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ATLAS OF COMMON SQUAMATOLOGICAL (FISH SCALE) MATERIAL IN COASTAL BRITISH COLUMBIA AND AN ASSESSMENT OF THE UTILITY OF VARIOUS SCALE TYPES IN PALEOFISHERIES RECONSTRUCTION

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ABSTRACT

Squamatological (fish scale) material from 48 common species found in coastal waters of British Columbia is presented. Fish-scale remains of extant species are well-preserved in Holocene core sediments in various anoxic basins along the coast of British Columbia. These remains are of considerable value in assessing natural variation in fish populations over time. Comparative micrographs of modern fish scales as well as an assessment of their preservation potential is provided. Photographs of various scales preserved in the sedimentary record (e.g., herring, rockfish, sardines, surfperch) are provided and discussed in the context of the taphonomic alteration that typically occurs after burial. This monograph—the first atlas of fish-scale material available for the northeast Pacific—will help resolve identification problems for future fish taxonomists, paleoceanographers, and fisheries-oriented researchers.

Key words: fish scales, squamatology, paleoceanography, Holocene, British Columbia, NE Pacific Ocean.

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INTRODUCTION

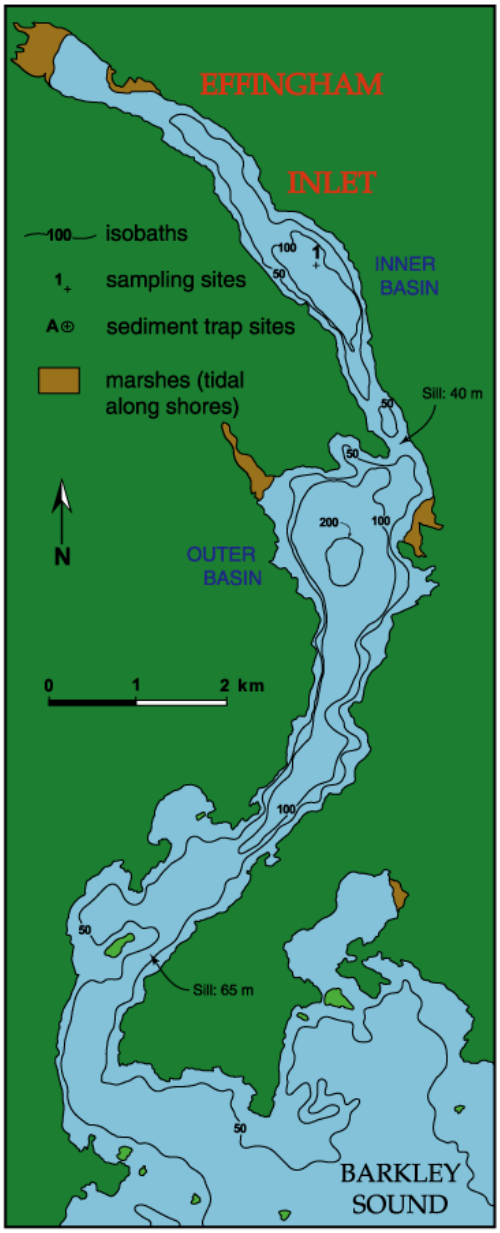
There has been a resurgence of interest in the relationship between fish population dynamics and oceanographic processes since the highly publicized Pacific salmon crisis off the west coast of British Columbia and the collapse of the Atlantic cod fishery. A relationship between ”ocean climate” changes and fish populations can be inferred, but in the Canadian context, real data are meager. Shifts in the position and intensity of the Aleutian Low-Pressure System, (over the northern North Pacific) exert a major control on fisheries recruitment off British Columbia by influencing stratification and coastal upwelling that can alter plankton abundance (Brodeur and Ware, 1992). Unfortunately, the nature of long-term oscillations in this system and the accompanying effect on fish stocks are not known. Thus, the analysis of a long record of fish abundance data and accompanying ocean-climate ”regime shifts” in coastal British Columbia is of strategic value to the Canadian west coast fishing industry. For example, the collapse of the Atlantic cod fishery has been partially linked to North Atlantic temperature/climate variation (Smith and Page, 1996).

Fishery collapses (in addition to the recent problems experienced by the salmon fishery) have occurred before on the west coast of North America. For example, the northern Pacific sardine fishery, initiated in the 1920s, began to collapse in the early to mid-1940s. By the early 1950s the central Californian fishery had also collapsed, followed by the southern Californian fishery in the 1960s. This progressive collapse from north to south was apparently aided by a significant change in the pelagic habitat in the California Current system and was associated with large-scale climate change in the Pacific during the 1940s (Francis and Hare, 1994). The gradual return of sardines to waters off Vancouver Island since 1990 is associated with the gradual recuperation of the populations off southern California (Baumgartner et al., 1992). A gradual expansion of the population probably began soon after a large-scale climate shift of the Pacific in 1977 (Robinson, 1994). Thus, although the historical fisheries record is limited for the Pacific coast of North America, sardine populations are known to expand and contract over time-scales of several decades or more and over distances that encompass the entire North American Upwelling Zone (Baumgartner et al., 1992).

We now know that many of the oceanic drivers that affect fish population dynamics in the NE Pacific (Ware and Thomson, 1991) have greater than decadal scale return times, and since the settlement history of the region, particularly British Columbia, is relatively short, available anecdotal and commercial fishing records are of limited use in assessing long-term variation in fish populations. Therefore, other methodologies are required for this research (Leaman, 1993). The use of osteological and squamatological (scale) fish remains as proxies to estimate paleofish populations was pioneered in the 1960s to better understand clupeid (sardine, herring, anchovy) population dynamics off the coast of southern California (Soutar, 1966; Soutar and Isaacs, 1969; Soutar and Isaacs, 1974). Subsequently research has been expanded all along the coast of the Americas (O’Connell and Tunnicliffe, 2001), most recently in Effingham Inlet on Vancouver Island (Dallimore, 2001). Effingham Inlet has proven to be an ideal area for this research because varved sediments deposited in the quiet and anoxic bottom waters of the contained basins archive a very well-preserved record of osteological (bone) and squamatological (scale) fish remains and other biologic proxies, such as diatoms, dinoflagellates, and foraminifera (Patterson et al., 2000).

Despite the existing body of research on fish remains available, it has proven surprisingly difficult to identify fish remains, not because of poor preservation, but due to a lack of accessible resource material. Most of the few research groups involved in this line of research have collections available on hand but there have been relatively no attempts at publishing definitive comparative references, with the exception of a few non illustrated keys (see Casteel, 1976, for summary). In this paper we aim to rectify this deficiency by presenting a detailed atlas of squamatological material collected from living representatives of common pelagic fish species found in southern British Columbia coastal waters. In addition, as some important types of scales (e.g., sardines, herrings, and anchovies) become altered and fragmented in the sedimentary record, making identification difficult, we provide comparative examples of selected fossilized material obtained from Effingham Inlet (Figure 1).

A



B INNER BASIN
Site 1: TUL 99 B03 (Piston Core)

Figure 1. A. Location map of southern British Columbia showing geographic features discussed in this paper. **B.** Details of Effingham Inlet showing location of core where scales were recovered.

SCALE CHARACTERISTICS

Most fish have a covering of scales, which can be divided into a variety of types, over the outer surface of their bodies. These types include the plate-like placoid scales of sharks; the diamond-shaped ganoid scales of the gars; the thin, smooth, disk-like cycloid scales of most freshwater fish and many marine species; and the ctenoid scales (with ctenii—small projections along the posterior margins) of perches and sunfish (Casteel, 1976). All the species presented in this atlas are referable to the cycloid and ctenoid types. Distinguishable scale characteristics include (1) overall scale shape; (2) position and shape of focus; (3) circuli appearance; (4)the appearance of the lateral, anterior, and posterior fields; and (5) to some extent, thickness/robustness of the scale.

As there is considerable variation in scale shape even between different areas of the same individual fish, scale outline is not always the best indicator for identification (Figure 2; Casteel, 1972; Chikuni, 1968). Size is also generally not a desirable characteristic, as scale size varies and overlap occurs not only between species and individuals, but also within a single specimen. Cyc-

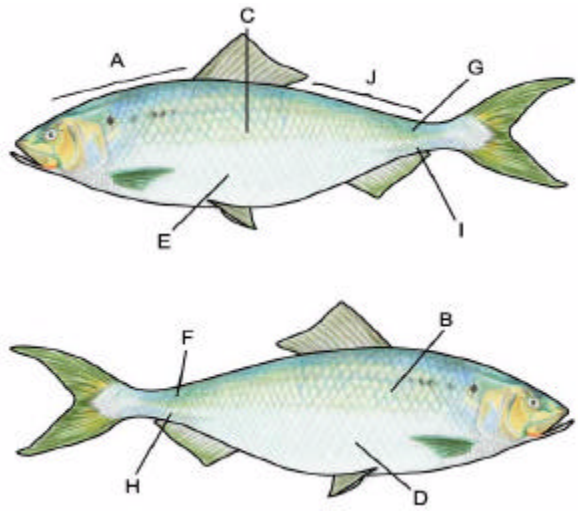


Figure 2. Various areas of fish that are characterized by distinctive scale morphologies as referred to in the scale descriptions found in the text. The line drawing is superimposed over an image of **Alosa sapidissima** (American Shad) for comparative purposes (line drawing modified after Casteel, 1976).

loid (Figure 3) and ctenoid (Figure 4) scales show considerable variation in their forms, although not always at either the genus or species level, permitting their use for identification purposes. The Salmonidae and, to a lesser extent, the Pleuronectidae, display particularly consistent morphological characters. At this time identification of preserved scales to higher taxonomic levels (e.g., Family) is straightforward providing that an adequate comparative reference collection is available. While species idenfication is possible for some genera, due to the lack of distinguishing characteristics, species-level assignments for many groups are not possible.

The terminology used to describe scales usually refers to topographical features such as surface sculpturing or internal variations (Figures 3, 4). Lagler (1947) established the terminology utilized here to describe various scale features as follows:

- 'Circuli' are defined as elevated markings on the surface, usually appearing as lines that more or less follow the outline of the scale.
- 'Focus' refers to the first part, often central, of the scale to appear in growth.
- 'Radii' are grooves that radiate from the focus to the scale margins.
- 'Primary Radii' are radii that extend from the focus to margin.
- 'Secondary Radii' are radii that begin outward from, not at, the focus.
- 'Ctenii' are toothlike structures on the posterior portion of some scales.
- 'Fields' are areas of the outer surface of the scale, either real as delimited by angulations of the circuli, or implied if the configuration of the circulii are otherwise. Various adjectives applied to fields are based on their position in relation to the orientation of the scale on a living fish.
- 'Anterior Field' is bounded by imaginary lines connecting the anterolateral corners (dorsal and ventral) or their equivalent points on rounded scales.
- 'Posterior Field' is bounded by imaginary lines connecting the posterolateral corners (dorsal and ventral) with the focus.

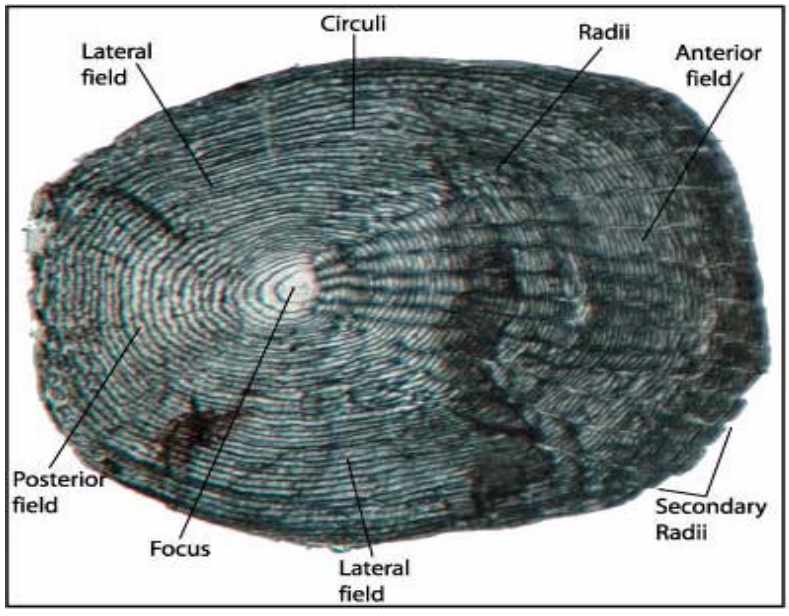


Figure 3. Scale features and terminology of a typical smooth, thin, and disk-like cycloid scale (following usage of Lagler, 1947).

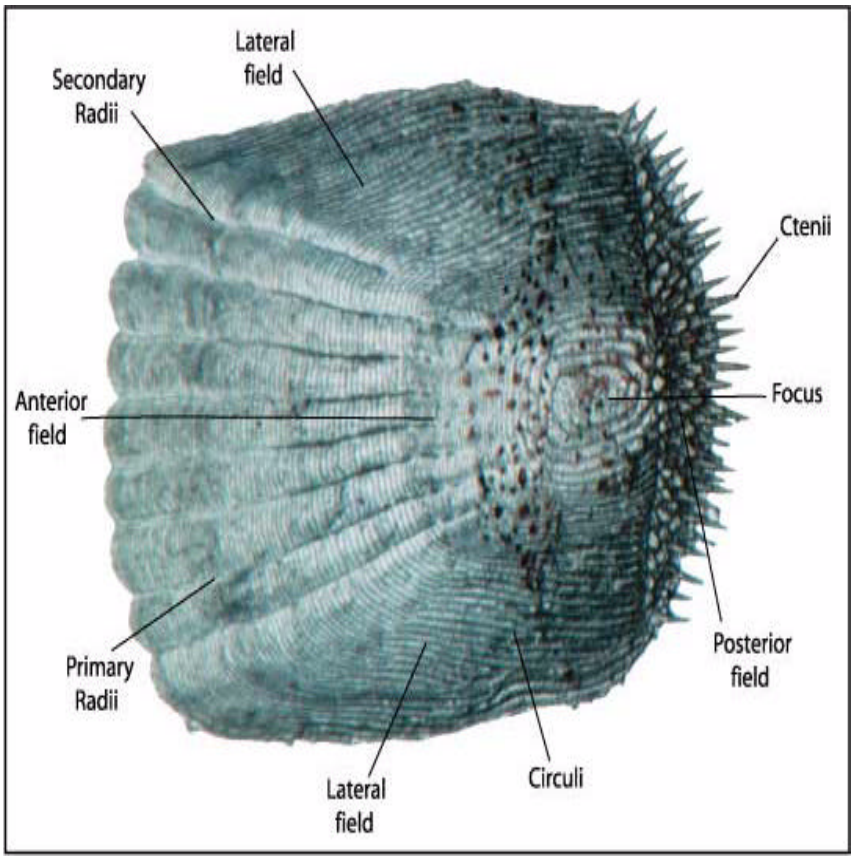


Figure 4. Scale features and terminology of a typical ctenoid scale showing typical projections along the posterior margins (following usage of Lagler, 1947).

- 'Lateral Fields' are the dorsal and ventral fields remaining after delimination of the anterior and posterior fields.

METHODS

Fish scales were obtained from frozen fish collected by fishermen and Department of Fisheries and Oceans research personnel, as well as from sediment core samples. Some scales were also collected from trypsin-treated fish; a standard method used for the digestion of tissue. The scales were processed and identified at the Pacific Geoscience Centre/Institute of Ocean Sciences in Sidney, British Columbia. Some additional slide material was also borrowed from the Bone Lab at the University of Victoria, British Columbia, and used as a reference for scale identification.

Fish Scale Reference Material

Scales were removed from frozen specimens in the A, C, E, G, I, and J regions of selected fish (Casteel, 1976). Effort was taken to remove as much tissue from the scales as possible without damaging the scale. Additional care must be taken to remove all tissue from fish that have a high oil content as this can damage the scale. Scales were then allowed to air dry. Next, they were gently sonicated in a dilute solution of a laboratory grade detergent (a standard jewelry-store type of sonicator will work) for approximately 30 minutes. Scales were then rinsed in freshwater and under a dissecting microscope, any remaining tissue was gently scraped off with a scalpel. Fish with a high oil content that were not properly cleaned in the previous step were difficult to scrape as the oily residue, once dried, did not soften or easily rehydrate. At this stage scales were either stored dry in plastic sample bags or mounted for subsequent microphotography.

Sampling of Sediments for Fish Remains

Sediment samples were placed in a 1L glass beaker with a few grams of sodium metaphosphate and enough water to allow the sample to disperse into a slurry. Samples were gently stirred and broken up with a plastic spatula to speed the process. The sample slurry was then allowed to sit for approximately 30 minutes. Next, samples were then sieved through a 250 µm sieve, and the residue was stored in 70% isopropyl alcohol or 70%

ethanol. Fish scales and bones, as well as other biogenic remains, were separated and identified using a dissecting microscope at relatively low power. Separated material was then tallied and stored in 70% ethanol. Figures of preserved scales are presented in downcore order from Effingham core B03 (for details see Dallimore, 2001).

Mounting of Reference and Paleontological Scale Collections

There are various methods used to mount fish scales. Methods utilizing mucilage were difficult to implement for this research, particularly when mounting many small scales per slide. It was found that the scale with the mucilage mixture dried very rapidly, causing the scales to curl before a cover glass could be laid down. However, other fish laboratories have successfully used this method. We found that the easiest mounting method was to allow the scales to sit in freshwater for a short period of time (<15 minutes). Once they had become flexible, the scales were mounted between glasses. Pairs of standard laboratory glass slides as well as the 2 cm x 2 cm glass slides used in making 35 mm slide mounts were found to be suitable. Care was taken to keep scales moist so that they did not curl or fracture prior to positioning the cover slide.

Using a dry mounting methodology is conducive to examination using both reflected and transmitted light microscopy. Although acetate peels also permit microscopic examination, many of the preserved scales are likely too fragile for the pressing process. In the case of the 35 mm slide mounts, these can also be projected onto screens using a standard projector and an appropriate slide carousel. These mounts can also be used in a microfiche reader, and printed out, greatly facilitating the identification of features critical to taxonomic assignment.

A shortcoming of dry mounting is that if there are scales of varying thickness on a mount, there is potential for the scales to move around under the glass. Care must also be taken with transportation of dry mounted slides as they can easily be broken. The metal brackets utilized in preparing micropaleontological research slides are particularly useful in securing glass laboratory slides together. Transparent adhesive tape was also used along the edges of the glass to secure some slides together. ‘Magic’-type tape is preferred, as it leaves no gummy residue on the glass and can easily be removed. When using this method some areas along the edges were left open to permit any remaining water residue to evaporate. Once completely dry, the edges were sealed with tape. To facilitate drying, a heating plate on a low setting can be used. Tape should only be used for slides that will be reopened again as the relatively short life spans of these sealants make them unsuitable for archival purposes. Dry mounted scale preparations are susceptible to desiccation cracks and the additional problems described above. In addition, for long-term preservation, we suggest use of water-soluble mounting media such as gum tragacanth, commonly used by foraminiferal researchers, or a non-solvent media such as Entellan.

Photography of Preserved Fish Scales

Microphotography digital image capture of the preserved fish scales was carried out using an Olympus SZH10 Research Stereo Microscope and a Polaroid Digital Microscope Camera at generally low magnification. Dimensions of scales were measured under the microscope, and scale bars were then digitally added to the images. All scales for publication were photographed using transmitted light to produce the characteristic “fingerprint” image. Some scales were initially also photographed with reflected light using a fiber optic light source. This method was quickly abandoned because it was difficult to achieve the desired light level and image quality. The digital images were then rendered on a Macintosh computer using Adobe Photoshop 6.0 software.

SYSTEMATIC DESCRIPTIONS

Detailed systematic treatment of the fish species themselves is not included and consists of only the genus and species name with a listing of common names. General descriptive information on the biology and distribution of fish taxa described in the following sections, except where indicated, is primarily after Hart (1973); Eschmeyer et al. (1983); Harbo (1999); and with assistance from Froese and Pauly (2001).Remarks on the preservation potential of some scales of some taxa apply equally to all members of a particular genera or family, and in some cases these comments are placed at the appropriate taxonomic level to avoid redundancy. Not all taxa in British Columbia waters are included here, as some were simply not available to us.

Order Clupeiformes

Diagnosis:

- Bony fish with soft rays only
- Abdominal pelvic fins have greater than five rays
- Adipose fin absent
- Tail supported by a urostyle
- Maxillary bones included in gape
- Teeth small or absent
- Cycloid Scales

Family Clupeidae (Herrings)

Diagnosis:

- Small and laterally compressed
- Large deciduous scales
- Midventral line often has specialized keeled scales
- Lateral line canal absent
- Single short dorsal fin
- Pelvic fins abdominal
- Caudal fin is deeply forked
- Usually a schooling species
- Three species in BC waters

Remarks: the scales of clupeids are generally large and easily shed. There is substantial variation in size and shape, not only between the sampling series, but also within a series. Amongst the species, however, the scales are remarkably similar and can be difficult to tell apart, especially if the scale material is fragmented. Along the midventral line of the body, the scales become keeled and highly modified, forming scutes. The focus definition is variable. The scales lack radii, but fracture cracks are common and often run parallel and across circuli. The circuli/annuli are concentric with the scale margin, but are not always concentric around the focus. Often the circuli/annuli run transverse across the scale. The fields (anterior, posterior, and lateral) are less distinct. The posterior field is considerably different from the rest of the scale, and looks similar to that of salmonids. It is sometimes referred to as a ”wing.” It is often clear with fracture cracks and striations, and the edge is crenulated.

The only other major study to consider the morphology of clupeid scales is that of Shackleton (1986), in her study on the sardine **Sardinops ocellata** and the anchovy, **Engraulis japonicus.** She cited approximately five-six types of clupeid scales, all differing in their overall shape. We have found that even within these types, there is considerable plasticity, although there is generally less variation in **Clupea** as compared to **Sardinops**, and relatively little variation amongst the scales of **Engraulis mordax.** Caution should be taken when using Shackleton’s study for comparisons to fish in Northeast Pacific waters as she was using different species that are present in this study. It should also be noted that in her diagrams, she also reversed the anterior and posterior fields. What we consider the posterior field is termed a ”wing” and the attachment of the wing to the edge of the anterior/lateral fields, the “wing join.” In these descriptions, the term posterior field will be retained for consistency.

Alosa sapidissima (American Shad)
(Other common names: Atlantic Shad, White Shad, Connecticut River Shad)
Figure 5.8

Description

Length: 76 cm (the largest herring in BC waters).
Mouth: moderately large, terminal, directed slightly upwards; upper jaw extends to the posterior part of orbit; lower jaw notched with a ”V-groove” into upper jaw; teeth absent in adults.
Body: coarse downward curving striae on the operculum; strong keels on the large midventral scutes.
Color: dorsal surface is metallic blue shading to white and then silver on the ventral surface; row(s) of four or more spots on side.

Biology

Depth: pelagic schooling species.
Habitat: juveniles will school in estuaries and rivers; adults live in marine waters, but their information on their movements is not recorded.
Season: anadromous; timing of spawning in BC waters is not well known but in the southern range there is evidence of almost year-round spawning; spawning takes place in coastal rivers with juveniles moving through the estuaries (generally in the summer months).
Diet: small crustaceans (e.g., copepods, mysids, insect larvae, amphipods) (Morrow, 1980).
Predators: other bony fish (Stevens, 1966), marine mammals (Scott and Crossman, 1973).
Distribution: native to the Atlantic region, include streams and inlets and was introduced in the 1870s to the Sacramento River, California; by 1891 it had reached British Columbia and Alaska by 1904; now common along the entire North American west coast.

Scale Description Figures 5.1-5.7

Relative Size of Scale: large (with adults, larger than **Clupea harengus**).
Position of Scales on Body: 60 rows in the midline region of the body; midventral line with heavy keeled scutes; scales above and below the midside of the tail fin (Hart, 1973).
Overall Scale Shape: circular to oval. The overall shape of the posterior field is highly variable depending on the scale type. The posterior field tends to be broad at the point of attachment and is gently convex. The outside edge of the posterior field is crentulated. The posterior field is clear with cracks and striations that run in the anterior/posterior axis. The outside edges of the scales are smooth but can be irregularly shaped.
Focus and Circuli: the focus varies from indistinct to very distinct. It is often situated just above the posterior field interface and is generally central between the lateral fields, although it is sometimes slightly offset. The circuli are straight to curved, but generally concentric with the

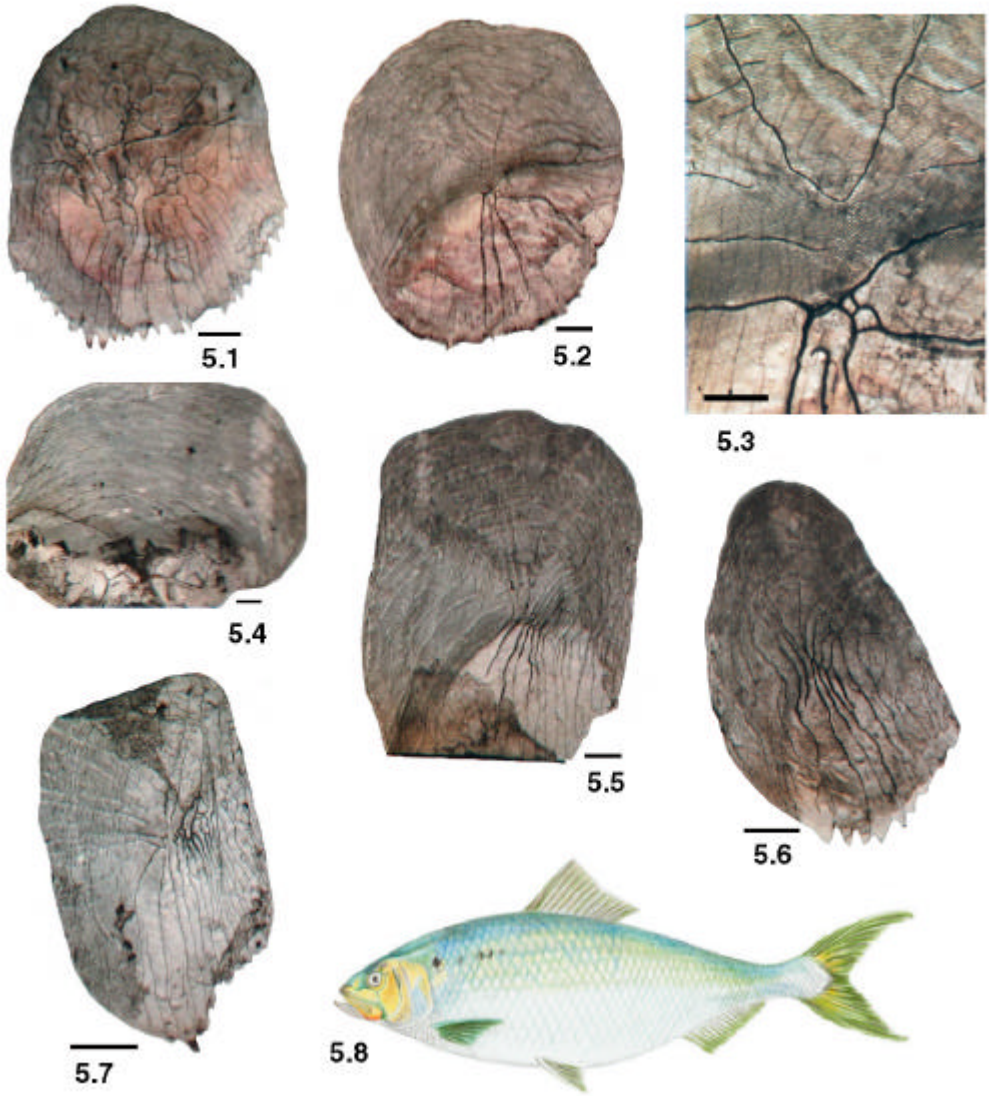


Figure 5.1- 5.8. 5.1. Alosa sapidissima (American Shad), lower flank; scale bar = 1.0 mm. **5.2.** Alosa sapidissima (American Shad), lower flank; scale bar = 1.0 mm. **5.3.** Alosa sapidissima (American Shad) lower flank. Magnified area from **5.2** showing circuli detail and the contact (join) between the posterior and anterior fields; scale bar = 500 µm. **5.4.** Alosa sapidissima (American Shad), pectoral; scale bar = 1.0 mm. **5.5.** Alosa sapidissima (American Shad), pelvic; scale bar = 1.0 mm. **5.6.** Alosa sapidissima (American Shad), pelvic; scale bar = 1.0 mm. **5.7.** Alosa sapidissima (American Shad); scale bar = 1.0 mm. **5.8.** Alosa sapidissima (American Shad); sketch of living specimen; length = 76 cm.

outline of the scale. The circuli are variable within a single scale: some are continuous between fields, others are discontinuous. The circuli tend to be less compacted than in **Sardinops**, but this is feature is plastic. In regenerated scales the circuli are quite distorted. The circuli are often broken along the midvertical axis of the scale, showing a reticulated pattern. Circuli do not proceed into **the posterior field, although some minor reticulation of the circuli may be present just below the attachment interface.**

Radii: there are no radii present, however, there are often groove and fracture lines in the scales that can run traversely across the scale, often crossing circuli. These fracture lines are also somewhat irregular.

