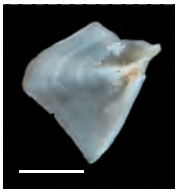
13. Opercular Opacity and Size

a. Opercle nearly translucent; anterior margin always less than 15 mm



Redside shiner

b. Opercle opaque; anterior margin may be greater than 15 mm



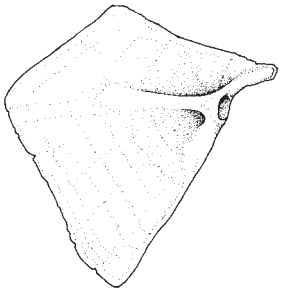
Northern pikeminnow

14. Shape of Posterior Margin

a. Midpoint of posterior margin is curved

Common carp

b. Midpont of posterior margin more protruding and distinctly angular



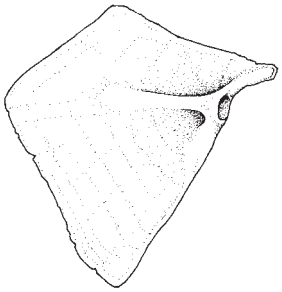
go to 15

15. Ratio: Dorsal Margin Length to Dorsal Crest Height

a. Dorsal margin length : dorsal crest height ≥ 0.70

Speckled dace

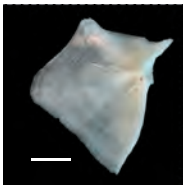
b. Dorsal margin length : dorsal crest height < 0.70



go to 16

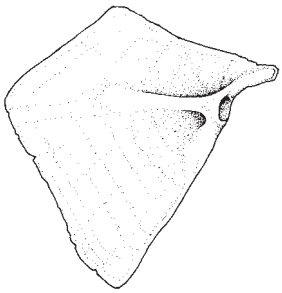
16. Ratio: Anterior Margin Length to Dorsal Crest Length

a. Anterior margin length : dorsal crest length < 1.00



Chiselmouth

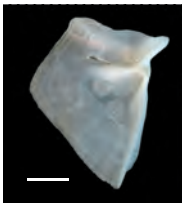
b. Anterior margin length : dorsal crest length ≥ 1.00



go to 17

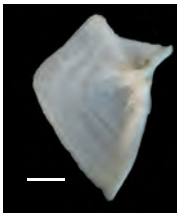
17. Ratio: Anterior Margin Length to Dorsal Margin Length

a. Anterior margin length : dorsal margin length ≤ 2.00



Peamouth

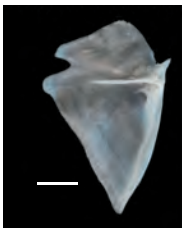
b. Anterior margin length : dorsal margin length > 2.00



Tench

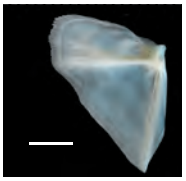
18. Posterior Notch on Dorsal Crest

a. Notch at posterior end of dorsal crest

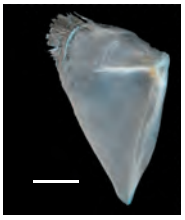


Black crappie

b. Posterior end of dorsal crest with crenulations or feathered tip



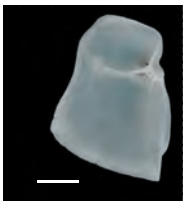
Pumpkinseed



Bluegill

19. Shape of Posterior Margin

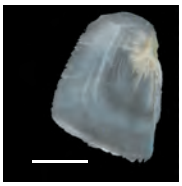
a. Posterior margin with concave scallop in line with dorsal ridge



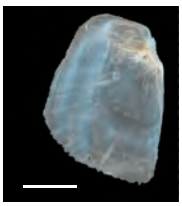
Mountain whitefish

b. Posterior margin usually straight

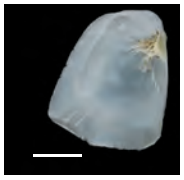
Sockeye



Chinook



Coho



Steelhead

Glossary

Adfluvial life history strategy in which adults live in lakes or reservoirs, returning to streams to spawn

Anadromous life history strategy in which adults live in the ocean, returning to freshwater streams to spawn

Anal fin base length distance between anal fin origin and insertion

Anterior located near or towards the head

Anterior dorsal fin lobe front lobe of a single dorsal fin that is separated by an indentation in the fin ray membranes into 2 lobes

Barbel fleshy whisker near the mouth

Body depth distance between dorsal-most and ventral-most points at the tallest part of the body, not including fins (Figure 1)

Caudal peduncle narrow support that connects the tail of a fish (caudal fin) to its body

Caudal peduncle depth distance between dorsal-most and ventral-most points at the narrowest part of the caudal peduncle

Ctenoid scales with tiny teeth on the exposed margin; feels rough when stroked toward head

Cycloid scales with a smooth exposed margin; feels smooth when stroked toward head

Dorso-ventrally compressed flattened top-to-bottom

Dorsal above the backbone; opposite of ventral

Dorsal standard length distance between dorsal fin insertion to most posterior end of hypural bones (Figure 1)

Dorsal fin base length distance from dorsal fin origin to insertion

Fork length distance from anterior-most point of the fish to the deepest point of the fork in the caudal fin (Figure 1)

Fossa a small cavity or depression in a bone

Insertion (of a fin) posterior-most point where a fin attaches to the body

Lateral line a line of sensory pores on the head and sides of fish

Laterally compressed flattened side-to-side

Maxillary bony portion of the upper jaw

Origin (of a fin) anterior-most point where a fin attaches to the body

Papillae small fleshy projections on the lips of suckers

Parr marks dark vertical bars on the sides of small salmonids

Pelvic fin base length distance from pelvic fin origin to insertion

Posterior refers to the rear; opposite of anterior

Separate dorsal fins each dorsal fin has an obvious origin and insertion; there is no membrane connecting the rays between the two fins

Snout the dorso-anterior part of a fish, anterior to the eye

Soft ray fin ray that is flexible, segmented, and usually branched

Spine (spiny ray) fin ray that is pointed and rigid; not segmented or branched

Standard length distance from the anterior-most point of the fish to the posterior-most edge of the hypural bones (Figure 1)

Subterminal mouth mouth overhung by snout

Terminal mouth mouth occurring at the anterior end

Ventral below the backbone; opposite of dorsal

Webbing thin, transluscent, membranous section of bone

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