Remarks: the scales of this species are extremely similar to **Clupea harengus**

Clupea harengus pallasi (Pacific Herring)
(Other common names: Iinang, K'aaw, Skah, Slhele lhong'et, Slhong'e)
Figure 6.11

Description

Length: 46 cm.

Mouth: moderate, terminal, directed moderately upwards; upper jaw extending to midpoint of orbit; teeth

in patch on vomer only; upper jaw does not have notch for lower jaw.
Body: elongate with a compressed head; no striations on operculum or head; no scales on head or on caudal region; last dorsal fin ray not elongates; scutes are weakly keeled.
Color: bluish green to olive on dorsal surface shading to silver on lateral and ventral sides; no spots on body.

Biology

Depth: pelagic schooling species.
Habitat: inlets, protected waters (e.g., embayments); nearshore waters while young; migrate into deeper waters offshore as adults.
Season: spawning occurs in winter-spring (December-March); occurs in protected waters where there is favourable substrate for egg deposition (e.g., kelp and/or eelgrass beds).
Diet: crustaceans (e.g., copepods, larval stages), molluscs, smaller fish; some phytoplankton species.
Predators: forage species (e.g., sardines, pollock, larger herring), salmon, marine mammals.
Distribution: Baja, California to Alaska to the Bering Sea to the Sea of Japan.

Scale Description
Figures 6.1-6.10

Relative Size of Scale: large.
Position of Scales on Body: 51-54 rows along the midside region; midventral line has weakly keeled scutes; and also there are scutes anterior to the pelvic fins and the anus (Hart, 1973).
Overall Scale Shape: circular to oval (G scales tend to be more elongated). In juveniles, the scales tend to be more teardroped shape with the main circuli portion being semi-circular and the adjoining wing join loosely V-shaped. The overall shape of the wing clips is highly variable. The posterior field attachment tends to be broad and can be straight to gently convex. The outside posterior edge is crenulated and curved. These scales are generally quite flexible mechanically.
Focus and Circuli: the focus varies from indistinct to very distinct. It is often situated just above the posterior field interface and is generally central between the lateral fields, although it is sometimes slightly offset. The circuli are straight to curved, but generally concentric with the outline of the scale. Annuli are generally distinct as a more pronounced ridge (this is less obvious is more circular scales). The circuli are variable within a single scale: some are continuous between fields, others are discontinuous. The circuli tend to be less compacted than in **Sardinops**, but this is feature is plastic. In regenerated scales the circuli and focal area are quite distorted. In juvenile scales, the circuli are often broken in the center of the scale, showing a reticulated pattern. Circuli do not proceed into the posterior field, although some minor reticulation of the circuli may be present just below the attachment interface.
Radii: there are no radii present, though there are often grooves and fracture lines in the scales that can run traversely across the scale, often crossing circuli. These fracture lines are also somewhat irregular.

Sardinops sagax (Pacific Sardine)
(Other common names: Pilchard)
Figure 7.13

Description

Length: up to 36 cm but usually less than 27 cm.
Mouth: moderate, terminal, directed slightly upwards; when jaws closed, the lower is contained within the upper; upper jaw extends to point below pupil; teeth absent.
Body: seven downward radiating striae on the operculum; scale-like appendages below midlateral region at the base of the caudal fin; fleshy appendage at the point of pelvic fin insertion.
Color: dark blue or green on dorsal surface that shades to silver on lateral and ventral sides; black spots on the sides of the body under the scales.

Biology

Depth: pelagic schooling species (may also form schools with anchovy, hake, and mackerels).
Habitat: young fish will school in sandy shallow beach areas; as they mature they move into deeper coastal waters and migrate north.
Season: main spawning location is California with only sporadic occurrences in the northern waters; spawning is temperature influenced, and peaks in California in the spring (April-May).
Diet: zooplankton.
Predators: larger fish, marine mammals, sea birds.
Distribution: eastern Pacific: South America (Chile, Peru) to Gulf of California and Baja, to Alaska.

Scale Description
Figures 7.1-7.12

Relative Scale Size: large.
Position of Scales on Body: 52-60 rows along midline of body; mid-ventral line has weakly keeled scutes (Hart, 1973).
Overall Scale Shape: circular to oval, the largest scales are squared. The posterior field is straight to gently convex. The outside edge of the posterior field is crenulated and curved. The overall shape of the posterior field can be highly variable depending on the scale type. The outside edges of the scales are smooth but can be irregularly shaped. These scales are generally more massive than **Clupea** and less flexible. In addition, many of the larger scales have protuberances in the central portion.
Focus and Circuli: the focus varies from indistinct to very distinct. It is often situated just above the posterior field interface and is generally central between the lateral fields, although it is sometimes slightly offset. The circuli are straight to curved, but generally concentric with the outline of the scale. Annuli seem to be more difficult to distinguish than in **Clupea**. The circuli are variable within a single scale with some being continuous between fields and others being discontinuous. The circuli tend to be more tightly compacted than in **Clupea,** but this is

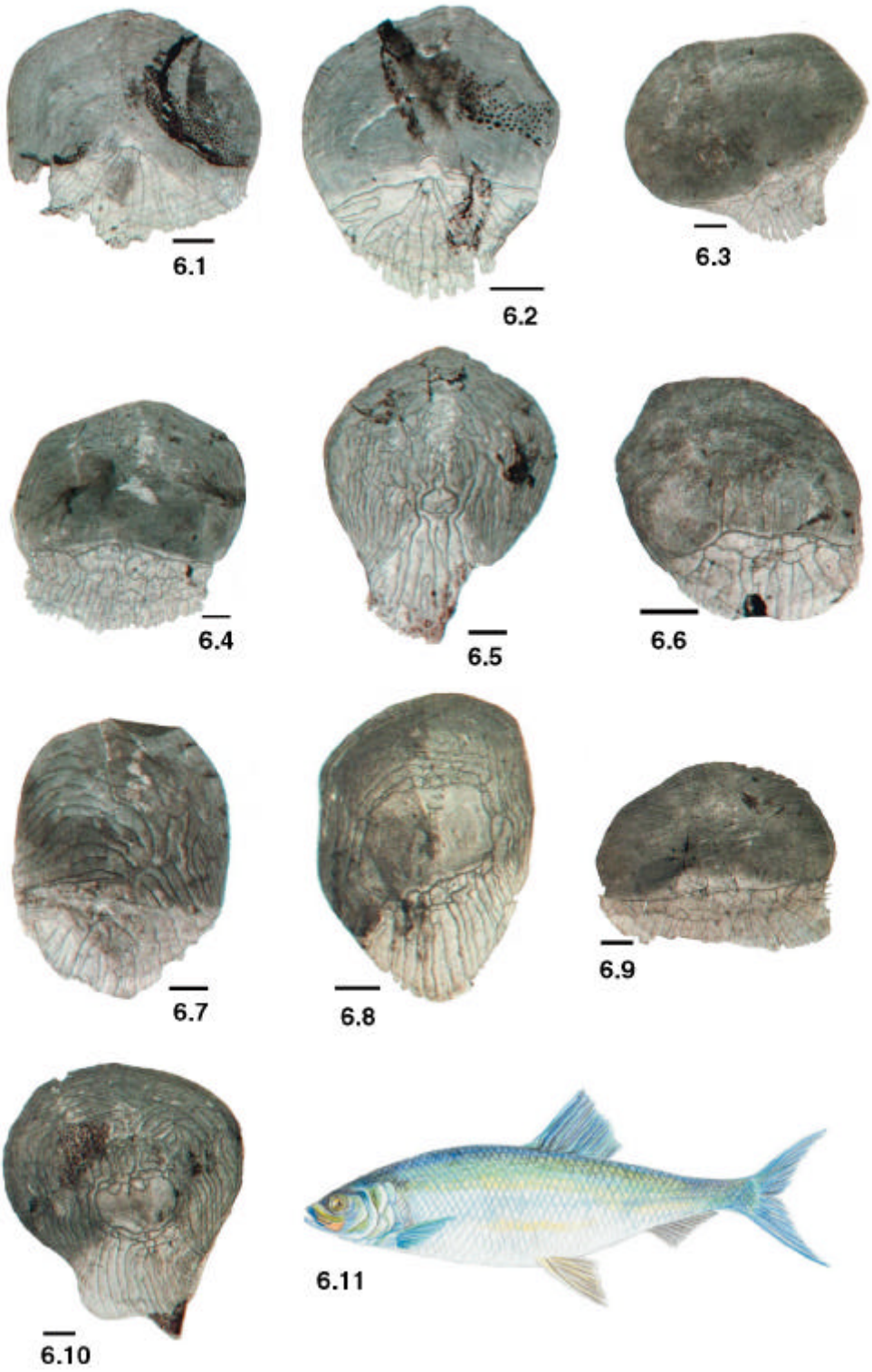


Figure 6.1-6.11. 6.1. Clupea harengus pallasi (Pacific Herring); body region A; scale bar = 1.0 mm. **6.2. Clupea harengus pallasi** (Pacific Herring); body region C; scale bar = 1.0 mm. **6.3. Clupea harengus pallasi** (Pacific Herring); body region E; scale bar= 1.0 mm. **6.4. Clupea harengus pallasi** (Pacific Herring); body region E; scale bar = 1.0 mm. **6.5. Clupea harengus pallasi** (Pacific Herring); body region G; scale bar = 1.0 mm. **6.6. Clupea harengus pallasi** (Pacific Herring); body region G; scale bar = 1.0 mm. **6.7. Clupea harengus pallasi** (Pacific Herring); body region I; scale bar = 1.0 mm. **6.8. Clupea harengus pallasi** (Pacific Herring); body region I; scale bar = 1.0 mm. **6.9. Clupea harengus pallasi** (Pacific Herring); body region J; scale bar = 1.0 mm. **6.10. Clupea harengus pallasi** (Pacific Herring); body region J; scale bar = 1.0 mm. **6.11. Clupea harengus pallasi** (Pacific Herring); sketch of living specimen; length = 46 cm.

Figure 7.1-7.12. 7.1. Sardinops sagax (Pacific Sardine); body region A; scale bar = 1.0 mm. **7.2. Sardinops sagax** (Pacific Sardine); body region A; scale bar = 1.0 mm. **7.3. Sardinops sagax** (Pacific Sardine); body region C; scale bar = 1.0 mm. **7.4. Sardinops sagax** (Pacific Sardine); body region E; scale bar = 1.0 mm. **7.5. Sardinops sagax** (Pacific Sardine); body region E; scale bar = 1.0 mm. **7.6. Sardinops sagax** (Pacific Sardine); body region G; scale bar = 1.0 mm. **7.7. Sardinops sagax** (Pacific Sardine); body region I; scale bar = 1.0 mm. **7.8. Sardinops sagax** (Pacific Sardine); body region I; scale bar = 1.0 mm. **7.9. Sardinops sagax** (Pacific Sardine); body region J; scale bar = 1.0 mm. **7.10. Sardinops sagax** (Pacific Sardine); scale bar = 1.0 mm. **7.11. Sardinops sagax** (Pacific Sardine); scale bar = 1.0 mm. **7.12. Sardinops sagax** (Pacific Sardine); scale bar = 1.0 mm. **7.13. Sardinops sagax** (Pacific Sardine); sketch of living specimen; length = 27 cm.

feature is plastic. In regenerated scales the circuli and focal area are quite distorted. Circuli generally end before the posterior field although a reticulation pattern may be present.

Radii: there are no radii present, however, some of the large square scales do have distinct fracture lines (looking similar to radii) in the lateral fields. These lines begin being parallel to the circuli then are directed away from the wing join and intersect circuli.

Scale Preservation
Clupea: Figures 8.1-8.35
Sardinops: Figures 9.1-9.17

Clupeid scales are, comparative to other fish species, thick and robust and therefore preserve easily in Quaternary/Holocene sediments. Our experience indicates that because of their robustness, sardine scales tend to preserve whole, sometimes even with the posterior field

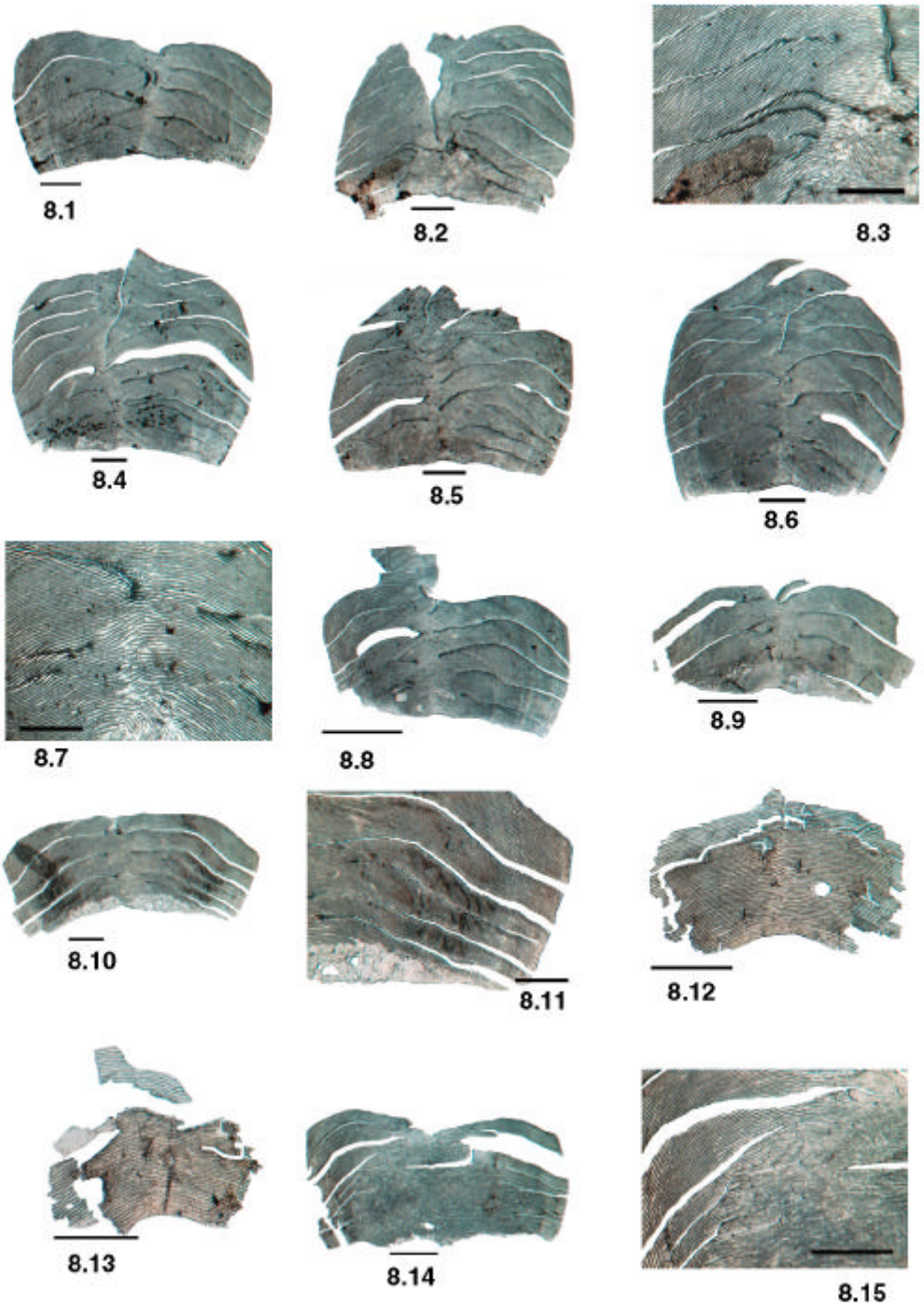


Figure 8.1-8.15 (continued on next page). 8.1. Herring, core B03 S01, surface sediment; scale bar = 1.0 mm. **8.2.** Herring, core B03 S01, surface sediment; scale bar = 1.0 mm. **8.3.** Herring, core B03 S01, surface sediment. Magnified area from Fig. 8.2 showing detail of circuli; scale bar = 500 µm. **8.4.** Herring, core B03 S01, surface sediment; scale bar = 1.0 mm. **8.5.** Herring, core B03 S01, surface sediment; scale bar = 1.0 mm. **8.6.** Herring, core B03 S01, surface sediment; scale bar = 1.0 mm. **8.7.** Herring, core B03 S01, surface sediment. Magnified area from Fig. 8.6 showing detail of circuli; scale bar = 500 µm. **8.8.** Herring, core B03 S01, interval 2-7 cm; scale bar = 1.0 mm. **8.9.** Herring, core B03 S01, interval 2-7 cm; scale bar = 1.0 mm. **8.10.** Herring, core B03 S01, interval 2-7 cm; scale bar = 1.0 mm. **8.11.** Herring, core B03 S01, interval 2-7 cm. Magnified area from Fig. 8.10; scale bar = 500 µm. **8.12.** Juvenile herring, core B03 S01, interval 2-7 cm; scale bar = 250 µm. **8.13.** Juvenile herring, core B03 S01, interval 2-7 cm; scale bar = 1.0 mm. **8.14.** Herring, core B03 S01, interval 16-21 cm, scale bar = 1.0 mm. **8.15.** Herring, core B03 S01, interval 16-21 cm. Magnified area from Fig. 8.14 showing circuli detail; scale bar = 500 µm.

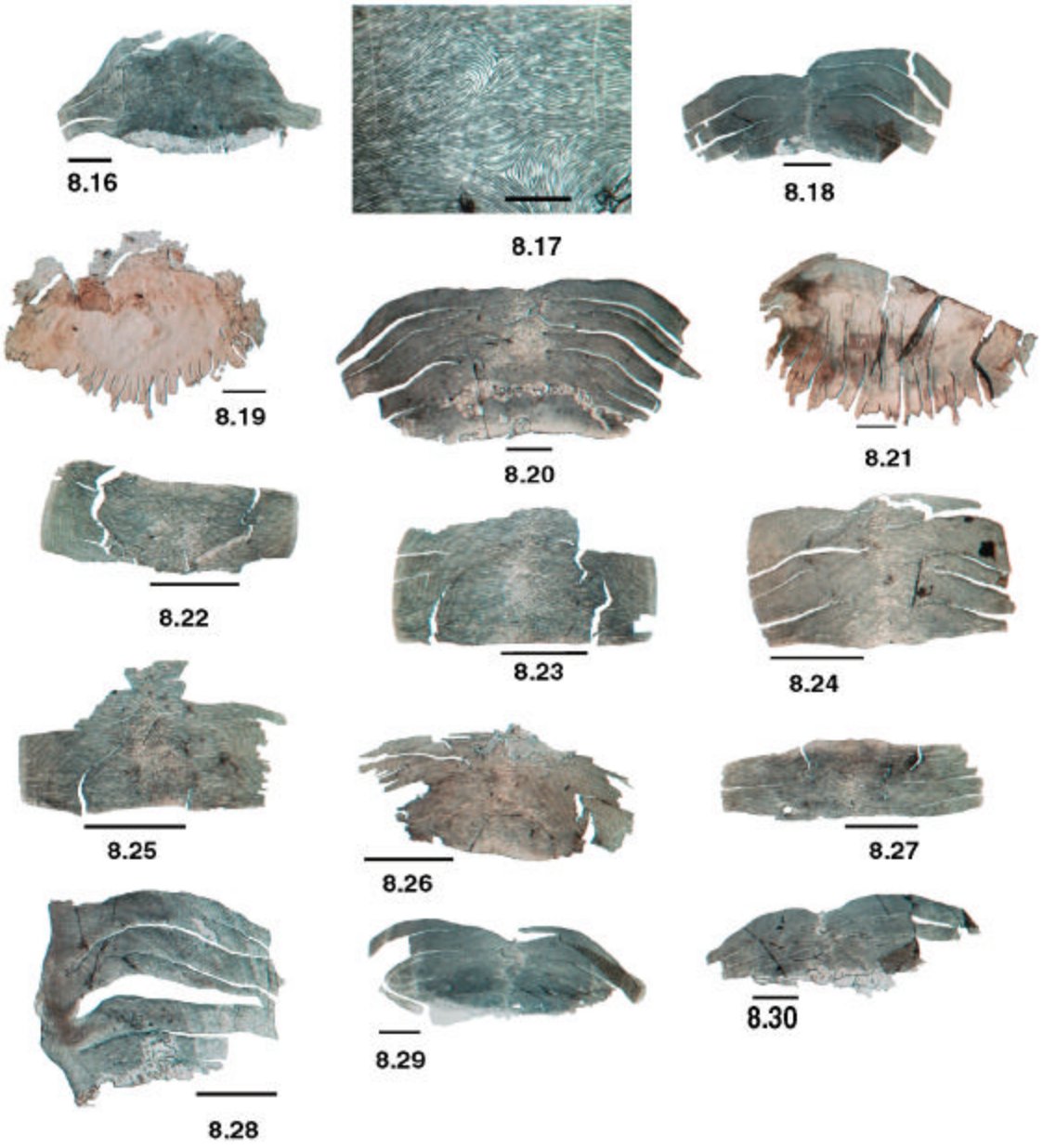


Figure 8.16 - 8.05 (continued on next page). 8.16. Herring, core B03 S01, interval 16-21 cm; scale bar = 1.0 mm. **8.17.** Herring, core B03 S01, interval 16-21 cm. Magnified central area from Fig. 8.16 showing circuli detail; scale bar = 250 µm. **8.18.** Herring, core B03 S02, interval 25-30 cm; scale bar = 1.0 mm. **8.19.** Herring wing, core B03 S02, interval 25-30 cm; scale bar = 1.0 mm. **8.20.** Herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.21.** Herring wing, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.22.** Juvenile herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.23.** Juvenile herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.24.** Juvenile herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.25.** Herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.26.** Herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.27.** Herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.28.** Herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.29.** Herring, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **8.30.** Herring, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm.

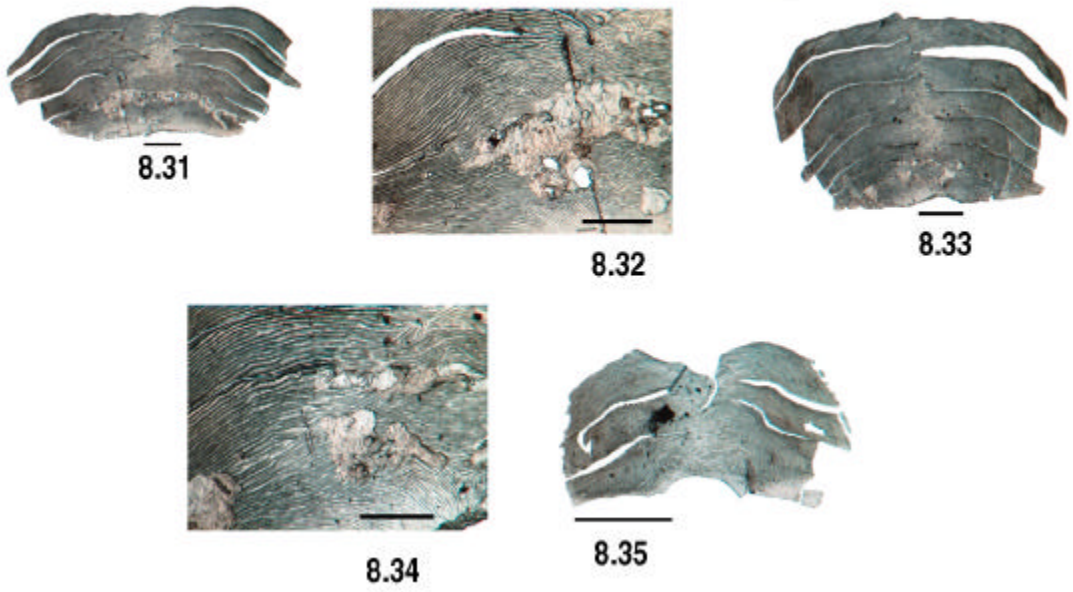


Figure 8.31 - 8.35. 8.31. Herring, core B03 S02, interval 110-120 cm; scale bar = 1.0 mm. **8.32.** Herring, core B03 S02, interval 110-120 cm. Magnified area from Fig. 8.31; scale bar = 500 µm. **8.33.** Herring, core B03 S02, interval 110-120 cm; scale bar = 1.0 mm. **8.34.** Herring, core B03 S02, interval 110-120 cm. Magnified area from Fig. 8.33 showing circuli detail; scale bar = 500 µm. **8.35.** Herring, core B03 S04, interval 73-78 cm; scale bar = 1.0 mm.

(wing) attached. That generality aside, **Clupea** scales tend to rip and break at fracture areas. This characteristic results in few **Clupea** scales, unless they are very recent, being found intact in sediments. The leading edges of the anterior field and the wing clips are also often detached. As a result it can often be quite difficult to distinguish **Clupea** and **Sardinops** fragments. However, **Clupea** scales (including the wings) are generally white and quite mechanically flexible, and to some extent easily ripped, while **Sardinops** scales are often amber and brittle.

Family Engraulidae (Anchovies)

Diagnosis:

- Slender bodies
- Lateral lines absent
- Adipose fin absent
- Large cycloid scales
- Operculum lengthens backwards
- Schooling species
- One species in BC waters

Engraulis mordax mordax (Northern Anchovy)
(Other common names: California Anchovy, Plain Anchovy)
Figure 10.8

Description

Length: up to 23 cm but most are around 18 cm.
Mouth: inferior, large, directed slightly upwards; upper jaw extends back approximately 2.5 times the distance of the tip of the snout to the midorbit point; lower jaw does not quite reach the anterior edge of the orbit; teeth on maxillary and mandibles.
Body: in cross-section is round; opercules prolonged backwards; caudal fin forked; scale-like appendages above and below the midlateral line on fin; fleshy appendages at the insertion of each fin.
Color: metallic blue to green above and silver on lateral and ventral sides.

Biology

Depth: pelagic schooling species (sometimes with other schooling species such as herring and mackerel).
Habitat: coastal nearshore waters.
Season: life history in BC not well known; in southern range spawning occurs at night in the upper warm water layers.
Diet: crustaceans (e.g., euphasiids, copepods, decapod larvae).
Predators: larger fish species, marine mammals, sea birds.
Distribution: Baja, California to the Queen Charlotte Islands.

Scale Description
Figures 10.1-10.7

Relative Size of Scale: large. The sampling area for the scales illustrated is not known but they all appear to be of a single morphology and size, suggesting that they came from one individual fish.
Position of Scales on Body: in oblique rows on the midside, 41-50 (Hart, 1973).
Overall Scale Shape: the overall shape is circular, the scale is tri-lobed in the anterior field and the posterior

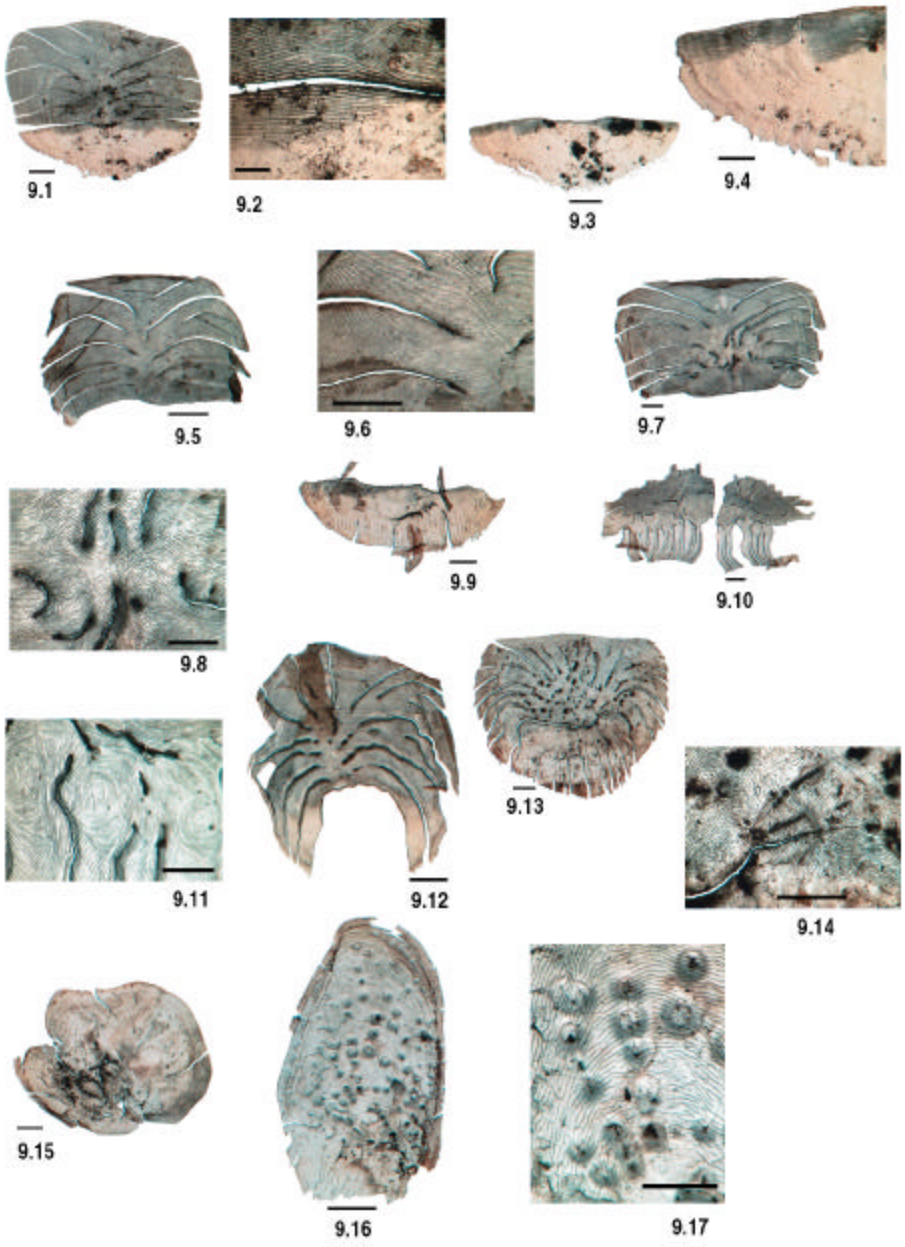


Figure 9.1 - 9.16. 9.1. Sardine, core B03 S01, surface sediment; scale bar = 1.0 mm. **9.2.** Sardine, core B03 S01, surface sediment. Magnified area from Fig. 9.1 showing circuli detail and the contact (join) between the anterior and posterior fields; scale bar = 250 µm. **9.3.** Sardine wing (posterior field), core B03 S01, surface sediment; scale bar = 1.0 mm. **9.4.** Sardine wing (posterior field), core B03 S01, surface sediment. Magnified area from **Fig. 9.3;** scale bar = 500 µm. **9.5.** Sardine, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **9.6.** Sardine, core B03 S02, interval 55-60 cm. Magnified central area from **Fig. 9.5;** scale bar = 500 µm. **9.7.** Sardine, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **9.8.** Sardine, core B03 S02, interval 55-60 cm. Magnified central area from Fig. 9.7 showing circuli ornamentation; scale bar = 500 µm. **9.9.** Sardine wing, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **9.10.** Sardine wing (?), core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **9.11.** Sardine wing (?), core B03 S02, interval 55-60 cm. Magnified area from Fig. 9.10 showing circuli ornamentation; scale bar = 500 µm. **9.12.** Sardine, core B03 S02, interval 110-120 cm, slide 3/9; scale bar = 1.0 mm. **9.13.** Sardine, core B03 S04, interval 73-78 cm; scale bar = 1.0 mm. **9.14.** Sardine, core B03 S04, interval 73-78 cm. Magnified area from Fig. 9.13 showing circuli and join (contact between wing and circuli); scale bar = 500 µm. **9.15.** Sardine, core B03 S04, interval 73-78 cm; scale bar = 1.0 mm. **9.16.** Sardine, core B03 S04, interval 73-78 cm; scale bar = 1.0 mm. **9.17.** Sardine, core B03 S04, interval 73-78 cm. Magnified area from **Fig. 9.16** showing protruberances in anterior field; scale bar = 500 µm.

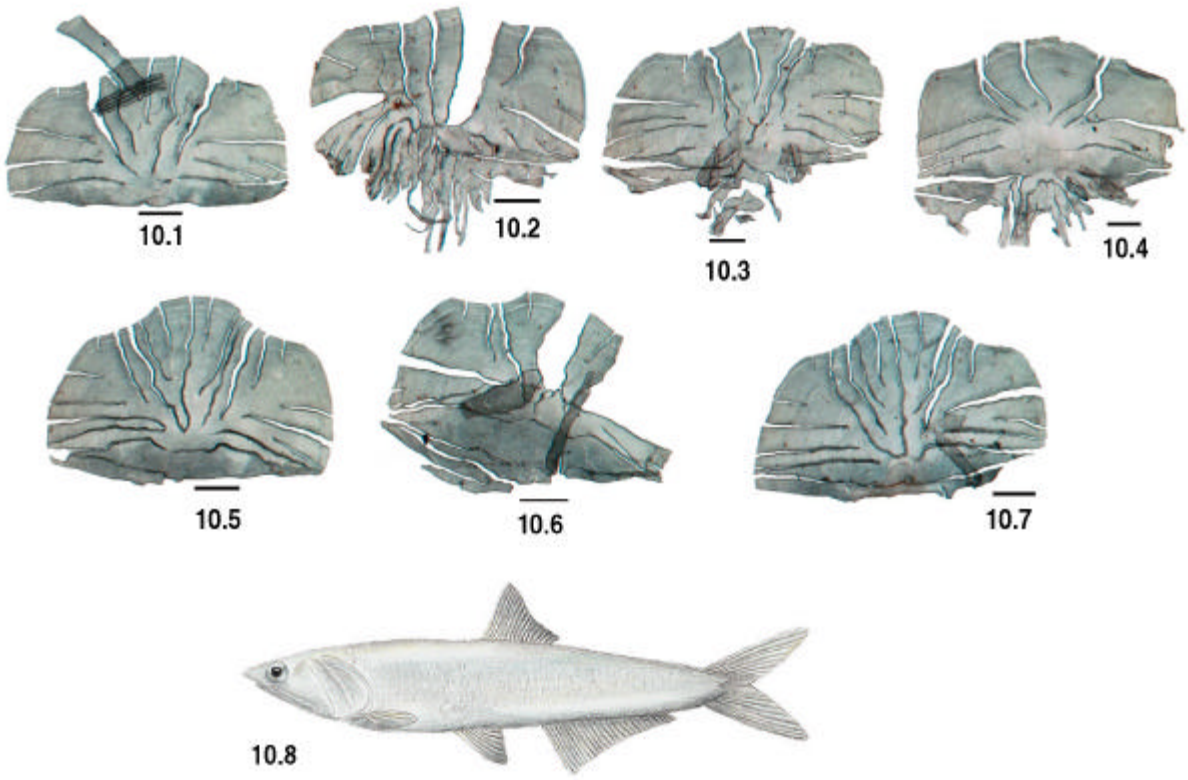


Figure 10.1. Engraulis mordax mordax (Northern Anchovy); scale bar = 1.0 mm. **10.2. Engraulis mordax mordax** (Northern Anchovy); scale bar = 1.0 mm. **10.3. Engraulis mordax mordax** (Northern Anchovy); scale bar = 1.0 mm. **10.4. Engraulis mordax mordax** (Northern Anchovy); scale bar = 1.0 mm. **10.5. Engraulis mordax mordax** (Northern Anchovy); scale bar = 1.0 mm. **10.6. Engraulis mordax mordax** (Northern Anchovy); scale bar = 1.0 mm. **10.7. Engraulis mordax mordax** (Northern Anchovy); scale bar = 1.0 mm. **10.8. Engraulis mordax mordax** (Northern Anchovy); sketch of living specimen; length = approximately 18 cm.

field is variable in shape. The posterior fields are heavily subjected to fracturing.

Focus and Circuli: the focus is generally indistinct. The area of growth appears to occur (as seen on scale morphology) as the area of the first concentric continuous circuli and the region posterior to that area, which consists of discontinuous transverse “circuli.” This is the region of interface between the anterior/lateral fields and the posterior field. The circuli are continuous between the lateral and anterior field (or the three lobes) and discontinuous in the posterior field. The circuli in the latter field can be indistinct. The continuous circuli are concentric with the outline shape of the scale.

Radii: there are no radii present, however, there are often transverse grooves and fracture lines that occur in predictable ways. Wing joins can fracture both transversely and in the anterior/posterior axis.

Scale Preservation
Figures 11.1-11.16

Scales of the northern anchovy preserve easily in Quaternary sediments. They are robust and have a high degree of mechanical flexibility. They are, however, subject to erosion and fracturing along points of weakness. The degree of abrasion in the sediments controls the degree of fragmentation. Wings (posterior fields) are often disarticulated, as is the central lobe in the anterior field. In some cases, all three lobes and wing are disarticulated, leaving only the central focal area. Care must be taken when determining counts so that a single fragmented scale is not counted several times. The scales are generally amber in color. Some geochemical conditions can ”bleach” them white and cause them to become extremely brittle.

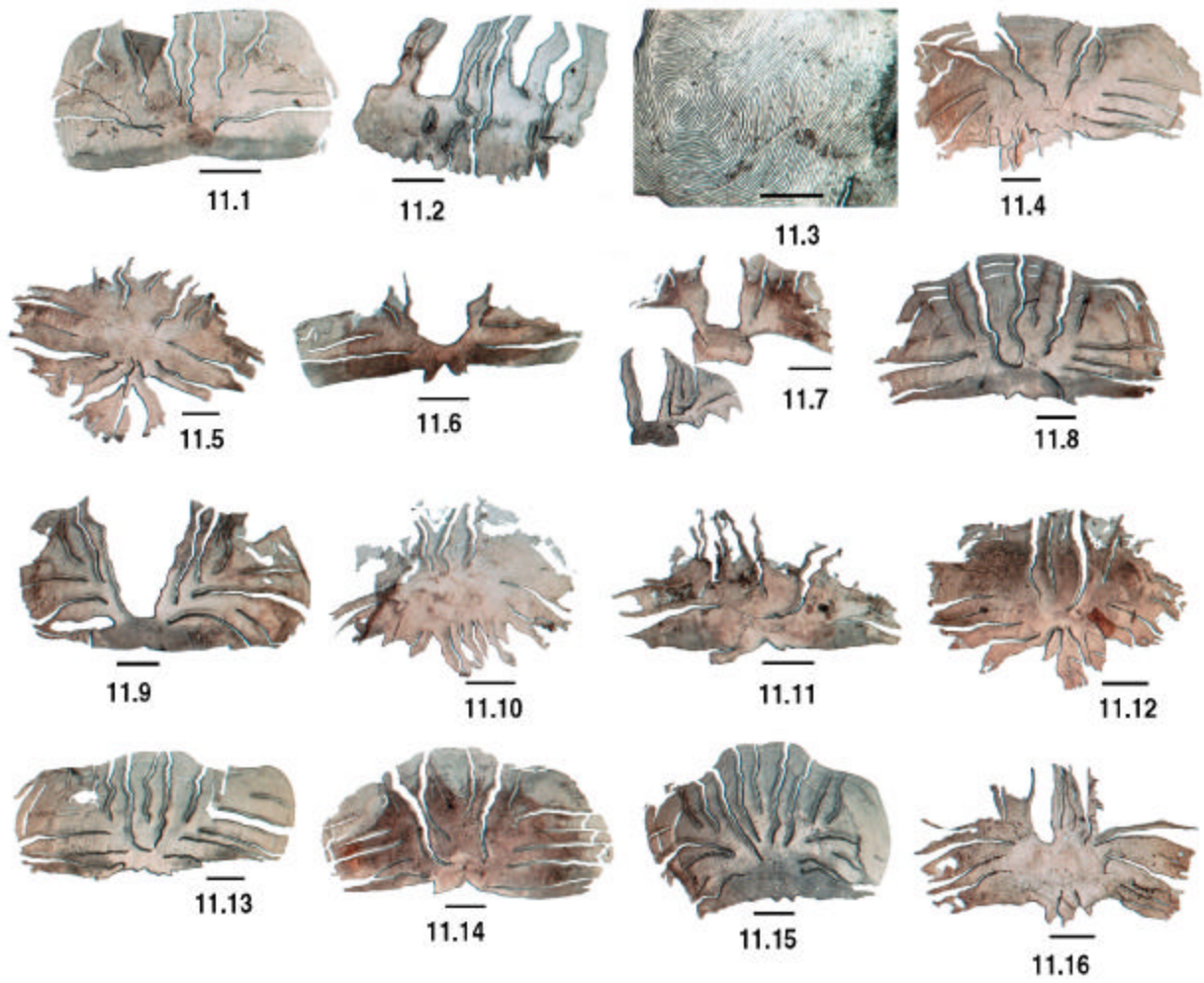


Figure 11.1 - 11.16. 11.1. Anchovy, core B03 S01, interval 16-21 cm; scale bar = 1.0 mm. **11.2.** Anchovy (?), core B03 S02, interval 25-30 cm; scale bar = 1.0 mm. **11.3.** Anchovy (?), core B03 S02, interval 25-30 cm. Magnified area from Fig. 11.2 showing circuli detail; scale bar = 250 µm. **11.4.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.5.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.6.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.7.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.8.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.9.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.10.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.11.** Anchovy, core B03 S02, interval 30-40 cm; scale bar = 1.0 mm. **11.12.** Anchovy, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **11.13.** Anchovy, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **11.14.** Anchovy, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **11.15.** Anchovy, core B03 S02, interval 55-60 cm; scale bar = 1.0 2mm. **11.16.** Anchovy, core B03 S04, interval 73-78 cm; scale bar = 1.0 mm.

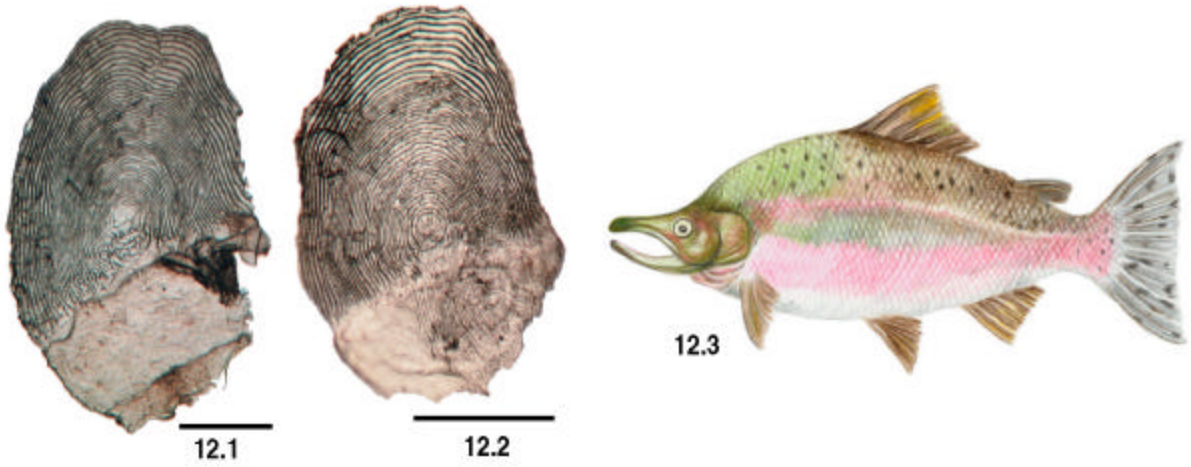


Figure 12.1 - 12.3. 12.1. Oncorhynchus gorbuscha (Pink Salmon); scale bar = 1.0 mm. **12.2. Oncorhynchus gorbuscha** (Pink Salmon); scale bar = 1.0 mm. **12.3. Oncorhynchus gorbuscha** (Pink Salmon); sketch of living specimen; length = 76 cm.

Order Salmoniformes
Family Salmonidae (Salmon)

Diagnosis:

- Fins are soft rayed
- Adipose fin present
- Auxillary pelvic scale present
- Last three vertebrae turned dorsally
- Teeth well developed on jaws, vomer, palatines, and tongue
- Lateral line present
- Generally anadromous
- Generally schooling
- Strong degree of sexual dimorphism
- Cycloid scales
- Scales are absent on the side of the tail

Remarks: two major keys have been developed for the identification of salmon using scales (Bilton, et al., 1964; Mosher, 1969). There is a degree of variation built into the Bilton et al. (1964) key not found in Mosher (1969). Bilton et al. (1964) is applicable for sockeye, pink, chum, and chinooks, but is less useful than Mosher (1969) for coho salmon. There are also some discrepancies between the keys confirmed by our own visual observations, especially with respect to the number of complete circuli below the focus. As the reader will note there are also differences between the authors regarding the presence of circuli in the posterior field. In addition, reticulation with reference to the salmonidae is defined as the posterior region of the focus where circuli appear to have ”broken up” and have become distorted. Types of reticulation include ladder-like and globular (Bilton et al., 1964).

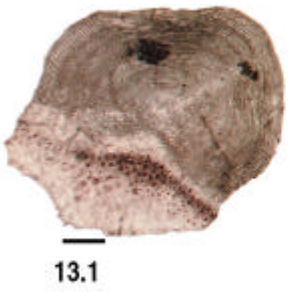
Oncorhynchus gorbuscha (Pink Salmon)
(Other common names: Humpback Salmon, Humpie)
Figure 12.3

Description

Length: 76 cm.
Mouth: large, terminal, directed upwards and forward; upper jaw reaches the posterior edge of orbit; snout is rounded and narrow; lips are fleshy; teeth small and weak, except in breeding males where the mouth becomes enlarged with well-developed teeth, the upper jaw becomes hooked downwards.
Body: elongate; caudal peduncle compressed; caudal fin slightly forked; adipose fin slender; 24-35 gill rakers over the first gill arch; breeding males develop a predorsal fin hump.
Color: metallic blue to green above; silvery to white below; large dark oval spots on back, adipose fins, and caudal fin; in breeding males, the dorsal surface becomes dark, the sides are red with green spots. Females are olive with dusky stripes.

Biology

Depth: pelagic schooling; 0-250 m.
Habitat: open Pacific offshore waters and coastal streams.
Season: spawns in the fall (September-October); eggs hatch in the spring and young spend first summer in river/estuarine systems, moving into deeper offshore waters in the fall; spend 18 months at sea then return to rivers to spawn.
Diet: juveniles/young eat crustaceans (e.g., copepods, euphasiids), salps, insects, forage fish (e.g., herring, hake); adults eat crustaceans (e.g., copepods, euphasiids), squid, forage fish species.
Predators: larger fish species including other salmon (on young), sea birds, marine mammals.
Distribution: North Pacific: southern California to Alaska to Bering Sea to the Arctic Ocean to Russia and Japan.


13.1


13.2

Figure 13.1 - 13.2. 13.1. Oncorhynchus keta (Chum Salmon); scale bar = 1.0 mm. **13.2. Oncorhynchus keta** (Chum Salmon); sketch of living specimen, female; length = 102 cm.

Scale Description
Figures 12.1-12.2

Relative Size of Scale: small.
Position of Scale on Body: >150 on the lateral line (Hart, 1973).
Overall Scale Shape: circular to somewhat oval, the posterior field can be rounded but the edge is often irregular.
Focus and Circuli: focus is clearly defined and often centralized between the fields; often just anterior to the interface of the posterior field. The circuli are concentric with the scale outline. Circuli are both continuous and discontinuous in the lateral and anterior fields. The posterior field is clear and circuli are absent.
Radii: absent.
Remarks: Mosher (1969) reported that there will be only one “winter zone” or year mark; circuli (discontinuous) and radial striations sometimes present in the posterior field; and six complete circuli below the focus. According to Bilton et al., (1964) at the base of the anterior field the circuli break up into “ladder-like” and sometimes “globular” reticulation; greater than seven broken circuli in the posterior field; and no freshwater year bands.

Oncorhynchus keta (Chum Salmon)
(Other common names: Dog Salmon, Fall Salmon, Calico Salmon)
Figure 13.2

Description

Length: 102 cm.
Mouth: large, terminal, directed forward; upper jaw reaches the posterior edge of orbit; snout is narrow; lips are fleshy; teeth in jaws well developed in sea-run salmon and in breeding males they are modified to canines; teeth also present in premaxillaries, maxillaries, palatines, and the anterior portion of the tongue.
Body: elongate; caudal peduncle moderately compressed; caudal fin slightly forked; adipose fin slender; 18-26 gill rakers over the first gill arch.
Color: metallic blue above (sometimes with dark speckles); silvery to white below; dark tips on anal, pectoral, and caudal fin; spawning males are gray-red with vertical green bars on their sides with dark gray beneath.

Biology

Depth: pelagic schooling; 0-250 m.
Habitat: open Pacific offshore waters and coastal streams.
Season: spawns in the winter to early spring (mainly winter); eggs hatch in the spring and move towards coastal nearshore waters and move offshore during the fall; spend two to seven years at sea then returns to rivers to spawn.
Diet: juveniles/young eat crustaceans (e.g., copepods, euphasiids), tunicates, molluscs (pteropods, squid) adults eat crustaceans (e.g., copepods, euphasiids), squid, forage fish species.
Predators: larger fish species including other salmon (on young), sea birds, marine mammals, and terrestrial mammals.
Distribution: North Pacific; southern California to Alaska to Bering Sea to the Arctic Ocean to Russia (Siberia) and the Sea of Japan.

Scale Description
Figure 13.1

Relative Size of Scale: large.
Position of Scales on Body: 130-153 above the lateral line canal and 126-151 on the lateral line canal**.** (Hart, 1973).
Overall Scale Shape: circular to somewhat oval anterior field, the posterior field is often irregular.
Focus and Circuli: focus is clearly defined and often centralized between the fields; often just anterior to the interface of the posterior field. The circuli are concentric with the scale outline. The circuli are generally continuous between the lateral and anterior fields, but there is a small number of discontinuous circuli. The posterior field is clear, and some discontinuous circuli or reticulation may be present.
Radii: absent.
Remarks: Mosher (1969) reported that no freshwater nucleus present; heavy granular reticulation (globular reticulation) at the anterior/posterior interface; less than seven complete circuli below the focus but no circuli in the posterior field; radial striations and sculpturing in the posterior field. The Bilton et al. (1964) key allows for one or more ocean annulus. If there is more than one ocean

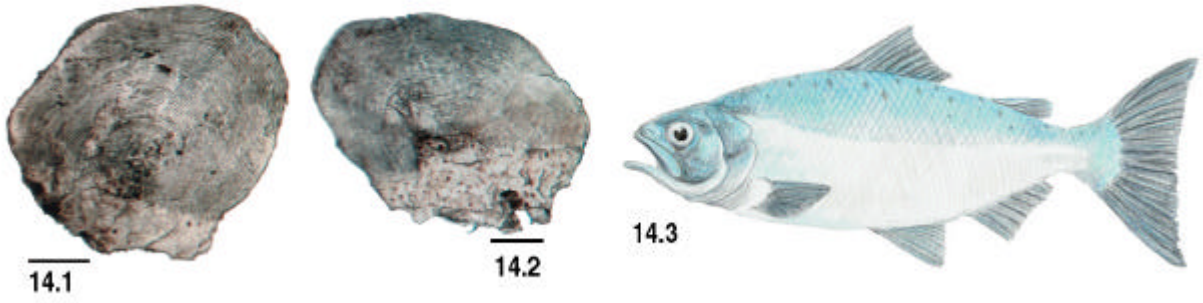


Figure 14.1 - 14.3. 14.1. Oncorhynchus kisutch (Coho Salmon); scale bar = 1.0 mm. **14.2. Oncorhynchus kisutch** (Coho Salmon); scale bar = 1.0 mm. **14.3. Oncorhynchus kisutch** (Coho Salmon); sketch of living specimen, non-spawning; length = 98 cm.

annulus, then broken circuli will be absent from posterior field, or there will be two or less complete circuli in the posterior field. If only one ocean annulus exists, then broken circuli will be absent from the posterior field, or there will be two or less complete circuli in posterior field. The diameter of the first ocean band is 2.11 mm or greater.

Oncorhynchus kisutch (Coho Salmon)
(Other common names: Silver Salmon, Hooknose)
Figure 14.3

Description

Length: 98 cm.
Mouth: large, terminal, directed forward; upper jaw extends beyond the posterior edge of orbit; snout is narrow; in both spawning males and females the jaws are hooked inwards; lips fleshy, teeth well developed and needle-like; no black colouration at the base of teeth, in spawning individuals the teeth become larger and hooked inwards (more expressed in the males).
Body: elongate; caudal peduncle compressed; caudal fin slightly indented; adipose fin small and slender; 19-25 widely spaced gill rakers over the first gill arch.
Color: metallic blue on dorsal with silver on the sides, the ventral area and the caudal peduncle; black spots on the upper lobe of the caudal fin; spawning males have bright red sides, bright green on the dorsal surface and head, with dark bellies.

Biology

Depth: pelagic schooling; 0-250 m.
Habitat: open Pacific offshore waters, coastal streams, and also lakes.
Season: spawns in the fall (October-November); fry appear in spring and usually spend one year in freshwater (sometimes longer); smolts will spend time in inshore waters before retreating to deeper offshore waters.
Diet: freshwater fry eat insects and larvae; young at sea feed on coastal plankton (e.g., copepods); adults feed on other forage species (e.g., herring, sand lance, greenlings, eulachon) and various planktonic crustaceans (e.g., copepods, euphasiids), squid.
Predators: larger fish species including other salmon (on young), sea birds, marine mammals, and terrestrial mammals.
Distribution: North Pacific; Baja, California to Alaska to Kamchatka, to Korea.

Scale Description
Figure 14.1-14.2

Relative Size of Scale: moderate.
Position of Scale on Body: in rows above the lateral line canal 118-147; also on the lateral line canal 121-140 (Hart, 1973).
Overall Scale Shape: circular to somewhat oval anterior field, the posterior field can be irregular.
Focus and Circuli: focus is clearly defined and often centralized between the fields; often just anterior to the interface of the posterior field. The circuli are concentric with the scale outline. They are generally continuous between the lateral and anterior fields, but a small number of discontinuous circuli can be present. The posterior field is clear and some circuli may extend into it.
Radii: absent.
Remarks: Mosher (1969) stated that there are one or two freshwater annuli that can vary in size; the oceanic region usually has only one ocean annulus, but there can be two; there are greater than six complete circuli below the focus; the segments of the circuli are present and prominent features of the posterior field; and it is unlikely for there to be a reticulation pattern. Bilton et al. (1964) indicated that there must be at least one freshwater annuli; the reticulation must be absent; one ocean annulus must be present; and there will be13 or more broken circuli in the posterior field.

Oncorhynchus nerka (Sockeye Salmon)
(Other common names: Red Salmon, Blueback Salmon)
Figures 15.3-15.4

Description

Length: 84 cm.
Mouth: large, terminal, directed forward; upper jaw extends beyond the posterior edge of orbit; snout is blunt; lips fleshy, teeth are in mandibles, premaxillaries, maxillaries, palatines, and the anterior region of the

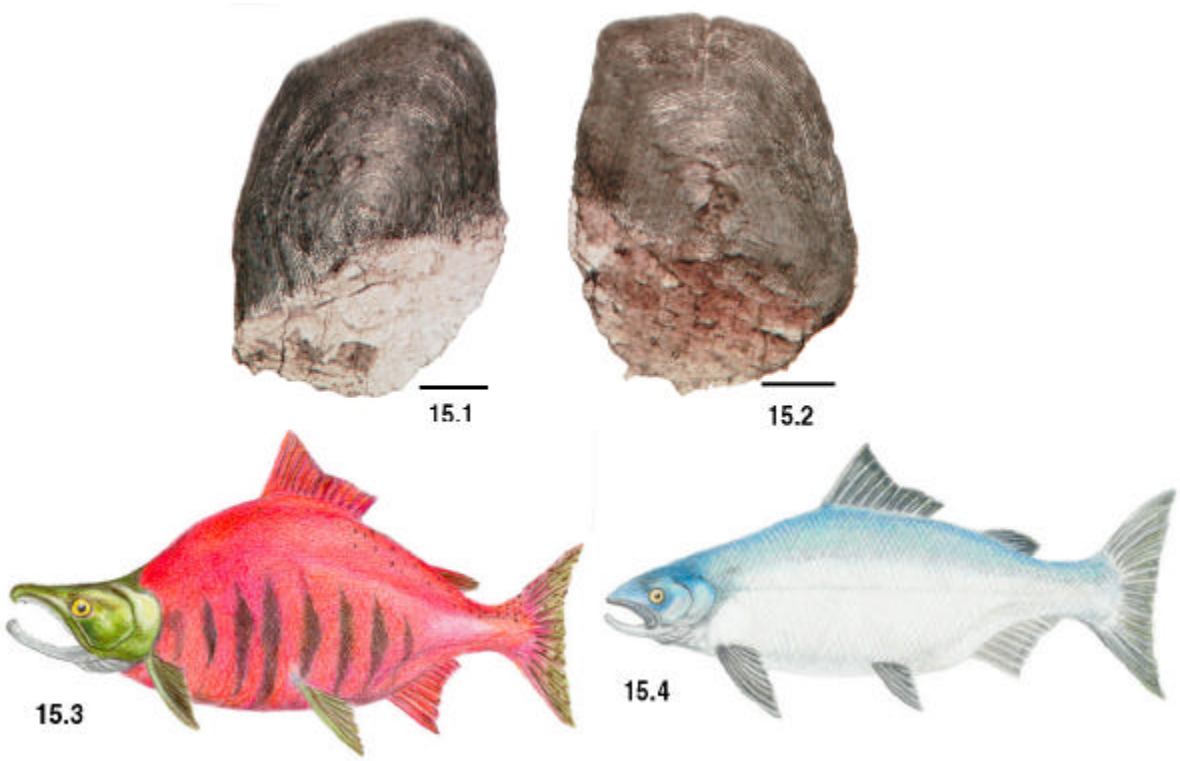


Figure 15.1 - 15.4. 15.1. Oncorhynchus nerka (Sockeye Salmon); scale bar = 1.0 mm. **15.2. Oncorhynchus nerka** (Sockeye Salmon); scale bar = 1.0 mm. **15.3. Oncorhynchus nerka** (Sockeye Salmon); sketch of living specimen, spawning male; length = 84 cm. **15.4. Oncorhynchus nerka** (Sockeye Salmon); sketch of living specimen, male or female; length = 84 cm.

tongue; teeth are small in sea-run individuals; in spawning males, they are large and hooked.
Body: elongate; caudal peduncle moderately compressed; caudal fin forked; adipose fin small and slender; 28-40 rough and close-set gill rakers over the first gill arch.
Color: greenish blue with dark speckling on the dorsal surface; no large dark spots; spawning males have a green head with dark jaws, red body, red fins, and pale ventral surface; spawning females are similar with green and yellow blotches.

Biology

Depth: pelagic schooling; 0-250 m.
Habitat: open Pacific offshore waters, coastal streams, and also lakes (some populations landlocked).
Season: in summer, sea-run adults move from continental shelves to coastal spawning rivers in the fall. Incubation can range from 50 days to five months depending on water temperature. Hatched young will remain in the gravel beds of the river for three to five weeks then migrate to a nursery lake where they will usually spend one year (some will migrate directly to the sea).
Diet: freshwater fry eat insects and larvae, copeods, amphipods; young at sea feed on coastal plankton (e.g., copepods); adults feed on other forage species (e.g., herring, sand lance, greenlings, eulachon) and various planktonic crustaceans (e.g., copepods, euphasiids), squid.
Predators: larger fish species including other salmon (on young), sea birds, marine mammals, and terrestrial mammals.
Distribution: southern California to Alaska to the Bering Sea, to Kamchatka, and the Sea of Japan.

Scale Description
Figure 15.1-15.2

Relative Size of Scale: moderate.
Position of Scales on Body: in rows above the lateral line canal 118-147; also on the lateral line canal 121-140 (Hart, 1973).
Overall Scale Shape: circular to somewhat oval anterior field, the posterior field is rounded but the edge can be irregular.
Focus and Circuli: focus is clearly defined and often centralized between the fields; often just anterior to the interface of the posterior field. The circuli are concentric with the scale outline. They are generally continuous between the lateral and anterior fields, but there may be a small number of discontinuous circuli. The posterior field is clear and some reticulation pattern may extend into it (but it may be difficult to see).
Radii: absent.
Remarks: Mosher (1969) found that there is a pronounced freshwater nucleus with one or more winter marks; the oceanic region usually has two or three winter marks; there are no more than six complete circuli below the focus; the circuli are not as distinct; the posterior field

Figure 16.1 - 16.3. 16.1. Oncorhynchus tshawytscha (Chinook Salmon); scale bar = 1.0 mm. **16.2. Oncorhynchus tshawytscha** (Chinook Salmon); scale bar = 1.0 mm. **16.3. Oncorhynchus tshawytscha** (Chinook Salmon); sketch of living specimen, non-spawning; length = 147 cm.

is clear with no markings (if markings present then they are poorly defined); and in ocean-run sockeye, the posterior field is still clear. Bilton et al (1964) indicated that there are at least one freshwater annuli, and reticulation at the edge of the posterior edge is ladder-like.

Oncorhynchus tshawytscha (Chinook Salmon)
(Other common names: Spring Salmon, King Salmon; Blackmouth Salmon)
Figure 16.3

Description

Length: 147 cm.
Mouth: large, terminal, directed forward; upper jaw extends beyond the posterior edge of orbit; snout is rounded; lips fleshy, teeth in jaws are sharp and movable; teeth also in premaxillaries, maxillaries, palatines, and the anterior region of the tongue; black colouration at the base of the teeth; teeth in spawning males become enlarged and hooked.
Body: elongate; caudal peduncle moderately compressed; caudal fin forked; adipose fin slender; 18-30 rough and widely spaced gill rakers over the first gill arch.
Color: green-blue to black on dorsal with large irregular black spots on upper side, the dorsal fine, and both lobes of the caudal fin; spawning individuals are olive to dark red or purple.

Biology

Depth: pelagic schooling; 0-200 m.
Habitat: open Pacific offshore waters, coastal streams.
Season: will enter spawning rivers throughout the year (see Hart, 1973) with some young moving out to sea immediately after hatch while some will stay in the river for up to one year. Young migrate northwards along the coast to feed, and some stocks will move offshore. Most return to spawn in their fourth or fifth year.
Diet: young/instream individuals will eat small crustaceans and invertebrates; young and adult/inshore individuals will eat crustaceans (e.g., copepods, euphasiids), forage fish species (e.g., herring, sand lance, pilchard).
Predators: larger fish species including other salmon (on young), sea birds, marine mammals, and terrestrial mammals.
Distribution: southern California to Alaska to the Bering Sea, to Kamchatka, and the Sea of Japan.

Scale Description
Figure 16.1-16.2

Relative Size of Scale: large.
Position of Scales on Body: in rows above the lateral line canal 118-147; also on the lateral line canal 121-140 (Hart, 1973).
Overall Scale Shape: circular to somewhat oval anterior field, the posterior field is rounded, at times it can be irregular.
Focus and Circuli: focus is clearly defined and often not centralized between the fields; often just anterior to the interface of the posterior field and is approximately one-third the total scale length from the edge of the posterior field. The circuli are concentric with the scale outline. Circuli are generally continuous between the lateral and anterior fields, but a small number of discontinuous circuli may be present. The posterior field is clear.
Radii: radii absent. There are radial “striations” present (although these are not always apparent).
Remarks: Mosher (1969) indicated that if the freshwater nucleus is present it is small. The oceanic region has four to five winter marks with the first oceanic zone large; there are seven to eight complete circuli below the focus; strong radial striations are present; posterior field is clear but some circuli may enter; and reticulations are usually absent, but sometimes present in net-like formation. In contrast Bilton et al. (1964) cited considerable variation in this species with regard to the number of continuous and/or broken circuli that enter the posterior field.

Oncorhynchus clarki clarki (Coastal Cutthroat Trout)
(Other common names: Red-Throated Trout, Clark’s Trout)
Figure 17.11

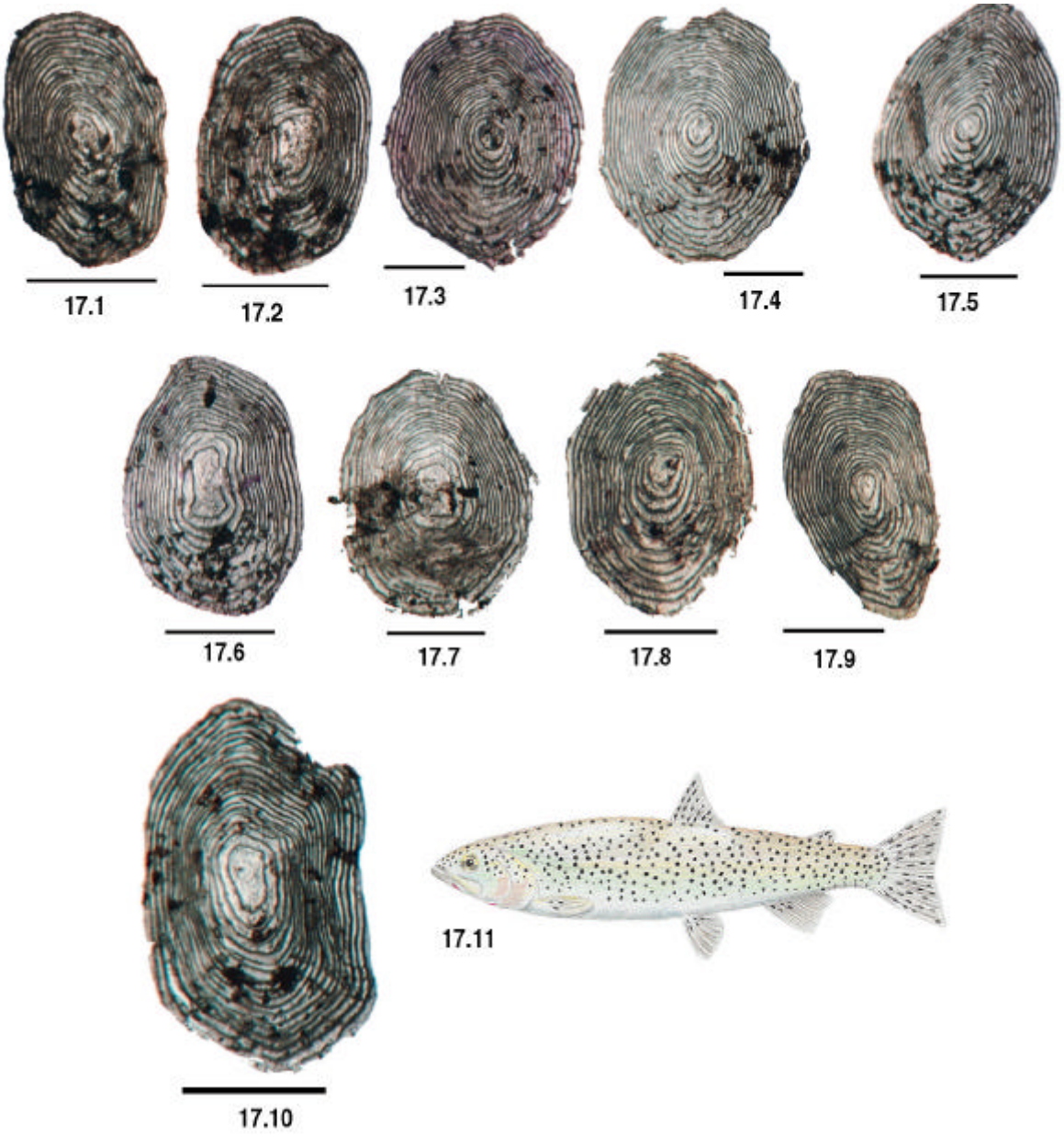


Figure 17.1 - 17.11. Oncorhynchus clarki clarki (Coastal Cutthroat Trout); body region A; scale bar = 500 µm. **17.2. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region A; scale bar = 500 µm. **17.3. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region C; scale bar = 500 µm. **17.4. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region C; scale bar = 500 µm. **17.5. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region E; scale bar = 500 µm. **17.6. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region E; scale bar = 500 µm. **17.7. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region G; scale bar = 500 µm. **17.8. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region G; scale bar = 500 µm. **17.9. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region J; scale bar = 500 µm. **17.10. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); body region J; scale bar = 500 µm. **17.11. Oncorhynchus clarki clarki** (Coastal Cutthroat Trout); sketch of living specimen; length = 76 cm.

Description

Length: up to 76 cm (listed from a non-migrating specimen).
Mouth: large, terminal, directed forward; upper jaw extends beyond the posterior edge of orbit; lips fleshy, jaws are even with red-orange streaks on the lower inner edge; teeth in jaws small, well developed, conical and hooked inwards on the maxillaries, premaxillaries, mandibles, the shaft of vomer and the back of the tongue.
Body: elongate; caudal peduncle moderately compressed; caudal fin slightly forked; adipose fin small and slender; 15-22 gill rakers over the first gill arch.
Color: green-blue on dorsal with silver sides; in irregular rows on the back, sides and belly are angular black

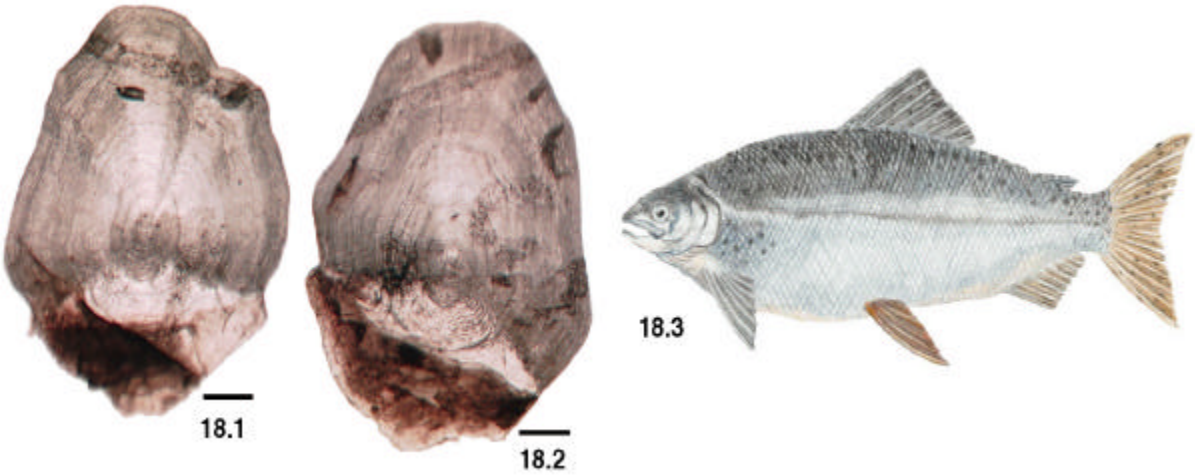


Figure 18.1 - 18.3. 18.1. Oncorhynchus gairdneri (Steelhead Trout); scale bar = 1.0 mm. **18.2. Oncorhynchus gairdneri** (Steelhead Trout); scale bar = 1.0 mm. **18.3. Oncorhynchus gairdneri** (Steelhead Trout); sketch of living specimen; length = 114 cm.

spots; black spots also on pectoral fins; seagoing individuals are more silvery with yellow on the flanks and fins.

Biology

Depth: pelagic schooling species.
Habitat: usually a freshwater species in lakes but is anadromous in some coastal streams.
Season: spawning occurs in early spring (February-March), young may head to sea or remain in the estuaries moving between the inlets and coastal waters.
Diet: other forage fish species (e.g., juvenile salmon, rockfish, sculpins, flatfish), crustaceans, and insects.
Predators: larger fish species including other salmon (on young), sea birds, marine mammals, and terrestrial mammals.
Distribution: northern California to Alaska.

Scale Description
Figures 17.1-17.10

Relative Size of Scale: small.
Position of Scales on Body: above lateral line canal 115-161 in oblique rows (Hart, 1973).
Overall Scale Shape: circular to somewhat oval with a smooth outside edge.
Focus and Circuli: focus is clearly defined and often centralized between the fields; the posterior field is not transparent as in other salmon species. The fields are less distinct (look for pigmented tissue on the posterior field); circuli are generally continuous between the anterior and lateral fields. Circuli are present in the posterior field,are both continuous and discontinuous, and are less compacted.
Radii: radii absent.

Oncorhynchus mykiss (Steelhead Trout)
a.k.a **Salmo gairdneri**
(Other common names: Rainbow Trout, Metalhead, Salmon Trout)
Figure 18.3

Description

Length: up to 114 cm.
Mouth: large, terminal, directed forward; upper jaw extends to the posterior edge of orbit; snout blunt; lips fleshy; teeth in jaws small, well developed, conical and hooked inwards on the maxillaries, premaxillaries, madibles, palatines, the shaft of vomer and the tongue (but not at back of tongue); no red colouration on lower jaw.
Body: elongate; caudal peduncle compressed; caudal fin slightly forked; adipose fin small and slender; 17-21 gill rakers over the first gill arch.
Color: metallic blue on dorsal with silvery sides; black spots on dorsal, back and caudal fins; spawning males have reddish band on side.

Biology

Depth: pelagic schooling species.
Habitat: freshwater and anadromous in coastal waters (freshwater fish are rainbow trout, marine are steelhead).
Season: spawning can occur in both summer and winter in gravelly rivers; young will remain in freshwater for two to three years; marine phase can last two to three years.
Diet: in freshwater systems will eat insect, worms, smaller minnow species; marine adults eat forage fish species (e.g., greenlings, herring, sand lance), crustaceans (e.g., copepods, euphasiids, amphipods).
Predators: larger fish species, sea birds, marine mammals, and terrestrial mammals.
Distribution: Mexico to Alaska.

Scale Description
Figures 18.1-18.2

Relative Size of Scale: large.
Position of Scales on Body: in rows above the lateral line canal 118-147; also on the lateral line canal 121-140 (Hart, 1973).

Overall Scale Shape: circular to somewhat oval anterior field, the posterior field is rounded, at times can be irregular.
Focus and Circuli: focus is clearly defined and is slightly offset between the fields; often just anterior to the interface of the posterior field. The circuli are concentric with the scale outline. Circuli are generally continuous between the lateral and anterior fields but a small number of discontinuous circuli may also be present. The posterior field is transparent and discontinuous circuli and/or reticulation patterns may be present.
Radii: radii absent
Remarks: Mosher (1969) indicated that the freshwater region is large with bold circuli and one and three (sometimes more winter marks); freshwater circuli can continue into the posterior field; oceanic circuli are continuous but not as likely to enter the posterior field and may show as weak striations, they are: discontinuous; granular reticulation are present; more than one spawning check may be present.

Scale Preservation

In our core material from Effingham Inlet no salmon scales have been observed thus far, even though salmon are present in the ecosystem. Although salmon scales are not decidous, this is not the only factor pertaining to their absence as we do find other non-deciduous species preserved. It is possible that these scales are too fragile, or too susceptible to erosion (chemical), and are thus poor candidates for preservation.

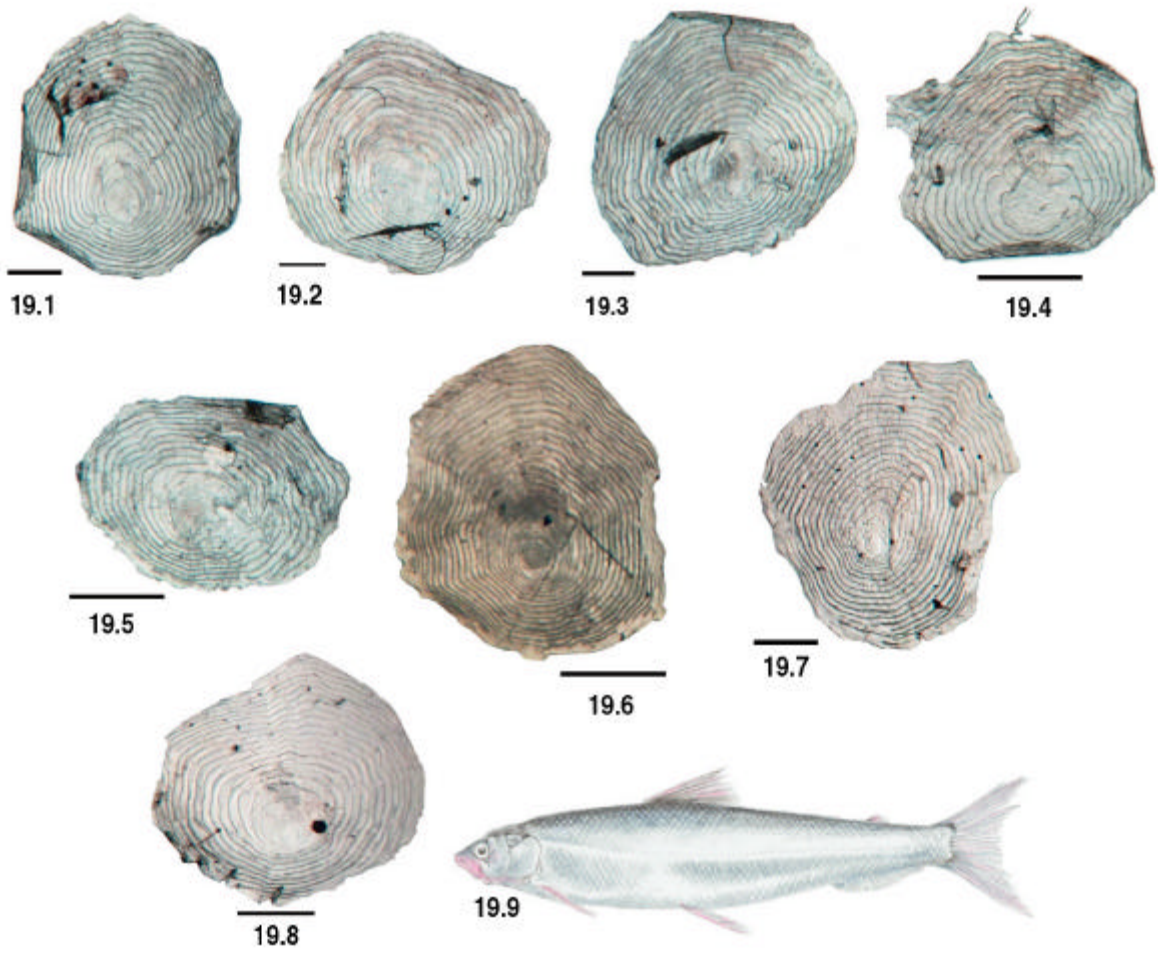


Figure 19.1 - 19.9. 19.1. Thaleichthys pacificus (Eulachon); body region A; scale bar = 500 µm. **19.2. Thaleichthys pacificus** (Eulachon); body region C; scale bar = 500 µm. **19.3. Thaleichthys pacificus** (Eulachon); body region E; scale bar = 500 µm. **19.4. Thaleichthys pacificus** (Eulachon); body region I; scale bar = 1.0 mm. **19.5. Thaleichthys pacificus** (Eulachon); body region I; scale bar = 1.0 mm. **19.6. Thaleichthys pacificus** (Eulachon); scale bar = 1.0 mm. **19.7. Thaleichthys pacificus** (Eulachon); scale bar = 500 µm. **19.8. Thaleichthys pacificus** (Eulachon); scale bar = 500 µm. **19.9. Thaleichthys pacificus** (Eulachon); sketch of living specimen; length = 23 cm.

Order Osmeriformes
Family Osmeridae
(Smelts)

Diagnosis:

- Soft-rayed
- Cycloid scales; head without scales
- Fleshy appendages at base of pelvic fins absent
- Last few vertebrae not turned dorsally (as per Salmonidae)
- Generally forked caudal fins
- Lateral line present
- Adipose fin present
- Generally small
- Generally anadromous
- Seven species in British Columbia waters. **Allosmerus elongates** (Whitebait Smelt), **Hypomesus pretiosus pretiosus** (Surf Smelt), **Mallotus villosus** (Capelin), **Osmerus mordax dentex** (Rainbow Smelt), **Spirinchus starksi** (Night Smelt), and **Spirinchus thaleichthys** (Longfin Smelt) are not included in this discussion.

Thaleichthys pacificus (Eulachon)
(Other common names: Candlefish, Oilfish, Oulachon, Columbia River Smelt)
Figure 19.9

Description

Length: 23 cm.
Mouth: large, terminal, directed upwards; upper jaw extends to the posterior margin of orbit; teeth small, pointed and on both jaws (teeth may be lost in spawning individuals).
Body: long; operculum smooth with concentric striae; concentric striae present also on subopercular; caudal peduncle compressed; dorsal fin originates behind mid-

point of the body (behind pelvic insertion); adipose fin sickle shaped; four to six gill rakers on the upper part of the first gill arch; at spawning, males have numerous tubercles (projections) on head, body and upper sides of paired and anal rays; adipose fin on its back, near the tail; lateral line canal curves downwards anteriorly.
Color: upper is blue to blue-brown; sides and lower are silvery white.

Biology

Depth: pelagic.
Habitat: nearshore; coastal inlets and rivers.
Season: anadromous; three-year old adults spawn in early spring (February –mid-May); spawning is done in large aggregations and generally at night with external fertilization; eggs then sediment out of the water column attach to substrate for development.
Diet: crustaceans (e.g., copepod larvae, mysids, ostracods, euphasiids).
Predators: fish species (e.g., shark, flatfish, sturgeon), marine mammals, seabirds.
Distribution: northern California to the eastern Bering Sea and the Pribilof Islands.

Scale Description
Figure 19.1-19.8

Relative Scale Size: small to moderate. The scales in the series are generally of similar size. This is a thin, somewhat fragile scale.
Position of Scales on Body: 70-78 scales in the lateral line canal (Hart, 1973).
Overall Scale Shape: circular with irregular outside edge.
Focus and Circuli: the focus is not centralized between the fields, it is approximately one-quarter of the way from the outside edge of the posterior field. It is difficult to demarcate the fields, but a good indicator is the posterior field; it is compressed and pigmented tissue may still be attached. The circuli are continuous between all fields, but are slightly more compacted in the posterior field.
Radii: absent.

Scale Preservation

To date, no eulachon scales have been found in Effingham sediments. This species is nearshore, but the primary migration route is through the Strait of Georgia, into the Fraser River to spawn. It is not known if this species uses the West Coast Vancouver Island inlets. The potential for preservation of scales seems low due to the thin and fragile nature of the scales.

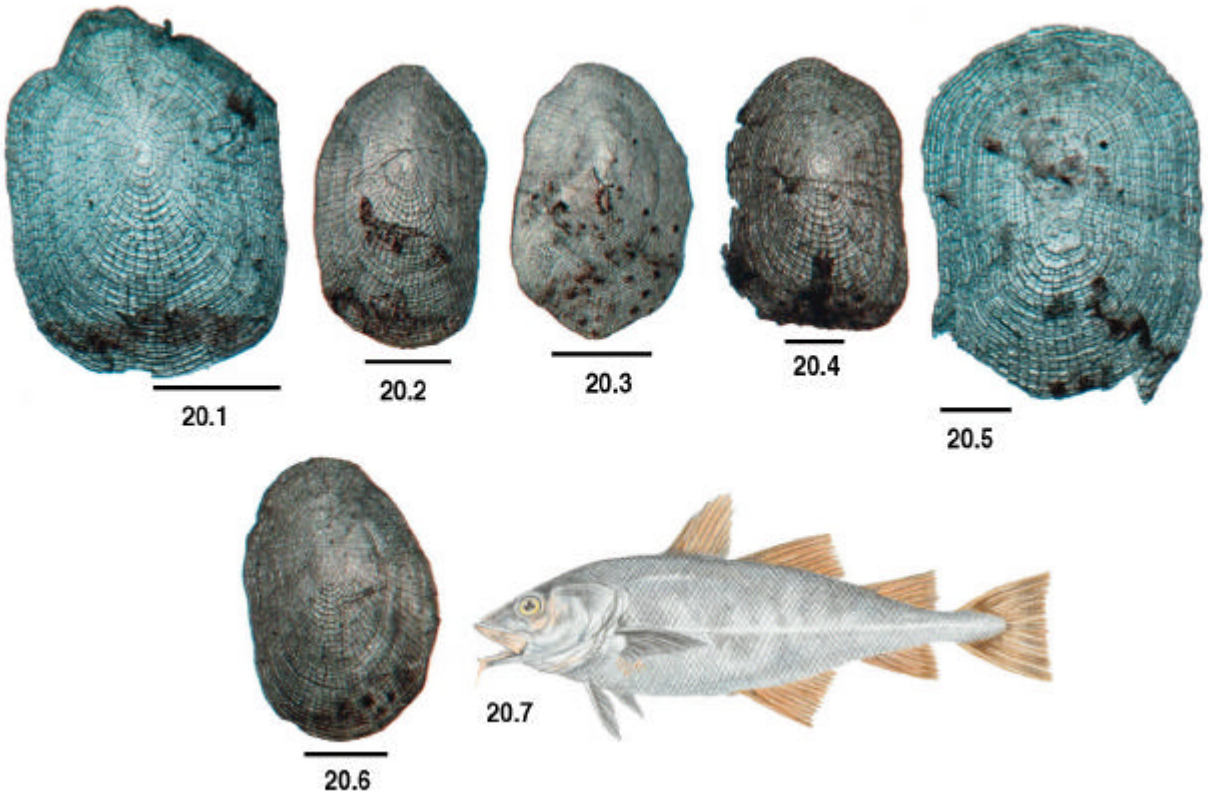


Figure 20.1 -20.7. 20.1. Gadus macrocephalus (Pacific Cod); body region A; scale bar = 1.0 mm. **20.2. Gadus macrocephalus** (Pacific Cod); body region C; scale bar = 1.0 mm. **20.3. Gadus macrocephalus** (Pacific Cod); body region E; scale bar = 1.0 mm. **20.4. Gadus macrocephalus** (Pacific Cod); body region G; scale bar = 500 µm. **20.5. Gadus macrocephalus** (Pacific Cod); body region I; scale bar = 500 µm. **20.6. Gadus macrocephalus** (Pacific Cod); body region J; scale bar = 1.0 mm. **20.7. Gadus macrocephalus** (Pacific Cod); sketch of living specimen; length = 114 cm.

Order Gadiformes
Family Gadidae
(Cods)

Diagnosis:

- Moderate length
- Two or three dorsal fins
- One or two anal fins
- Generally all species school
- Many have chin barbells
- Pelvic fins thoracic
- Cycloid scales
- Four species in BC waters (Hart, 1973; Eschmeyer, 1983)

Remarks: all Gadidae scales are similar so that it not possible to identify particular species with certainty. Although Pacific tomcod is a considerably smaller species than Pacific cod, the size of the scale, in this family, is not a reliable characteristic. Cod scales tend to be robust (thick) with distinct ridged circuli. They are also brittle, especially when desiccated.

Gadus macrocephalus (Pacific Cod)
(Other common names: True Cod, Gray-Cod, Cod)
Figure 20.7

Description

Length: 114 cm.

Mouth: moderate, terminal; maxillary extends to mid-pupil; teeth are small and sharp.
Body: elongate; three separate dorsal fins, two anal fins with first beginning below front of second dorsal fin, caudal fin truncate (but slightly indented); barbel is about equal in length to the eye diameter; lateral line high anteriorly, dipping mid-body.
Color: brown to gray on dorsal side with numerous brown spots or pale areas on back and side; lighter on ventral side; fins somewhat dusky with dorsal, caudal, and anal fins usually white-edged.

Biology

Depth: up to 550 m; undergo seasonal migrations tending to concentrate on the shelf edge and upper slope (100-250 m) in the winter and moving to shallower waters (generally <100 m) in the summer.
Habitat: generally benthic on sandy/muddy substrate.
Season: spawn in winter; eggs hatch in from 8 to 17 days depending on temperature.
Diet: benthic crustaceans, forage fish species (herring, sand lance, flatfish).
Predators: seals and sea lions (Olesiuk, 1993).
Distribution: widely distributed in the coastal north Pacific, from the Bearing Sea to southern California, in the east, and to the Sea of Japan in the west; less common in southern waters. For management purposes four

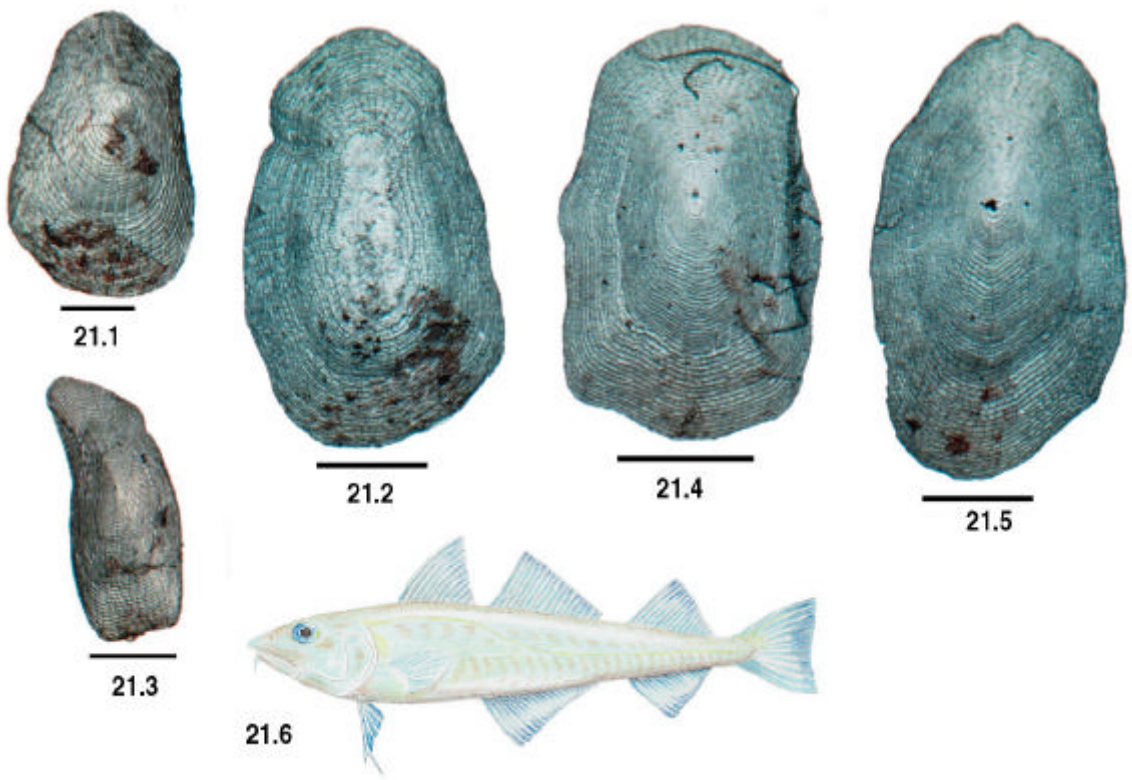


Figure 21.1 - 21.6. 21.1. Microgadus proximus (Pacific Tomcod); body region A; scale bar = 1.0 mm. **21.2. Microgadus proximus** (Pacific Tomcod); body region C scale bar = 1.0 mm. **21.3. Microgadus proximus** (Pacific Tomcod); body region G; scale bar = 1.0 mm. **21.4. Microgadus proximus** (Pacific Tomcod); body region I; scale bar = 1.0 mm. **21.5. Microgadus proximus** (Pacific Tomcod); body region J; scale bar = 1.0 mm. **21.6. Microgadus proximus** (Pacific Tomcod); sketch of living specimen; length = 30 cm.

stocks of Pacific cod are defined on the British Columbia coast: Strait of Georgia, West Coast Vancouver Island, Queen Charlotte Sound, and Hecate Strait.

Scale Description
Figures 20.1-20.6

Relative Scale Size: small.
Position of Scales on Body: not determined.
Overall Shape: the scale varies from semi-circular to oval (this can be somewhat exaggerated depending on how desiccated the scale is).
Focus and Circuli: the focus is not centralized between the four fields and is approximately one-third of the total length from the anterior margin. The focus and surrounding circuli are concentric. Circuli are generally continuous but in the leading edges of the fields, can be distorted or broken by the intermarkings.
Radii: there are no radii, however, there are distinct intermarkings (sensu Batts, 1964), which are perpendicular or irregular “ines/structures” between the circuli. These intermarkings can align between the circuli to give a loosely similar appearance to radii.

Microgadus proximus (Pacific Tomcod)
(Other common names: Wachna)
Figure 21.6

Description

Length: 30 cm.
Mouth: moderate, terminal; directed slightly upwards; maxillary extends to mid-pupil; teeth in bands on jaws and vomer; outer row enlarged; lateral line high anteriorly, dipping mid-body.
Body: elongate and tapers towards caudal fin; three separate and spineless dorsal fins, two anal fins; caudal fin truncate; chin barbel is about equal to pupil diameter; anus below first dorsal fin.
Color: olive green on dorsal; creamy white below; dusky fin tips.

Biology

Depth: up to 220 m; young in shallower waters.
Habitat: generally benthic on sandy substrate.
Season: spawn in winter; eggs hatch in from 8 to 17 days depending on temperature (citation in Hart, 1973).
Diet: shrimps, small crustaceans; worms, mollusks.
Predators: seals and sea lions, Scombridae, hake.
Distribution: southern California to Alaska to the Bering Sea; in BC not abundant.

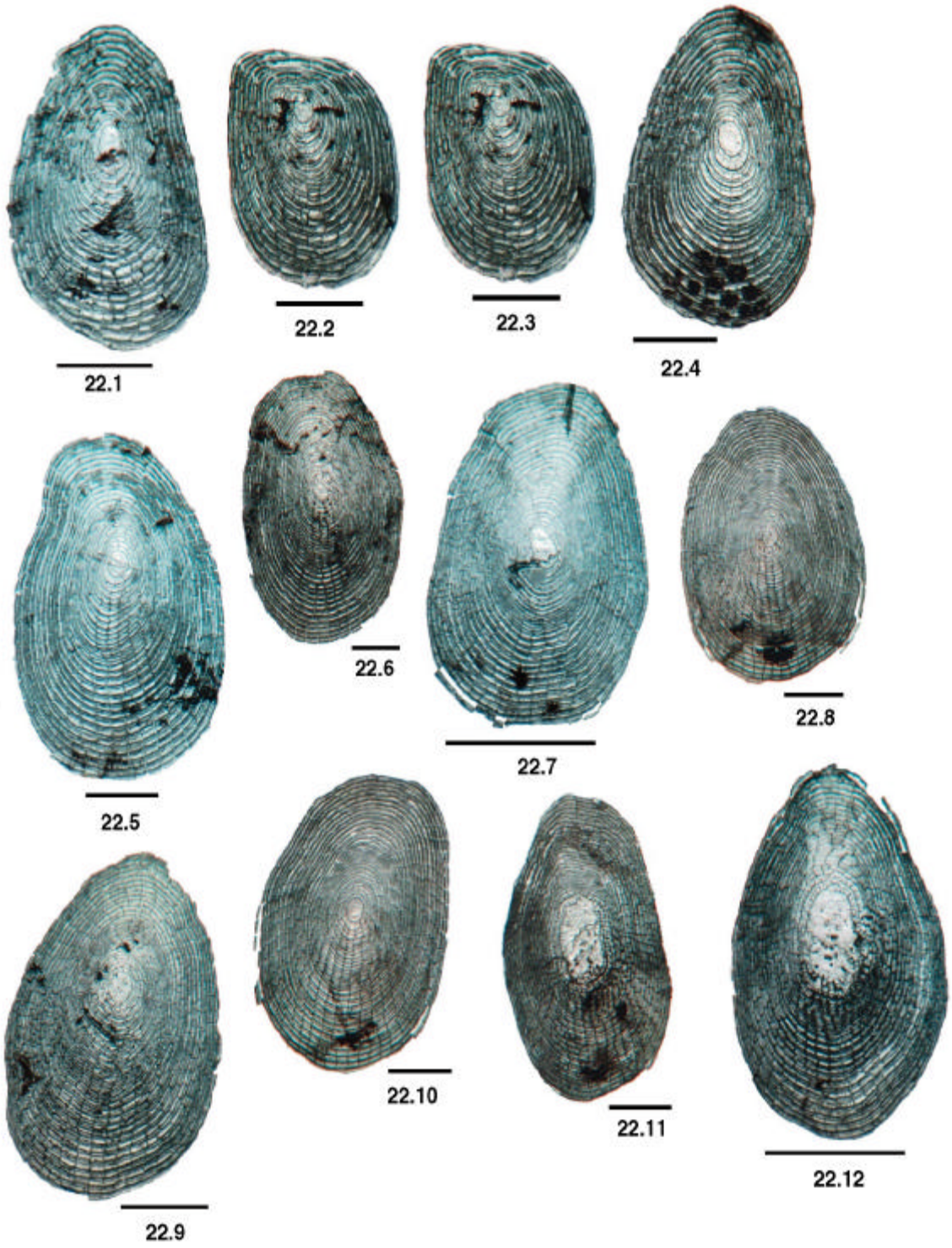


Figure 22.1 - 22.20 (continued on next page). 22.1. Theragra chalcogramma (Walleye Pollack); body region A; scale bar = 500 µm. **22.2. Theragra chalcogramma** (Walleye Pollack); body region A; scale bar = 500 µm. **22.3. Theragra chalcogramma** (Walleye Pollack); body region A; scale bar = 500 µm. **22.4. Theragra chalcogramma** (Walleye Pollack); body region A; scale bar = 500 µm. **22.5. Theragra chalcogramma** (Walleye Pollack); body region C; scale bar = 500 µm. **22.6. Theragra chalcogramma** (Walleye Pollack); body region C; scale bar = 500 µm. **22.7. Theragra chalcogramma** (Walleye Pollack); body region E; scale bar = 1.0 mm. **22.8. Theragra chalcogramma** (Walleye Pollack); body region E; scale bar = 500 µm. **22.9. Theragra chalcogramma** (Walleye Pollack); body region G; scale bar = 500 µm. **22.10. Theragra chalcogramma** (Walleye Pollack); body region G; scale bar = 500 µm. **22.11. Theragra chalcogramma** (Walleye Pollack); body region I; scale bar = 500 µm. **22.12. Theragra chalcogramma** (Walleye Pollack); body region I; scale bar = 1.0 mm.

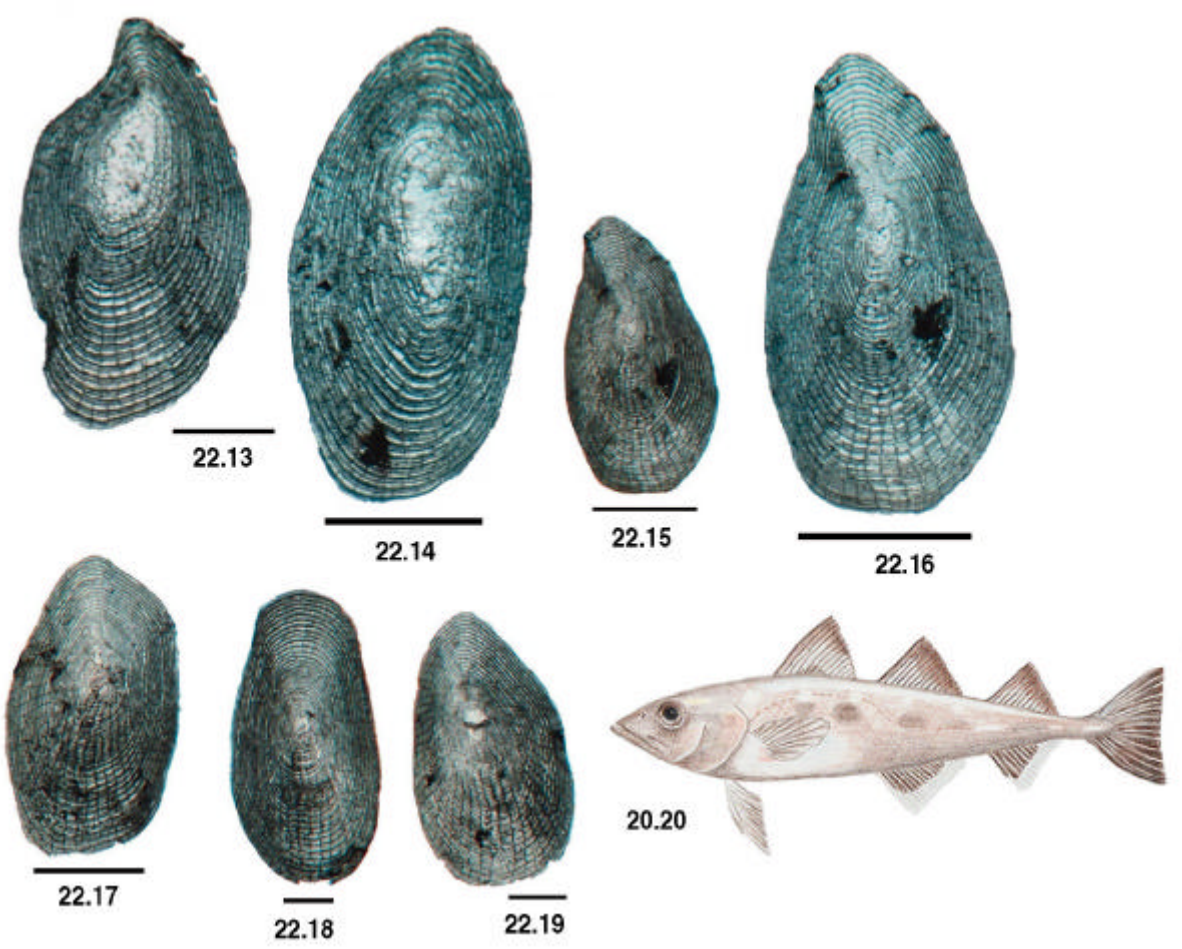


Figure 22.13 - 22.20. 22.13. Theragra chalcogramma (Walleye Pollack); body region I; scale bar = 500 µm. **22.14. Theragra chalcogramma** (Walleye Pollack); body region I; scale bar = 500 µm. **22.15. Theragra chalcogramma** (Walleye Pollack); body region J; scale bar = 1.0 mm. **22.16. Theragra chalcogramma** (Walleye Pollack); body region J; scale bar = 1.0 mm. **22.17. Theragra chalcogramma** (Walleye Pollack); body region J; scale bar = 1.0 mm. **22.18. Theragra chalcogramma** (Walleye Pollack); body region J; scale bar = 500 µm. **22.19. Theragra chalcogramma** (Walleye Pollack); body region J; scale bar = 500 µm. **22.20. Theragra chalcogramma** (Walleye Pollack); sketch of living specimen; length = 90 cm.

Scale Description
Figures 21.1-21.5

Relative Scale Size: small but size is variable not only across the body but within sampling areas.
Scale Position on the Body: not determined.
Overall Shape: the scale varies from semi-circular to oval and the leading edges of the fields can appear distorted (this can be exaggerated depending on how desiccated the scale is).
Focus and Circuli: the focus is not centralized between the four fields and is approximately one-third of the total length from the anterior margin. The exception in this collection is the C scale. This is a more rounded circular scale, and the focus is centralized. The circuli are generally continuous but in the leading edges of the fields, they can be distorted or broken by the intermarkings.
Radii: there are no radii, however, there are distinct intermarkings (sensu Batts, 1964), which are perpendicular or irregular ”lines/structures” between the circuli. These intermarkings can align between the circuli to give a loosely similar appearance to radii.

Theragra chalcogramma (Walleye Pollock)
(Other common names: Pacific Pollock, Alaska Pollack; Bigeye, Scrapcod)
Figure 22.20

Description

Length: 90 cm.
Mouth: moderate, terminal; lower jaw slightly projecting; maxillary extends to front edge of pupil; teeth are small and slender.
Body: elongate; snout pointed; three separate dorsal fins, two anal fins with first beginning below front of second dorsal fin, caudal fin is slightly forked; chin barbel tiny or absent; lateral line high anteriorly, dipping midbody; anus below space between first and second dorsal fin.

Color: brown to olive green on dorsal side with numerous brown spots; lighter on ventral side; fins are dusky to black.

Biology

Depth: surface to 366 m; diurnal migrations (Cohen et al., 1990).
Habitat: generally offshore; benthic on sandy/muddy substrate.
Season: little is known about its season cycle and reproduction.
Diet: crustaceans, forage fish (e.g., sand lance, herring).
Predators: marine mammals and larger fish.
Distribution: central California to Bering Sea; Kamchatka, Okhotsk Sea and Sea of Japan.

Scale Description
Figures 22.1-22.19

Relative Scale Size: small.
Position of Scale on Body: not determined.
Overall Shape: mostly ovoid to tear-drop shaped.
Focus and Circuli: the focus is not centralized between the four fields and is approximately one-third of the total length from the anterior margin. The scales of this species are more tear-dropped shaped. The circuli are generally continuous but can be broken by the intermarkings, especially in the leading edges.
Radii: there are no radii, however, there are distinct intermarkings (sensu Batts, 1964), which are perpendicular or irregular “lines/structures” between the circuli. These intermarkings can align between the circuli to give a loosely similar appearance to radii.

Scale Preservation

Gadidae species scales do preserve well but they are often not entirely intact. They are quite brittle and easily subject to erosion, cracking, or breaking, often at the leading edges. The intermarkings are quite distinct for assignment to family. Scales recovered from sediments are often clear/transparent.

Family Merluccidae
(Hakes)

Diagnosis:

- Have some external cod features

Merluccius productus (Pacific Hake or Pacific Whiting)
(Other common names: Pacific Whiting, California Hake)
Figure 23.13

Description

Length: 90 cm.
Mouth: large, terminal; directed slightly upwards; lower jaw protrudes; maxillary extends to below pupil; teeth strong in bands in jaws and vomer.
Body: elongate; snout long; two dorsal fins; second dorsal long and notched; one anal long and notched caudal peduncle slender; caudal fin truncate; chin barbel absent; lateral line decurved then straight.
Color: silvery gray with black speckles on dorsal; silver below; brown on pectoral fins; black inside mouth and on the inside of the gill covers.

Biology

Depth: surface to 900 m; diurnal vertical migrations.
Habitat: generally offshore; benthic on sandy/muddy substrate.
Season: spawn in spring; eggs take three days to hatch.
Diet: euphasiids, sand lance, herring, anchovy, shrimp; feeds nocturnally
Predators: sharks.
Distribution: Gulf of California to Gulf of Alaska; in BC in intermediate water layers.

Scale Description
Figures 23.1-23.12

Relative Scale Size: moderate to large.
Position of Scales on Body: along lateral line; 147-166; scales are deciduous.
Overall Shape: oval; this cycloid scale is distinctly different from the Gadidae
Focus and Circuli: the focus is not centralized between the four fields and is slightly more than one-third the total length from the anterior margin. The focus and the circuli are somewhat ovoid along the anterior-posterior axis. The circuli are continuous and can appear in a crenulated pattern. In mounted material, desiccation cracks can appear.
Radii: there are no radii and no distinct intermarkings.

Scale Preservation
Figures 24.1-24.9

Like scales of the closely related species in the Gadidae, these scales are found preserved, but are often not entirely intact. They are quite brittle and easily subject to erosion, cracking, or breaking, often at the leading edges. There is often also a tendency for them to break along a circuli. This results in central portions “popping” out from the leading edges. Merluccidae have distinct scales, and this is the only species in British Columbia waters making identification easy. Tallying should be made on the basis of the presence of a focus.

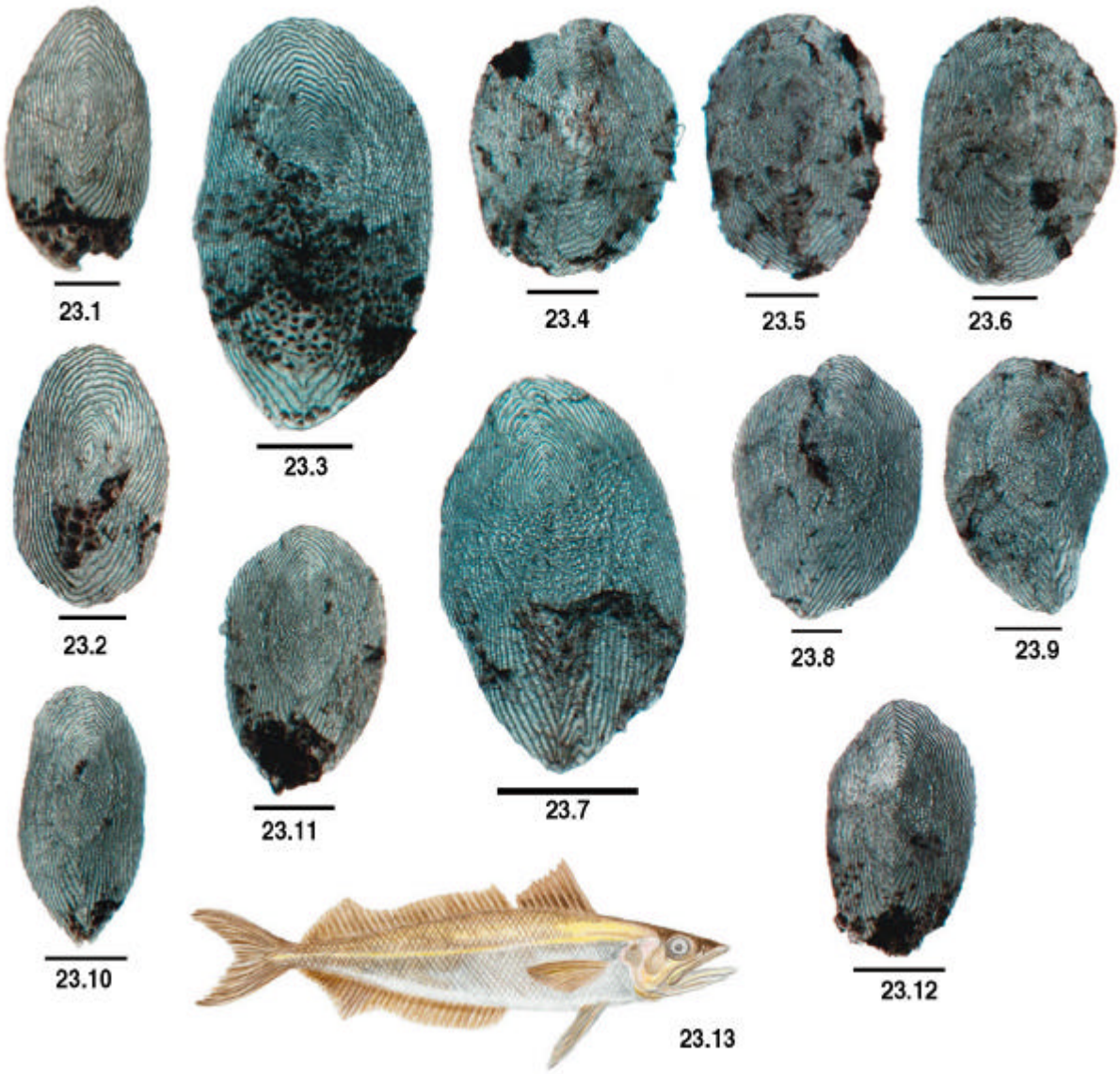


Figure 23.1 - 23.13. 23.1. Merluccius productus (Pacific Hake); body region A; scale bar = 500 µm. **23.2. Merluccius productus** (Pacific Hake); body region A; scale bar = 500 µm. **23.3. Merluccius productus** (Pacific Hake); body region C; scale bar = 1.0 mm. **23.4. Merluccius productus** (Pacific Hake); body region E; scale bar = 1.0 mm. **23.5. Merluccius productus** (Pacific Hake); body region E; scale bar = 1.0 mm. **23.6. Merluccius productus** (Pacific Hake); body region E; scale bar = 1.0 mm. **23.7. Merluccius productus** (Pacific Hake); body region G; scale bar = 1.0 mm. **23.8. Merluccius productus** (Pacific Hake); body region G; scale bar = 500 µm. **23.9. Merluccius productus** (Pacific Hake); body region I; scale bar = 1.0 mm. **23.10. Merluccius productus** (Pacific Hake); body region J; scale bar = 1.0 mm. **23.11. Merluccius productus** (Pacific Hake); body region J; scale bar = 1.0 mm. **23.12. Merluccius productus** (Pacific Hake); body region J; scale bar = 1.0 mm. **23.13. Merluccius productus** (Pacific Hake); sketch of living specimen; length = 90 cm.

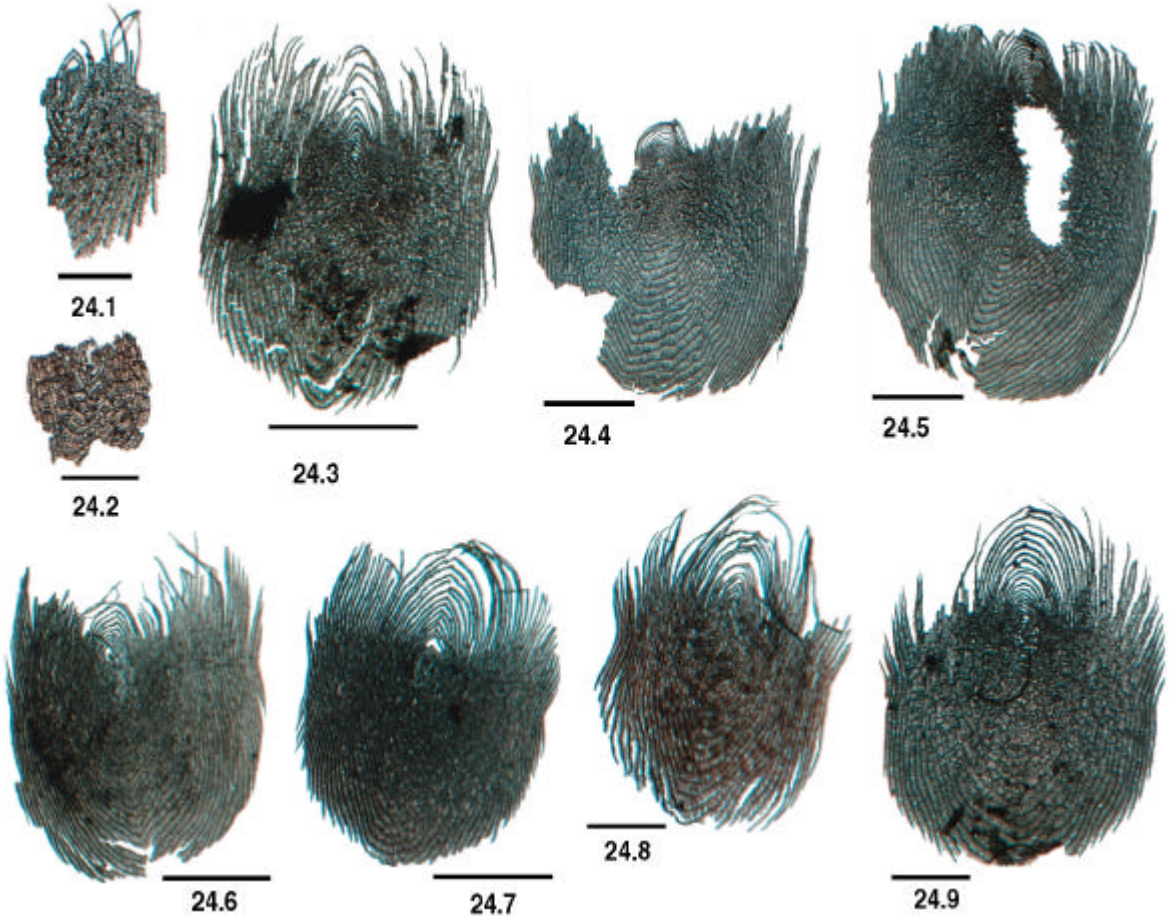


Figure 24.1 - 24.9. 24.1. Hake, core B03 S01, interval 2-7 cm; scale bar = 500 µm. **24.2.** Hake, core B03 S01, interval 2-7 cm; scale bar = 1.0 mm. **24.3.** Hake, core B03 S01, interval 16-21 cm; scale bar = 1.0 mm. **24.4.** Hake, core B03 S02, interval 25-30 cm; scale bar = 1.0 mm. **24.5.** Hake, core B03 S02, interval 25-30 cm3; scale bar = 1.0 mm. **24.6.** Hake, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **24.7.** Hake, core B03 S02, interval 55-60 cm; scale bar = 1.0 mm. **24.8.** Hake, core B03 S02, interval 55-60 cm; scale bar = 500 µm. **24.9.** Hake, core B03 S04, interval 73-78 cm; scale bar = 1.0 mm.

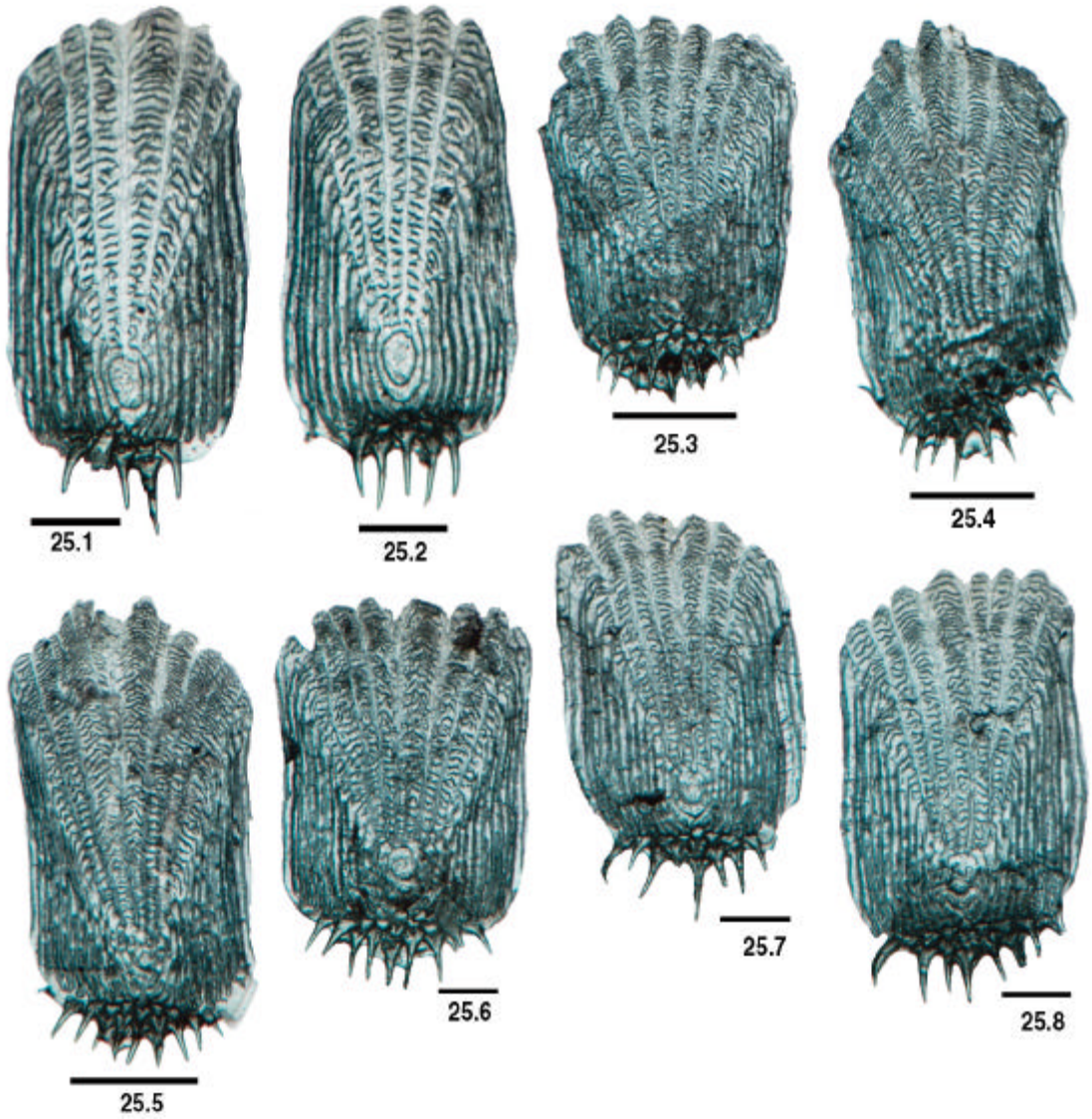


Figure 25.1 - 25.8 (continued on next page). 25.1. Anoplopoma fimbria (Sablefish aka Blackcod); body region A; scale bar = 250 µm. **25.2. Anoplopoma fimbria** (Sablefish aka Blackcod); body region A; scale bar = 250 µm. **25.3. Anoplopoma fimbria** (Sablefish aka Blackcod); body region C; scale bar = 500 µm. **25.4. Anoplopoma fimbria** (Sablefish aka Blackcod); body region C; scale bar = 500 µm. **25.5. Anoplopoma fimbria** (Sablefish aka Blackcod); body region C; scale bar = 250 µm. **25.6. Anoplopoma fimbria** (Sablefish aka Blackcod); body region E; scale bar = 250 µm. **25.7. Anoplopoma fimbria** (Sablefish aka Blackcod); body region E; scale bar = 500 µm. **25.8. Anoplopoma fimbria** (Sablefish aka Blackcod); body region E; scale bar = 250 µm.

Order Scorpaeniformes
Family Anoplopomatidae
(Sablefish)

Diagnosis:

- Moderate-large size
- Two dorsal fins
- One lateral line canal
- No scales on branchiostegals
- Ctenoid scales
- No cirri or ridges on head
- Large slit behind last gill arch
- Pelvic fins are thoracic with one spine and five soft rays
- Two genera found in British Columbia waters; **Anoplopoma** and **Erilepis. Erilepis zonifer** (Skilfish) is not included here.

Anoplopoma fimbria (Sablefish)
(Other common names: Blackcod, Coalfish, Coalcod)
Figure 25.16

Description

Length: up to 107 cm (Lamb and Edgell, 1986), but generally around 76 cm (Eschmeyer et al., 1983).
Mouth: moderate, terminal, directly slightly upwards; lower jaw does not extend past upper jaw; maxillary narrow and reach to below point below orbit; teeth fin and found in patches in jaws, vomer, and palatines.

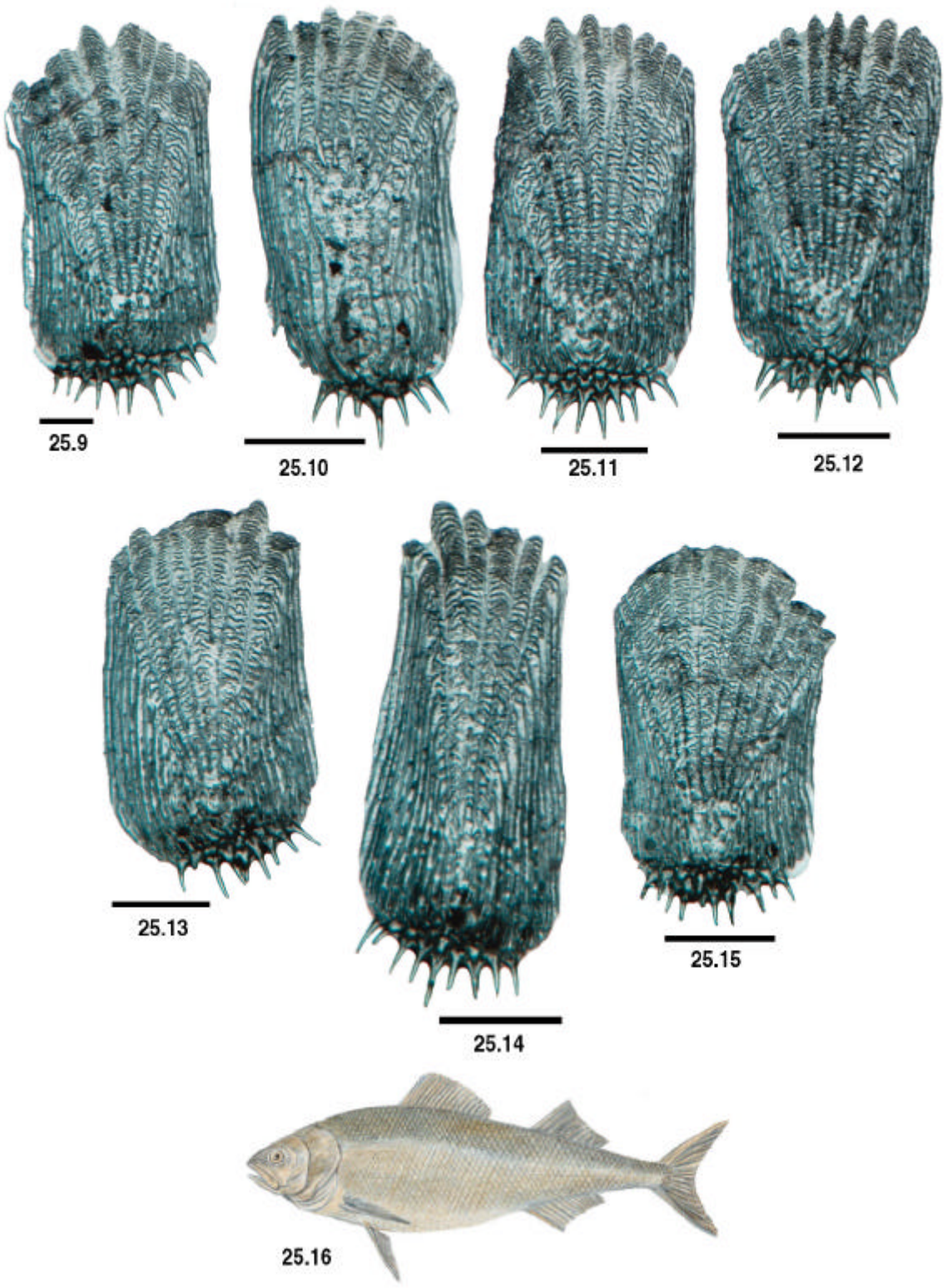


Figure 25.9 - 25.16. 25.9. Anoplopoma fimbria (Sablefish aka Blackcod); body region G; scale bar = 500 µm. **25.10. Anoplopoma fimbria** (Sablefish aka Blackcod); body region G; scale bar = 500 µm. **25.11. Anoplopoma fimbria** (Sablefish aka Blackcod); body region I; scale bar = 500 µm. **25.12. Anoplopoma fimbria** (Sablefish aka Blackcod); body region I; scale bar = 500 µm. **25.13. Anoplopoma fimbria** (Sablefish aka Blackcod); body region J; scale bar = 500 µm. **25.14. Anoplopoma fimbria** (Sablefish aka Blackcod); body region J; scale bar = 500 µm. **25.15 Anoplopoma fimbria** (Sablefish aka Blackcod); body region J; scale bar = 500 µm. **25.16. Anoplopoma fimbria** (Sablefish aka Blackcod); sketch of living specimen; length = approximately 76 cm.

Body: elongate and slightly compressed; conical head; two dorsal fins of equal size but well separated; greater than 15 spines in first dorsal fin; caudal fin forked.
Color: slatey black to green/gray on dorsal surface; light grey on ventral region; outer fin margins are pale; dorsal fin has black margin; operculum has black lining. Dorsolateral region may have small irregular dark stripes.

Biology

Depth: up to 1829 m.
Habitat: young and adults prefer muddy/silty bottoms with young in shallow and adults often in deeper waters.
Season: spawning occurs January to March along the continental shelf at depths greater than 1000 m. Larval sablefish are found in surface waters over the shelf and slope in April and May. Juveniles migrate inshore over the following six months and rear in nearshore and shelf habitats until age two to five when they migrate offshore and into the fishery.
Diet: forage fish (e.g., laternfish, saury), crustaceans, worms.
Predators: larger fish (e.g., halibut, lingcod), marine mammals.
Distribution: Baja, California to Alaska to the Bering Sea to the Sea of Japan.

Scale Description
Figures 25.1-25.15

Relative Size of Scale: small to moderate; in the scale series, smallest to largest: A, C, E, G, I, J; reference material is from a 250 cm long individual).
Position of Scales on the Body: cover the body and head (Hart, 1973).
Overall Scale Shape: generally oval to slightly rectangular with slightly elongated lateral fields.
Focus and Circuli: the focus is not centralized between the fields and is approximately one-quarter to one-fifth of the way from the outside edge of the posterior field. The circuli are compact and continuous in the lateral fields only. Circuli are discontinuous in the anterior field. The posterior field is short, and the circuli do not appear to continue into it (may be partially masked by ctenii).
Radii: there are approximately four to six primary radii with a variable number of secondary radii. It is not determined whether this number is diagnostic. The radii are present in the anterior field only. The anterior field is convex and strongly scalloped.
Remarks: there is the potential to get sablefish scales confused with rockfish scales, however, there are some key differences. In sablefish the circuli in the anterior field are clearly discontinuous and the anterior edge is more strongly scalloped (almost fluted). If the ctenoid region is intact, rockfish seem to have a more heavily ctenoid posterior field with several small ctenii overlapping, giving an armoured appearance.

Scale Preservation

To date, there have been no sablefish found in Effingham Inlet cores. Because the scales are reasonably robust, they should have a good preservation potential, although the ctenoid region would likely disarticulate.

Family Hexagrammidae (Greenlings and Lingcod)

Diagnosis:

- Moderate size; moderately elongate
- Six branchiostegal rays
- Posterior nostril reduced or absent
- Teeth small; gill membranes joined (except in **Ophiodon**)
- Slit behind last gill arch
- Pelvic fins are thoracic
- Seven species in British Columbia waters. **Hexagrammos lagocephalus** (Rock Greenling), **Hexagrammos octogrammus** (Masked Greenling) and **Zaniolepis latipinnus** (Longspine Combfish) are not included here.

Remarks: many species of hexagrammids (with the exception of **Ophiodon**) have primarily ctenoid scales. However, some species also have cycloid scales on specific regions of the body. Ctenoid numbers, patterns, or meristics are not determined. All the species of **Hexagrammos** in this atlas can be considered to have distinctively ”greenling” scales, as all have a similar morphology with differences primarily in size.

Hexagrammos decagrammus (Kelp Greenling)
(Other common names: Greenling Sea Trout, Speckled Sea Trout, Tommy Cod)
Figure 26.8

Description

Length: 60 cm.
Mouth: small, terminal, directed upwards; upper jaw reaches anterior point below eye orbit; snout is blunt with thickened lips; teeth moderate and in rows on the sides of the jaws and in patches at the tip.
Body: head is conical and compressed; one notched dorsal fin; caudal fin trucate or rounded; anal fin with one dorsal spine; erectable cirrus above and behind each eye; small pair of cirri in between eyes and dorsal fin; five lateral lines.
Color: males: brown to olive with blue or copper; blue spots on head and anterior portion of body; each blue spot has a round ring of reddish spots; dorsal and caudal fins are brown to black, pelvic fins dusky blue; pectoral fins spotted white. Females: light brown with orange to blue spots; dorsal fins red to orange with clouds of blue; pectoral fins pale yellow; both sexes have an ocellus on the posterior end of the dorsal fin; dark spots at the base of each eye.

Biology

Depth: up to 46 m.
Habitat: benthic in shallow waters; rocky and sandy substrate; common in with kelp beds.
Season: spawns in fall/winter with males actively guarding nest.
Diet: polychaetes, mussels (Fitch and Lavenburg, 1971), and small crustaceans.

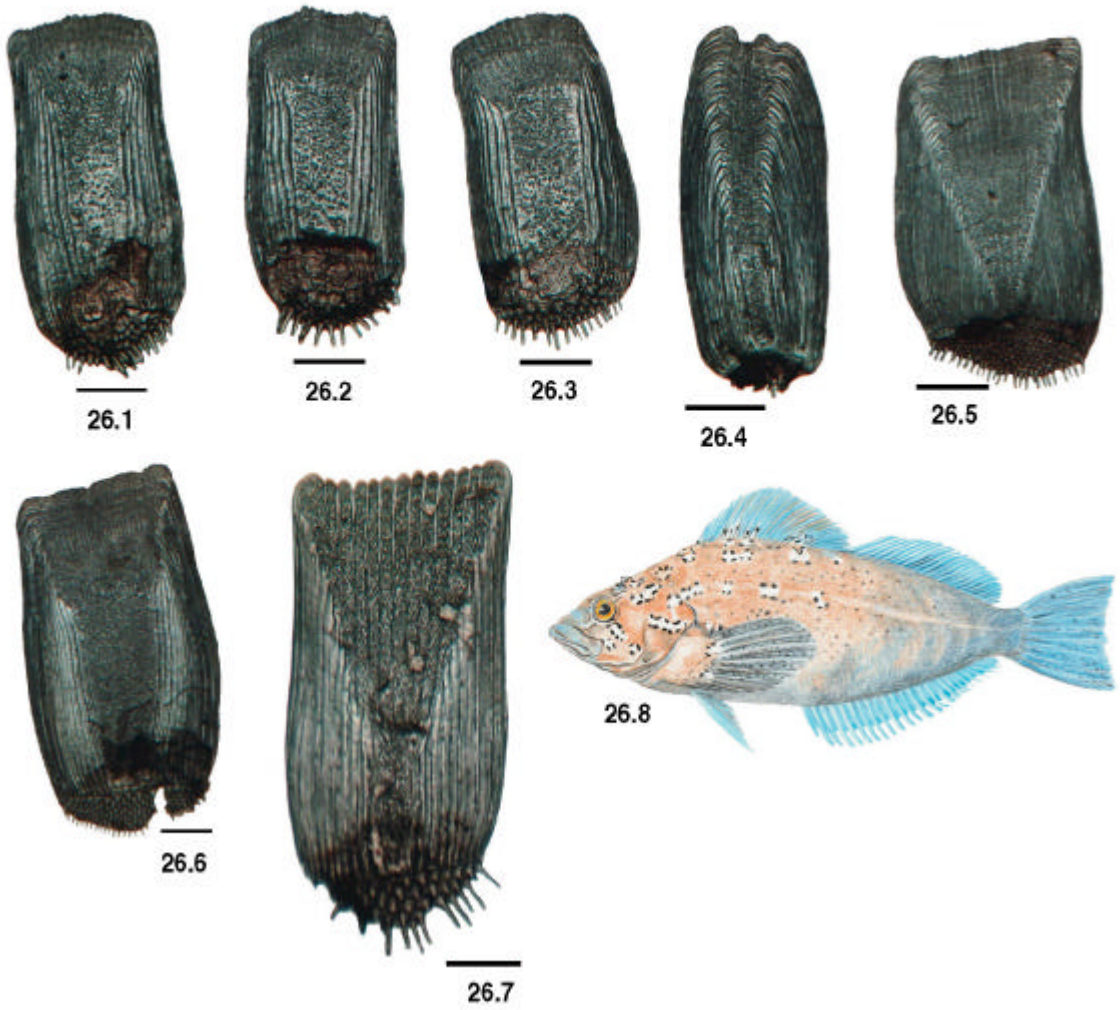


Figure 26.1 - 26.8. 26.1. Hexagrammos decagrammus (Kelp Greenling); body region A; scale bar = 1.0 mm. **26.2. Hexagrammos decagrammus** (Kelp Greenling); body region C; scale bar = 1.0 mm. **26.3. Hexagrammos decagrammus** (Kelp Greenling); body region E; scale bar = 1.0 mm. **26.4. Hexagrammos decagrammus** (Kelp Greenling); body region G; scale bar = 1.0 mm. **26.5. Hexagrammos decagrammus** (Kelp Greenling); body region I; scale bar = 1.0 mm. **26.6. Hexagrammos decagrammus** (Kelp Greenling); body region J; scale bar = 1.0 mm. **26.7. Hexagrammos decagrammus** (Kelp Greenling); scale bar = 500 µm. **26.8. Hexagrammos decagrammus** (Kelp Greenling); sketch of living specimen, male; length = 60 cm.

Predators: salmonids (Pearcy et al., 1990).
Distribution: southern California to the Aleutian Islands (more common in northern waters).

Scale Description
Figures 26.1-26.7

Relative Scale Size: small.
Position of Scales on Body: cover the upper part of the head and body along the five lateral lines (Hart, 1973).
Overall Shape: scales are rectangular, elongated in the anterior/posterior axis.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth. Regeneration appears to be common. The circuli are not continuous between fields. The region of radii formation in the anterior field causes definite disruption of the circuli pattern. Within the anterior field/radii region itself, circuli are difficult to distinguish. Circuli in the lateral fields are well defined. The ridges are quite pronounced and thick.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is slightly scalloped.

Hexagrammos stelleri (Whitespotted Greenling)
(Other common names: Greenling, Kits, Kits Chai, Kiijii)
Figure 27.18

Description

Length: 48 cm.
Mouth: small, terminal, directed upwards; upper jaw does not reach anterior margin of eye orbit; snout curves downwards to upper jaw; thickened lips with small teeth that are in rows along the jaws and in patches inside the tip of the jaws.

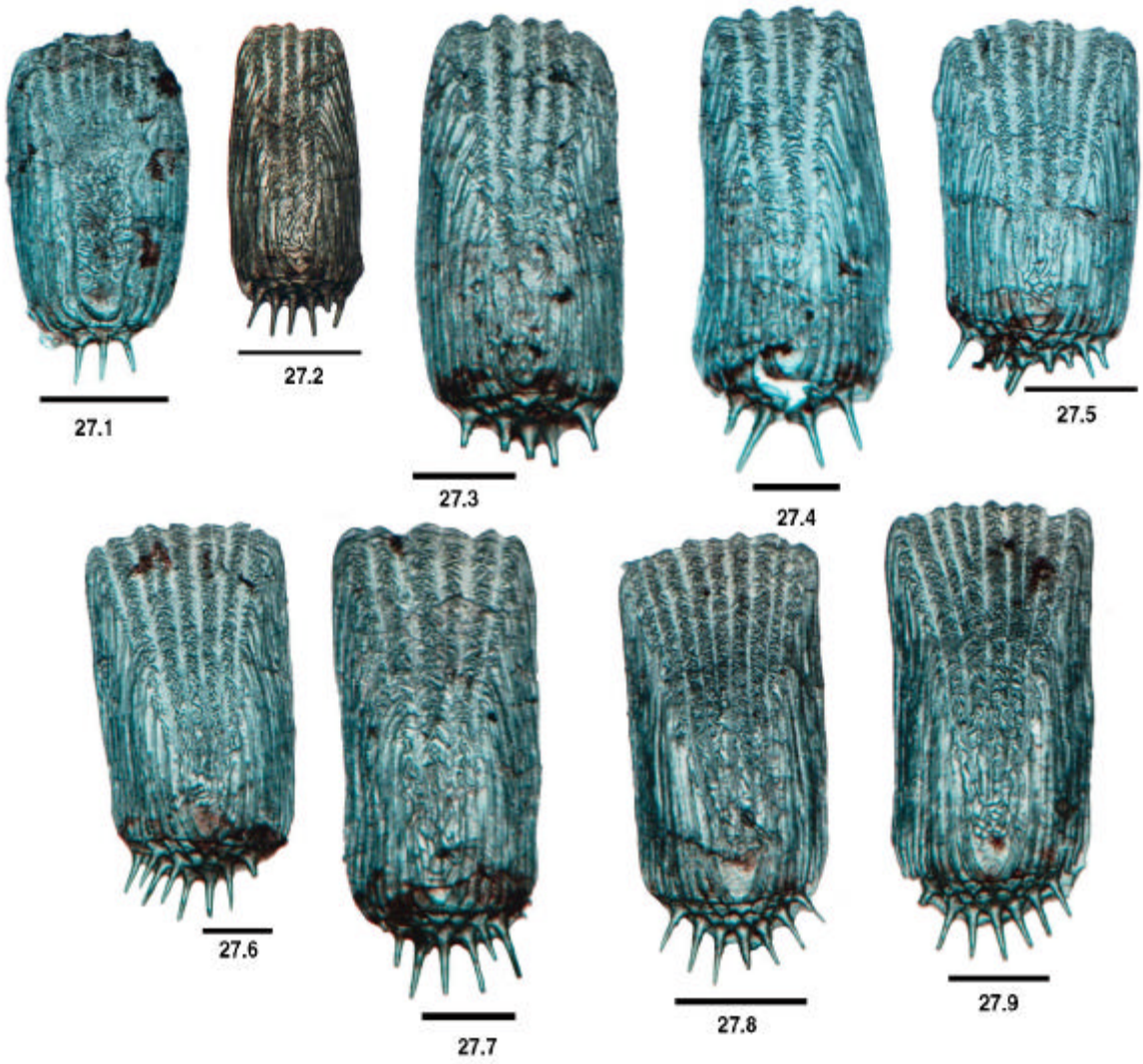


Figure 27.1 - 27. 9 (continued on next page). 27.1. Hexagrammos stelleri (Whitespotted Greenling); body region A; scale bar = 500 µm. **27.2. Hexagrammos stelleri** (Whitespotted Greenling); body region A; scale bar = 500 µm. **27.3. Hexagrammos stelleri** (Whitespotted Greenling); body region A; scale bar = 250 µm. **27.4. Hexagrammos stelleri** (Whitespotted Greenling); body region C; scale bar = 250 µm. **27.5. Hexagrammos stelleri** (Whitespotted Greenling); body region C; scale bar = 500 µm. **27.6. Hexagrammos stelleri** (Whitespotted Greenling); body region C; scale bar = 250 µm. **27.7. Hexagrammos stelleri** (Whitespotted Greenling); body region C; scale bar = 500 µm. **27.8. Hexagrammos stelleri** (Whitespotted Greenling); body region E; scale bar = 500 µm. **27.9. Hexagrammos stelleri** (Whitespotted Greenling); body region E; scale bar = 500 µm.

Body: one notched dorsal fin; one anal fin; five lateral lines but the first and fourth are short; large cirrus above eye; caudal peduncle slender.
Colour: light brown to greenish with blotched white spots; anal fin yellow; dark rows or bars of spots on all fins (except pelvics); dark stripes on dorsal surface.

Biology

Depth: shallow up to 175 m.
Habitat: coastal waters in rocky habitat; also pilings and eelgrass.
Season: spawn in spring.
Diet: worms, crustaceans, smaller forage fish.
Predators: not determined.
Distribution: northern California to Aleutian Islands to Bering Sea, to Hokkaido (less common in southern waters).

Scale Description
Figures 27.1-27.17

Scale Type: ctenoid on body and behind the head, cycloid on cheeks, opercle, behind the eye and along the mid-line (Hart, 1973).

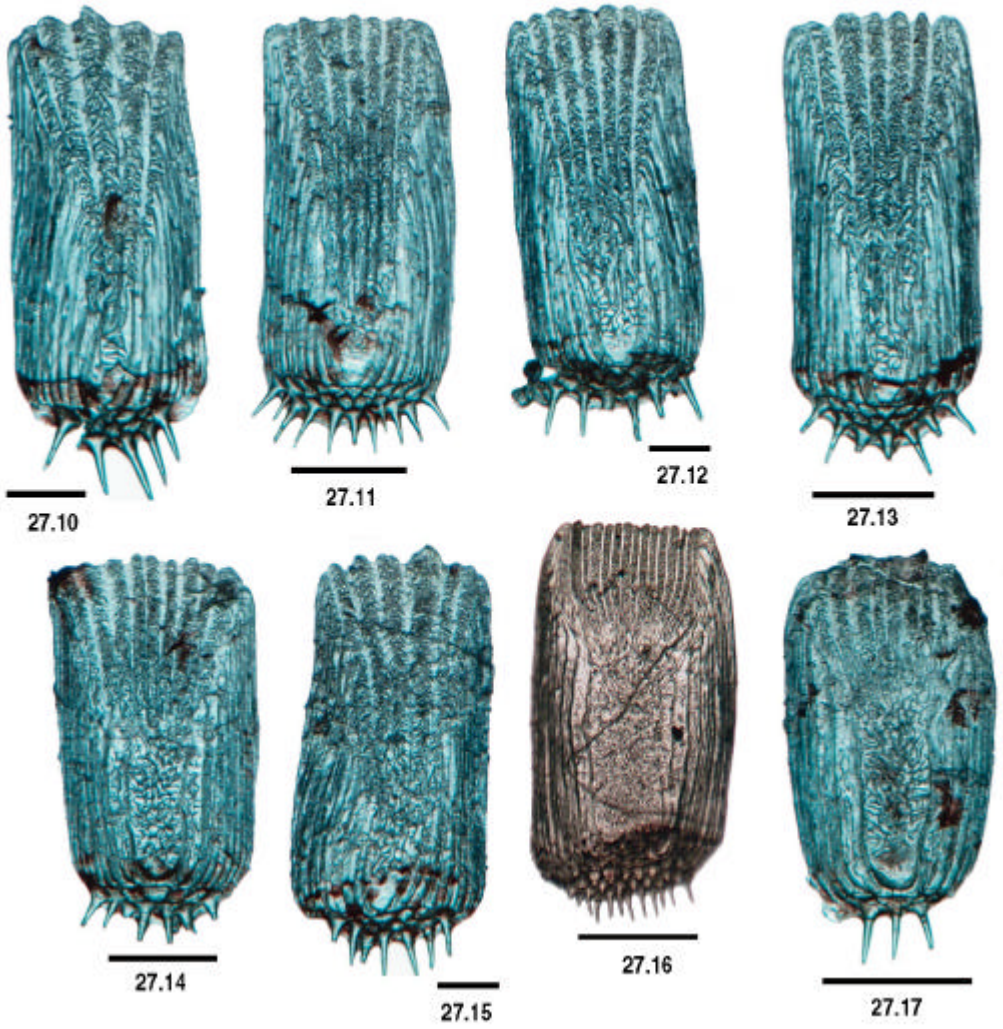


Figure 27.10 - 27.17 (continued on next page). 27.10. Hexagrammos stelleri (Whitespotted Greenling); body region G; scale bar = 250 µm. **27.11. Hexagrammos stelleri** (Whitespotted Greenling); body region I; scale bar = 500 µm. **27.12**. **Hexagrammos stelleri** (Whitespotted Greenling); body region I; scale bar = 250 µm. **27.13. Hexagrammos stelleri** (Whitespotted Greenling); body region J; scale bar = 500 µm. **27.14. Hexagrammos stelleri** (Whitespotted Greenling); body region J; scale bar = 500 µm. **27.15. Hexagrammos stelleri** (Whitespotted Greenling); body region J; scale bar = 250 µm. **27.16. Hexagrammos stelleri** (Whitespotted Greenling); scale bar = 1.0 mm. **27.17. Hexagrammos stelleri** (Whitespotted Greenling); scale bar = 1.0 mm.

Relative Scale Size: small (especially in comparison to other greenlings).
Position of the Scales on Body: on cheeks, opercule, behind eye, and midline; also along the lateral lines (Hart, 1973).
Overall Shape: they are rectangular, elongated in the anterior/posterior axis.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth. Regeneration appears to be common. The circuli are not continuous between fields. The region of radii formation in the anterior field causes definite disruption of the circuli pattern. Within the anterior field/radii region itself, circuli are difficult to distinguish. Circuli in the lateral fields is well defined. The ridges are quite pronounced and thick.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is slightly scalloped.

Ophiodon elongatus (Lincod)
(Other common names: Buffalo Cod; Blue Cod; Pacific Cultus)
Figure 28.8

Description

Length: 152 cm; females larger than males.

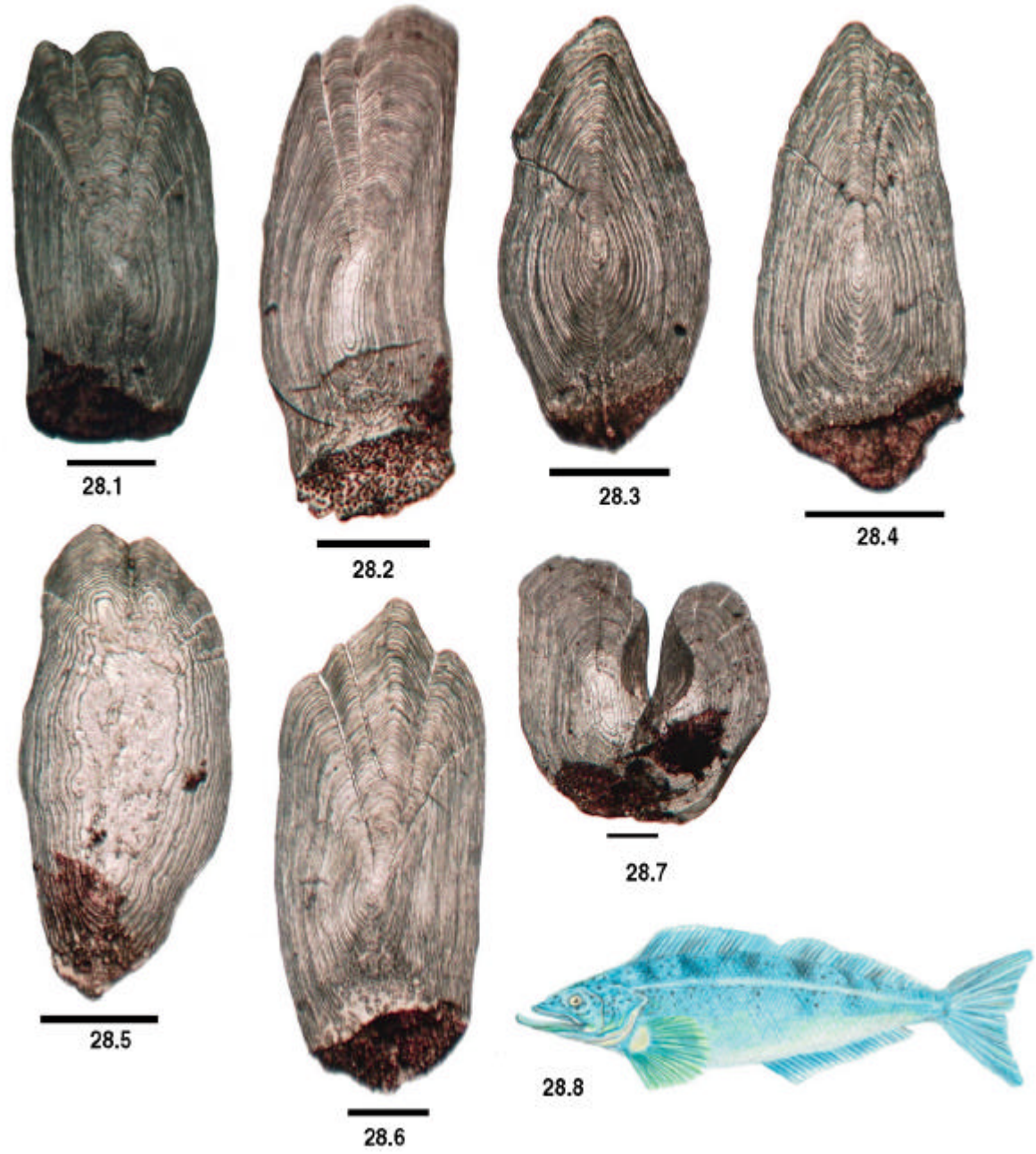


Figure 28.1. Ophiodon elongatus (Lingcod); scale bar = 1.0 mm. **28.2. Ophiodon elongatus** (Lingcod); scale bar = 1.0 mm. **28.3. Ophiodon elongatus** (Lingcod); scale bar = 1.0 mm. **28.4. Ophiodon elongatus** (Lingcod); scale bar = 1.0 mm. **28.5. Ophiodon elongatus** (Lingcod); scale bar = 1.0 mm. **28.6. Ophiodon elongatus** (Lingcod); scale bar = 1.0 mm. **28.7. Ophiodon elongatus** (Lingcod); scale bar = 500 µm. **28.8. Ophiodon elongatus** (Lingcod); sketch of living specimen; length =152 cm.

Mouth: large with gape, terminal, directed upwards; maxillary extend beyond the posterior edge of the orbit; lower jaw projects; teeth large and canine.
Body: long notched (separates soft-rayed and spinous portions) single dorsal fin; single anal fin with three spines; caudal fin truncate; thoracic pelvic fins; four to five preopercule spines; one lateral line; multifidus circus over each eye.
Colour: dark green to bluish to mottled brown; pale below; light spots.

Biology

Depth: 475 m; seasonal migration between shallow and deep waters.
Habitat: juveniles in sandy or mud bays; adults in rocky reefs and kelp; both migratory and non-migratory populations.
Season: spawns winter to early spring.
Diet: the diet of the juveniles may consist of copepods, shrimp, and other crustaceans. The adults feed upon

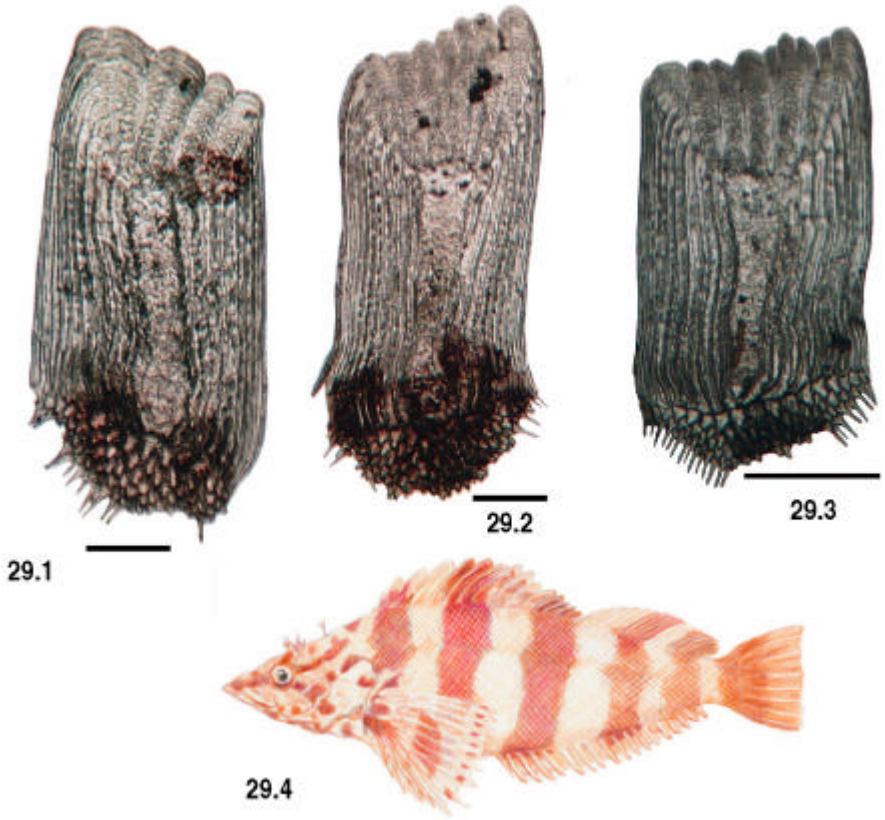


Figure 29.1. Oxylebius pictus (Painted Greenling); scale bar = 500 µm. **29.2. Oxylebius pictus** (Painted Greenling); scale bar = 500 µm. **29.3. Oxylebius pictus** (Painted Greenling); scale bar = 1.0 mm. **29.4. Oxylebius pictus** (Painted Greenling); sketch of living specimen; length = 25 cm.

herring, flounders, cod, whiting, squid, and juvenile lingcod.
Predators: not determined.
Distribution: southern California to Alaska.

Scale Description
Figures 28.1-28.7

Scale Type: cycloid.
Relative Scale Size: small to moderate.
Position of Scales on Body: covers body and head (Hart, 1973).
Overall Shape: elongate to oval.
Focus and Circuli: the focus is centralized between the four fields. The posterior field is speckled with protruberances. The circuli are continuous between the anterior and lateral fields.
Radii: numbers are variable and not diagnostic. Present in the anterior field only. The outer edge of the anterior field is convex and distinctly scalloped.

Oxylebius pictus (Painted Greenling)
(Other common names: Convict Fish)
Figure 29.4

Description

Length: 25 cm.
Mouth: small, terminal, directed upwards; upper jaw not reaching anterior margin of orbit; thickened lips with upper separated from nasals; teeth fine.
Body: single notched dorsal fin with rayed portion higher than spinous; single notched anal fin; caudal fin rounded; two pairs of erect cirri behind eyes; one lateral line.
Color: gold to tan to grey; five to seven vertical dark red bars that continue through the dorsal and anal fins; three darkened stripes radiating from each eye, one which goes to the snout; dark spots on pectoral, pelvic, and caudal fins.

Biology

Depth: 46 m; larvae have been collected in the shallow intertidal zone.
Habitat: intertidal/subtidal rocky substrate; protected reefs.
Season: winter months, variable.
Diet: crustaceans, polychaetes; small molluscs, bryozoans.
Predators: not determined.
Distribution: Baja, California to Aleutian Islands.

Figure 30.1. Greenling, core B03 S08, interval 129-134 cm; scale bar = 1.0 mm.

Scale Description
Figure 29.1-29.3

Scale Type: ctenoid on body, except on head to the interorbital region and along the midside where they are cycloid (not shown in figures).
Relative Scale Size: small to moderate.
Position of Scales on Body: 76 scales along the midline (Hart, 1973).
Overall Shape: they are rectangular, elongated in the anterior/posterior axis. One of the lateral fields appears longer then others, but the extent to which this is expressed is variable.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth fields and is approximately one third of the total length from the posterior margin. Regeneration appears to be common. The circuli are not continuous between fields. The region of radii formation in the anterior field causes definite disruption of the circuli pattern. Within the anterior field/radii region itself, circuli are difficult to distinguish. Circuli in the lateral fields is well defined. The ridges are quite pronounced and thick.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is slightly scalloped.

Scale Preservation
Figure 30.1

Only limited hexagrammid scale material has been found in our core studies so it is difficult to generalize on their preservation. Although the scales appear to preserve, they are generally not in good condition. They appear to be quite brittle and fragment easily. The posterior field/ctenoid region breaks off, truncating the circuli in the edge of the lateral fields.

Family Scorpaenidae
(Scorpionfish or Rockfish)

Diagnosis:

- Gill opening extends to base of pectoral ray
- Opening behind fourth gill arch reduced or absent
- Two opercular spines
- Five preocpercular spines
- Generalized head has eight spines: nuchal; parietal; typmpanic; corornal; postocular postorbital; supraocular supraorbitat; preocular preorbital; nasal
- Elongate, laterally compressed bodies
- Single dorsal fine with 11 to17 spines and 8 to 18 rays
- Anal fin with three spines and five to nine rays
- Pelvic fins thoracic each with one spine and five rays
- Scales are ctenoid; regeneration is common

In British Columbia there are two genera in this family: **Sebastolobus** (two species) and **Sebastes** (approximately 35 species). The following species are not included here; **Sebastes aleutianus** (Rougheye Rockfish), **Sebastes alutus** (Pacific Ocean Perch), **Sebastes aurora** (Aurora Rockfish), **Sebastes babcocki** (Redbanded Rockfish), **Sebastes ciliatus** (Dusky Rockfish), **Sebastes crameri** (Darkblotched Rockfish), **Sebastes diploproa** (Splitnose Rockfish), **Sebastes elongatus** (Greenstriped Rockfish), **Sebastes emphaeus** (Puget Sound Rockfish), **Sebastes entomelas** (Widow Rockfish), **Sebastes goodie** (Chilipepper Rockfish), **Sebastes helvomaculatus** (Rosethoorn Rockfish), **Sebastes jordani** (Shortbelly Rockfish), **Sebastes miniatus** (Vermilion Rockfish), **Sebastes mystinus** (Blue Rockfish), **Sebastes nebulosus** (China Rockfish), **Sebastes reedi** (Yellowmouth Rockfish), **Sebastes ruberrimus** (Yelloweye Rockfish), **Sebastes saxicola** (Stripetail Rockfish), **Sebastes variegates** (Harlequin Rockfish), **Sebastes wilsoni** (Pygmy Rockfish), **Sebastes zacentrus** (Sharpchin Rockfish) **Sebastolobus alascanus** (Shortspine Thornyhead), and **Sebastolobus altivelis** (Longspine Thornyhead).
Remarks: based on available species it seems that it is difficult to use scale morphology (including meristic measurements) to identify **Sebastes** to the species level. The scales across species are essentially the same (no distinguishing characteristics), and size is not a desirable characteristic since many of the species overlap in size. Size can be used to suggest a species (or a number of

them), but with only a small degree of confidence. At this time, we do not have any **Sebastolobus** for comparison to **Sebastes** so we are not able to make any conclusions about identification of scales to species level within that genus.

Sebastes auriculatus (Brown Rockfish)
(Other common names: Brown Rock Cod, Snapper, Bass)
Figure 31.16

Description

Length: 55 cm.
Mouth: large, terminal, lower jaw projects slightly; upper jaw extends past posterior margin of orbit;
Body: head spines well developed and strong (especially coronal); nuchals (reduced or absent) and subocular absent; spine on lower gill cover edge; flat interobital space; caudal fin rounded.
Color: light brown mottled with darker brown; vertical brown bars on back and operculum; fins are dusky pink.

Biology

Depth: up to 128 m.
Habitat: rocky substrate and kelp beds; juveniles in nearshore bays and piers 10 to 30 m; adults in shallow bays and offshore to depths of 128 m; generally sedentary.
Season: ovoviparous; fertilization in the spring; larvae released in late spring to mid-summer.
Diet: polychates, crustaceans, and smaller forage fish.
Predators: lingcod (Kramer and O'Connell, 1995).
Distribution: Baja, California to southeast Alaska.

Scale Description
Figures 31.1-31.15

Relative Scale Size: moderate but variable.
Position of Scales on Body: 45-52 diagonal rows below lateral line canal (Hart, 1973).
Overall Shape: square to slightly rectangular. Smaller scales are generally more rectangular than the larger scales. In some scales, the anterior field is slightly convex. Some leading edges of the lateral fields can be slightly wavy, making the lateral field appear to slightly bulge.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth. The focus is approximately one-quarter of the total scale length from the outside edge of the posterior margin. The circuli are continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is generally straight to slightly convex and is scalloped.

Sebastes borealis (Shortraker Rockfish)
(Other common names: Buoy Keg, Grouper)
Figure 32.3

Description

Length: 91-108 cm.
Mouth: large, terminal, directed upwards; lower jaw projecting; upper jaw extends beyond mid-orbit; large pores on lower jaw (Kramer and O'Connell, 1995).
Body: head spines moderate to weakly developed (coronal may be absent); spine on lower gill cover edge; flat interobital space; preopercular spines close together; caudal fin indented; single lateral line that slopes ventrally at the point above the anal opening, then is straight to the caudal peduncle; one or more spines on lower gill cover.
Color: pink with vertical red bands; fins red; pelvics and pectorals may be ridged with black; mouth and gill cavity red with black blotches (occasionally reversed); silver to grey peritoneum.

Biology

Depth: up to 305 m (possibly as deep as 875 m).
Habitat: large individuals are probably solitary and live on silt or cobble bottoms near boulders.
Season: ovoviparious; mating occurs in the fall with birthing in April.
Diet: crustaceans (e.g., euphasiids, shrimps); forage fish (e.g., herring).
Predators: not determined.
Distribution: northern California to Kamchatka.

Scale Description
Figures 32.1-32.2

Relative Scale Size: large.
Position of Scales on Body: 36 to 46 diagonal rows below lateral line canal (Hart, 1973).
Overall Shape: square to slightly rectangular with the anteriolateral corners somewhat protruding past the anterior field.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth and is approximately one-fifth the total scale length from the outside edge of the posterior margin. The circuli are continuous between the lateral and anterior fields (except broken by radii). The circuli are tightly compact.
Radii: numbers are variable and not diagnostic. Present in the anterior field only. The outer edge of the anterior field is generally straight (the odd scale is slightly convex) and is slightly to moderately scalloped.

Sebastes brevispinis (Silvergray Rockfish)
(Other common names: Shortspine Rockfish)
Figure 33.2

Description

Length: 71 cm.
Mouth: large, terminal; maxillary extends posterior to the orbit; lower jaw greatly proturdes in profile; prominent symphyseal knob.
Body: parietal, preocular and nasal spines weak, other head spines absent; supracleithrals well develop; five preopercular but lower one or two can be weak or absent; caudal fin indented.
Color: green to silvery gray; darker on back with silver sides; white below; lips black; paired fins may have tinges of orange-dusky.

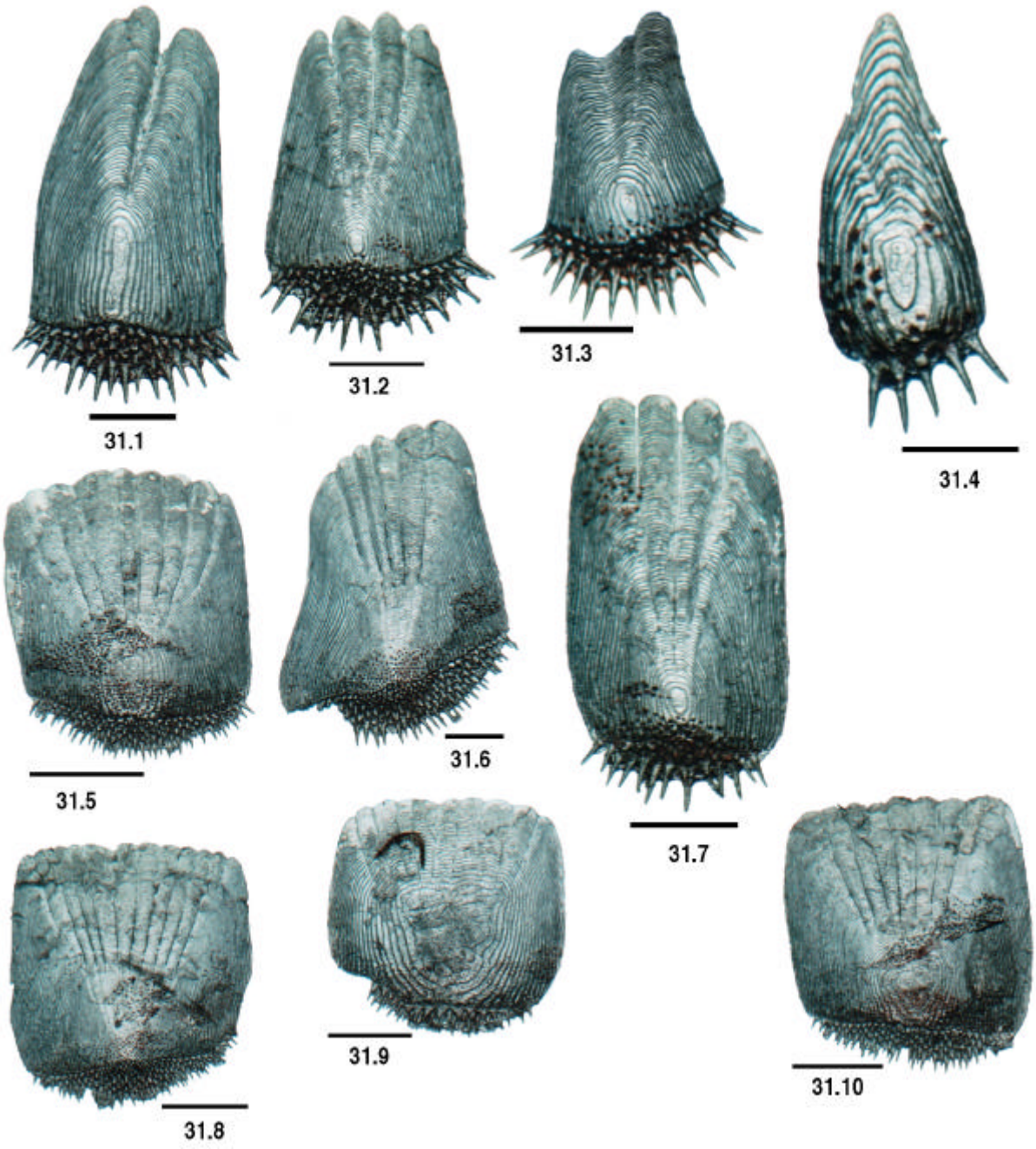


Figure 31.1 - 31.10 (continued on next page). 31.1. Sebastes auriculatus (Brown Rockfish); body region A; scale bar = 500 µm. **31.2. Sebastes auriculatus** (Brown Rockfish); body region A; scale bar = 500 µm. **31.3. Sebastes auriculatus** (Brown Rockfish); body region A; scale bar = 500 µm. **31.4. Sebastes auriculatus** (Brown Rockfish); body region A; scale bar = 500 µm. **31.5. Sebastes auriculatus** (Brown Rockfish); body region C; scale bar = 1.0 mm. **31.6. Sebastes auriculatus** (Brown Rockfish); body region C; scale bar = 500 µm. **31.7. Sebastes auriculatus** (Brown Rockfish); body region C; scale bar = 500 µm. **31.8. Sebastes auriculatus** (Brown Rockfish); body region E; scale bar = 1.0 mm. **31.9. Sebastes auriculatus** (Brown Rockfish); body region E; scale bar = 1.0 mm. **31.10. Sebastes auriculatus** (Brown Rockfish); body region E; scale bar = 1.0 mm.

Biology

Depth: adults in waters 100-375 m; young in shallower waters <100 m.
Habitat: rocky substrates with crevices and caverns; dermersal.
Season: oviviparous; mate in spring; young released in summer; long lived species-up to 80 years.
Diet: forage fish (e.g., herring, sand lance); crustaceans (e.g., crabs, shrimps, euphasiids)
Predators: not determined.
Distribution: southern California to the Bering Sea.

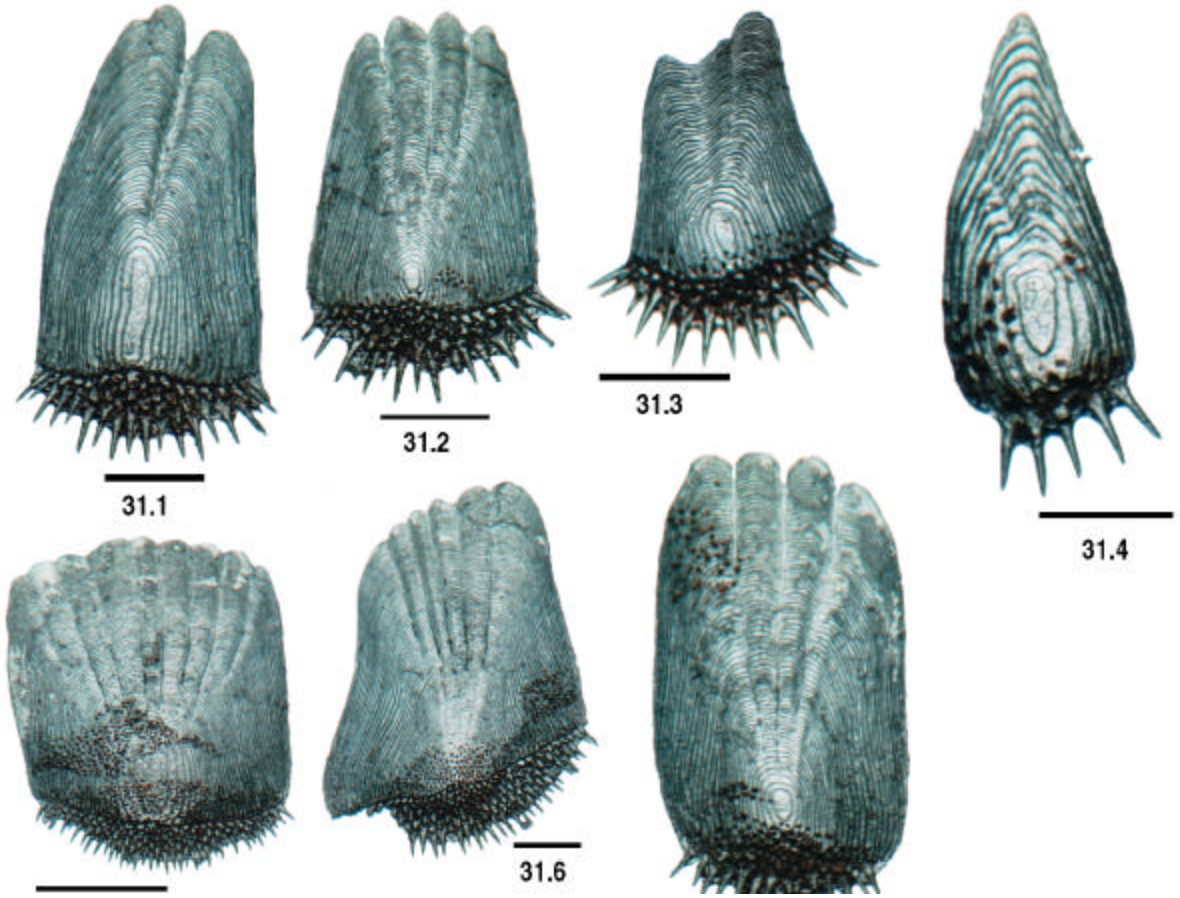


Figure 31.11 - 31.16 31.11. Sebastes auriculatus (Brown Rockfish); body region G; scale bar = 500 µm. **31.12. Sebastes auriculatus** (Brown Rockfish); body region G; scale bar = 1.0 mm. **31.13. Sebastes auriculatus** (Brown Rockfish); body region G; scale bar = 500 µm. **31.14. Sebastes auriculatus** (Brown Rockfish); body region I; scale bar = 500 µm. **31.15. Sebastes auriculatus** (Brown Rockfish); scale bar = 500 µm. **31.16. Sebastes auriculatus** (Brown Rockfish); sketch of living specimen; length = 55 cm.

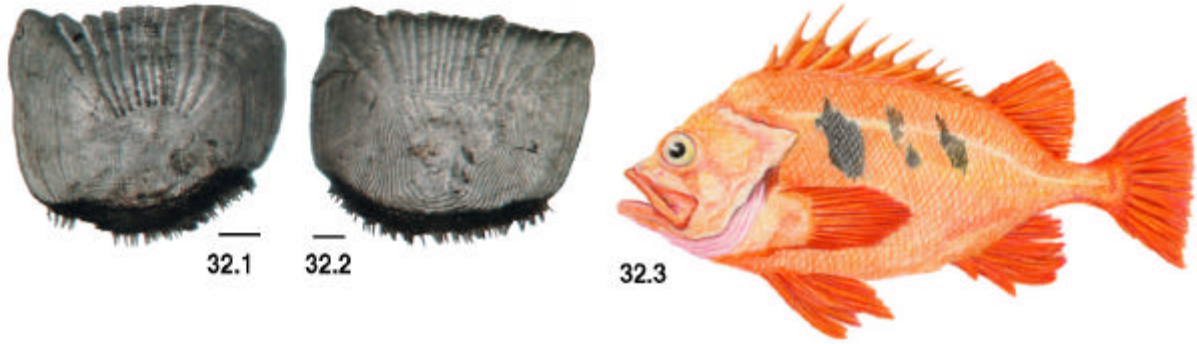


Figure 32.1 - 32.3. 32.1. Sebastes borealis (Shortraker Rockfish); scale bar = 1 mm. **32.2. Sebastes borealis** (Shortraker Rockfish); scale bar = 1 mm. **32.3. Sebastes borealis** (Shortraker Rockfish); sketch of living specimen; length = 100 cm.

Scale Description
Figure 33.1

Relative Scale Size: large.
Available Scale Material: below lateral line canal 58-70; in oblique rows (Hart, 1973).

Overall Shape: square to rectangular, depending on the degree of lateral field elongation.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth and is approximately one-fifth to one-sixthof the total scale length from the outside edge of the posterior margin. The circuli are continuous between the lateral and anterior fields

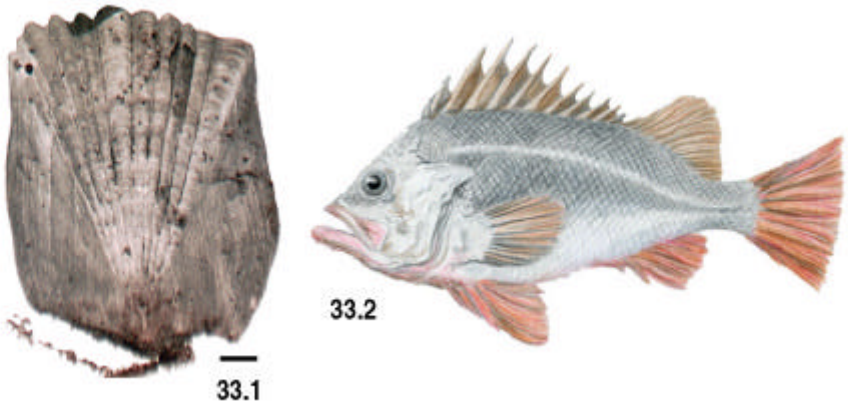


Figure 33.1 - 33.2. 33.1. Sebastes brevispinis (Silvergrey Rockfish); scale bar = 1 mm. **33.2. Sebastes brevispinis** (Silvergrey Rockfish); sketch of living specimen; length = 71 cm.

(except broken by radii) and are tightly compact. The posterior field is quite short and weakly ctenoid.
Radii: numbers are variable and not diagnostic. Radii in the anterior field only. The outer edge of the anterior field ranges from straight to slightly convex and is slightly to moderately scalloped.

Sebastes caurinus (Copper Rockfish)
(Other common names: Rockcod, Bass, Whitebelly Rockfish, Chucklehead)
Figure 34.16

Description

Length: 58 cm.
Mouth: large, terminal; lower jaw projected but not into dorsal profile; upper jaw extends to the posterior edge of orbit; no teeth on lower jaw.
Body: supraocular, coronal, and nutchal spines absent; nasal, preocular, postocular, tympanic, and parietal thick; preocular spines blunt and triangular directed backwards; ocular spines blunt and short; cleithral and supracleithral spines well developed; spine at lower edge of gill covering; caudal fin rounded; slight curve in upper profile.
Color: dark olive brown with copper to pink; two-thirds of lateral line is white; two yellow light bands radiating from posterior of eye; occassional yellow cheeks and orange chin; midside has light blotch; fins all copper-black.

Biology

Depth: 10–183 m.
Habitat: rocky and sandy substrate; also found protected bays and inlets amongst kelp beds; juveniles aggregate in shallow weedy areas.
Season: ovoviparous; spring.
Diet: worms, molluscs, and crustaceans.
Predators: not determined.
Distribution: Baja, California to Alaska.

Scale Description
Figure 34.1-34.15

Relative Scale Size: large.
Position of Scales on Body: in diagonal rows below the lateral line canal 39-45 (Hart, 1973).
Overall Shape: the scales are generally square, but differential elongation can make them look more rectangular and in some cases, give a bulbous appearance to the lateral fields, and also a convex shape to the anterior field.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth. Approximately one-fourth of the total scale length is from the outside edge of the posterior margin. The posterior field is short. The circuli are continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Present in the anterior field only. The outer edge of the anterior field can be straight to convex and is slightly to moderately scalloped.

Sebastes flavidus (Yellowtail Rockfish)
(Other common names: Yellowtail Rock Cod, Green Snapper)
Figure 35.3

Description

Length: 66 cm.
Mouth: large, terminal; lower jaw projects but does not enter the upper profile; upper jaw extends to just before orbit; snout is pointed; symphyseal knob prominent and projects downwards.
Body: nasal spines weak; preopercular spines stong; two opercular spines strongly developed but thin; cleithral spines weak; supracleithral spine weak or absent; convex interorbital space; anal fin posterior edge is vertical; caudal fin truncate but slightly forked.
Color: olive green with mottled brown; fins and caudal tip is yellow; young often have a black blotch on the caudal fin.

Biology

Depth: up to 274 m but most between 24-46 m.
Habitat: pelagic schooling species often found over deep reefs.

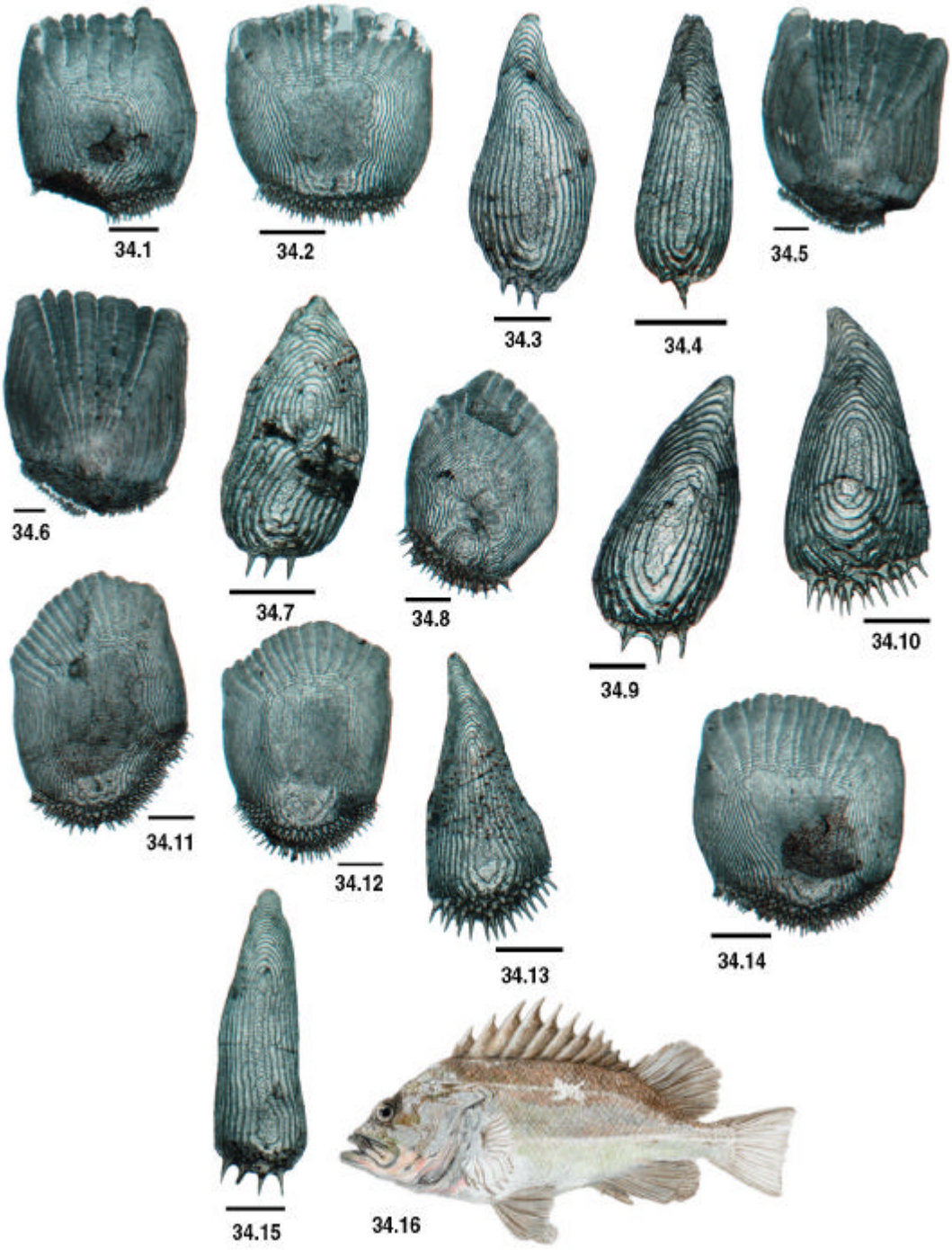


Figure 34.1 - 34.16. 34.1. Sebastes caurinus (Copper Rockfish); body region C; scale bar = 1.0 mm. **34.2. Sebastes caurinus** (Copper Rockfish); body region C; scale bar = 1.0 mm. **34.3. Sebastes caurinus** (Copper Rockfish); body region C; scale bar = 500 µm. **34.4. Sebastes caurinus** (Copper Rockfish); body region C; scale bar = 500 µm. **34.5. Sebastes caurinus** (Copper Rockfish); body region E; scale bar = 1.0 mm. **34.6. Sebastes caurinus** (Copper Rockfish); body region E; scale bar = 1.0 mm. **34.7. Sebastes caurinus** (Copper Rockfish); body region E; note the doubled focal region that developed during scale regeneration; scale bar = 500 µm. **34.8. Sebastes caurinus** (Copper Rockfish); body region G; scale bar = 1.0 mm. **34.9. Sebastes caurinus** (Copper Rockfish); body region G; scale bar = 250 µm. **34.10. Sebastes caurinus** (Copper Rockfish); body region G; scale bar = 500 µm. **34.11. Sebastes caurinus** (Copper Rockfish); body region I; scale bar = 1.0 mm. **34.12. Sebastes caurinus** (Copper Rockfish); body region I; scale bar = 1.0 mm. **34.13. Sebastes caurinus** (Copper Rockfish); body region I; scale bar = 500 µm. **34.14. Sebastes caurinus** (Copper Rockfish); body region J; scale bar = 1.0 mm. **34.15. Sebastes caurinus** (Copper Rockfish); body region J; scale bar = 500 µm. **34.16. Sebastes caurinus** (Copper Rockfish); sketch of living specimen; length = 58 cm.

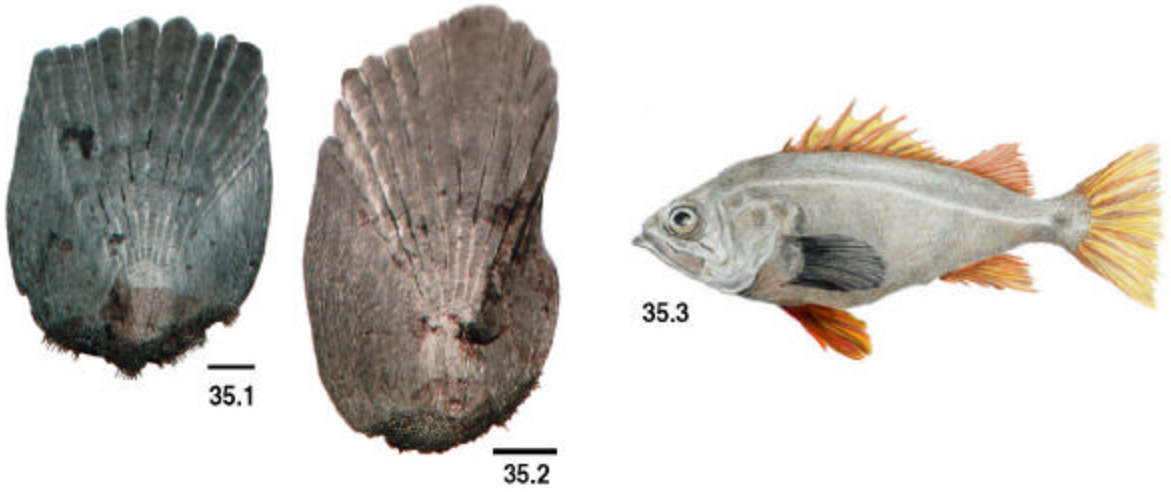


Figure 35.1 - 35.3. 35.1. Sebastes flavidus (Yellowtail Rockfish); scale bar = 1.0 mm. **35.2. Sebastes flavidus** (Yellowtail Rockfish); scale bar = 1.0 mm. **35.3. Sebastes flavidus** (Yellowtail Rockfish); sketch of living specimen; length = 66 cm.

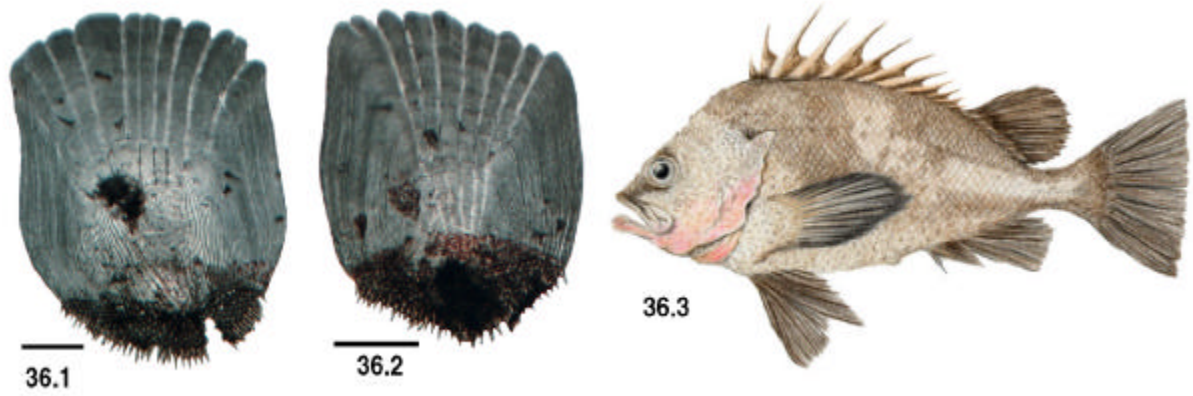


Figure 36.1 - 36.3. 36.1. Sebastes maliger (Quillback Rockfish); scale bar = 1.0 mm. **36.2. Sebastes maliger** (Quillback Rockfish); scale bar = 1.0 mm. **36.3. Sebastes maliger** (Quillback Rockfish); sketch of living specimen; length = 61 cm.

Season: ovoviparious; young are born late winter to early spring.
Diet: pelagic crustaceans, fish (e.g., laternfish).
Predators: unknown.
Distribution: southern California to Alaska

Scale Description
Figure 35.1-35.2

Relative Scale Size: moderate.
Position of Scales on Body: below lateral line in 55-60 diagonal rows (Hart, 1973).
Overall Shape: the scales are generally square to rectangular with a short posterior field that is weakly ctenoid.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth, approximately one-fourth the total scale length from the outside edge of the posterior margin. The circuli are compact and continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Present presently only in the anterior field. The outer edge of the anterior field edge is straight to slightly convex and is scalloped.

Sebastes maliger (Quillback Rockfish)
(Other common names: Gopher Rock Cod, Speckled Rockfish, Rock Cod)
Figure 36.3

Description

Length: 61 cm.
Mouth: large, terminal; upper jaw projects to approximately mid-orbit; no teeth patches at top of lower jaw; symphyseal knob weak.
Body: nuchals subocular; and coronals absent; nasal, preocular, postocular, tympanic, and parietal present

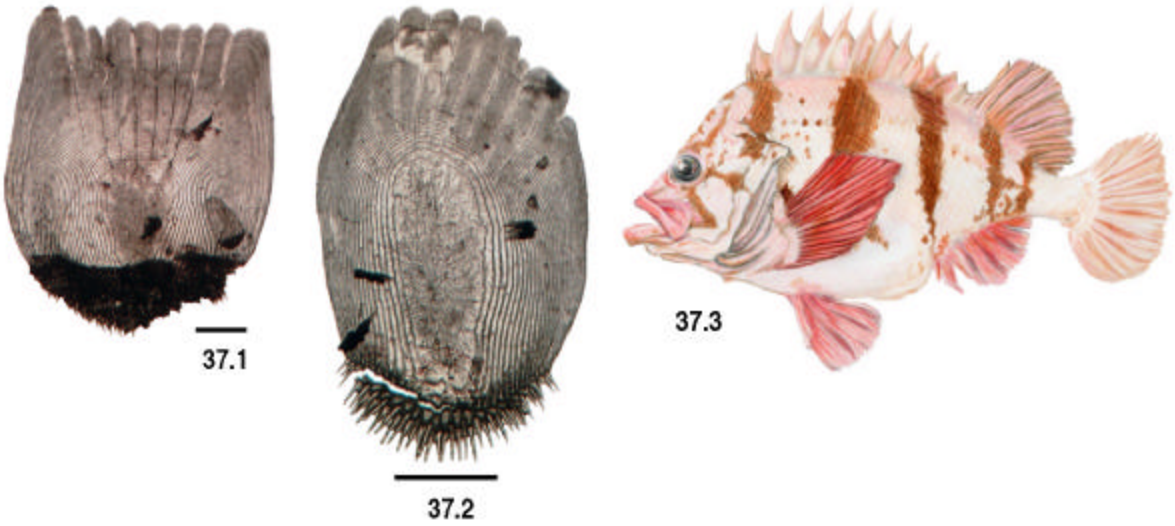


Figure 37.1 - 37.3. 37.l. Sebastes nigrocinctus (Tiger Rockfish); scale bar = 1.0 mm. **37.2. Sebastes nigrocinctus** (Tiger Rockfish); scale bar = 1.0 mm. **37.3. Sebastes nigrocinctus** (Tiger Rockfish); sketch of living specimen; length = 61 cm.

and strong; tympanic can sometimes be weak; preopercular spines short; opercular spines moderate; cleithral and supracleithral spines present, sometimes embedded; dorsal fin is high with an incised spinous region; caudal fin rounded.
Color: brown with yellow-tan areas on the head and back; pale below; orange and brown spots on lower anterior region; fins dark; yellow in the dorsal fin spinous region.

Biology

Depth: up to 275 m; shallower in northern waters.
Habitat: demersal over rocky substrate, reefs, and inlets; solitary.
Season: ovoviparious**;** larvae in spring; juveniles found in summer in tideline.
Diet: crustaceans (e.g., shrimps, crabs), worms, forage fish (e.g., herring, sand lance).
Predators: not determined.
Distribution: central California to Alaska.

Scale Description
Figure 36.1-36.2

Relative Scale Size: small to moderate.
Position of Scales on Body: below lateral line canal in 39-45 rows (Hart, 1973).
Overall Shape: the scales are generally square to rectangular.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth, and approximately one-fourth of the total scale length from the outside edge of the posterior margin. The circuli are compact and continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Radii are only in the anterior field. The outer edge of the anterior field is straight to slightly convex and is slightly to moderately scalloped.

Sebastes nigrocinctus (Tiger Rockfish)
(Other common names: Banded Rockfish, Black-Banded Rockfish)
Figure 37.3

Description

Length: 61 cm.
Mouth: large, terminal; upper jaw extends to mid-orbit; lower jaw projects past upper; snouth is blunt; teeth at tip lower jaw absent; symphyseal knob not always present.
Body: head spines well developed, sometimes they are divided into points; supraocular spines absent; preopercular spines coarse; opercular spines long and sharp; cleithral and supracleithral sharp and strong; caudal fin rounded; intraorbitat space concave.
Color: shades of gray, pink, to red with five black or red vertical bars across the body; two black or red bars radiate posteriorly from eye.

Biology

Depth: 10 to 275 m.
Habitat: rocky reefs with caves and crevices; juveniles pelagic and as they become adults they become demersal; solitary; highly territorial.
Season: ovoviparious; larvae in spring and summer juveniles drift with floating debris.
Diet: crustaceans (e.g., euphasiids, shrimps, crabs); forage fish (e.g.herring, sand lance).
Predators: not determined.
Distribution: central California to Alaska.

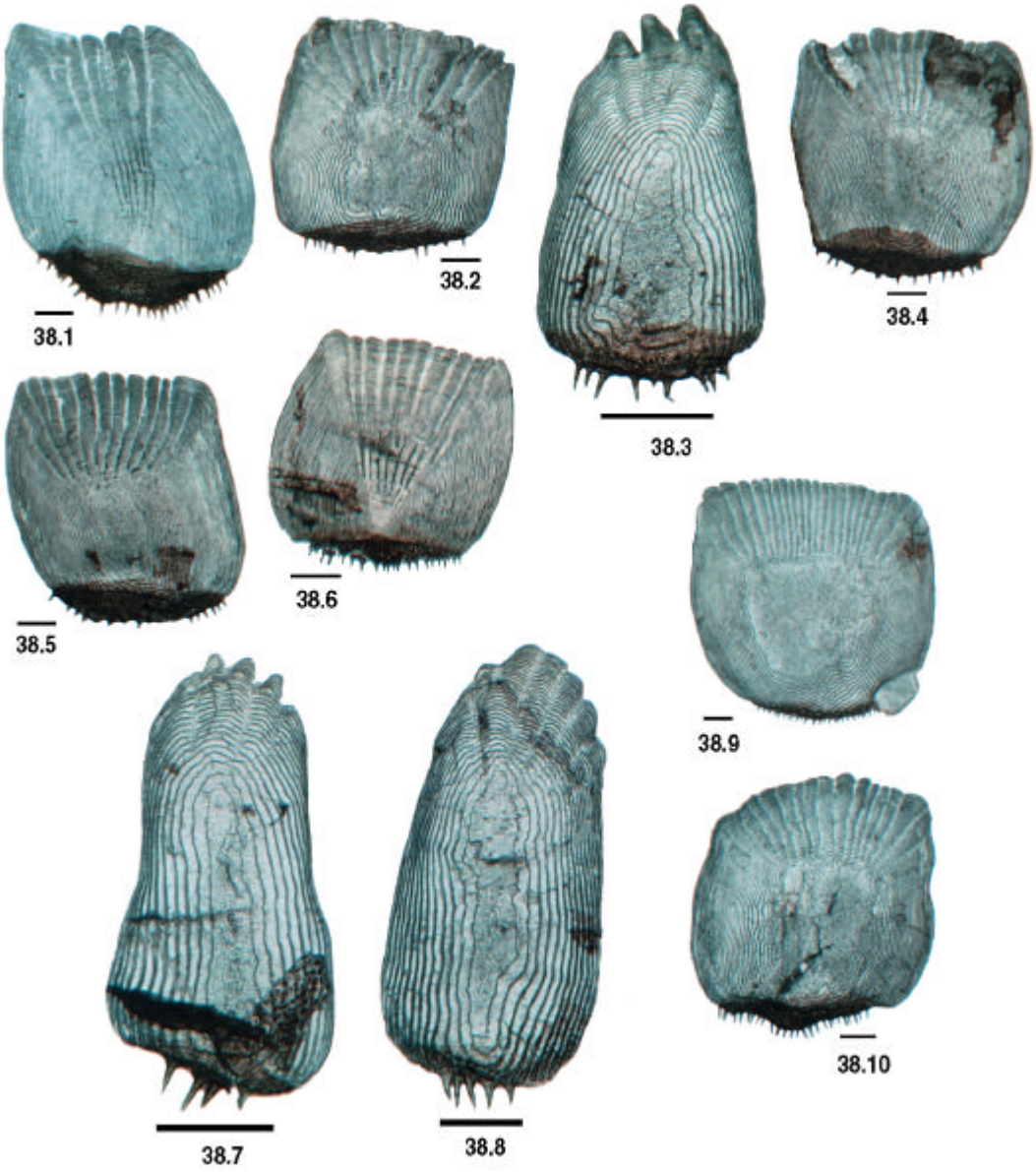


Figure 38.1 - 38.10 (continued on next page). 38.1. Sebastes paucispinis (Boccacio Rockfish); scale bar = 1.0 mm. **38.2. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.3. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.4. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.5. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.6. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.7. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.8. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.9. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.10. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm.

Scale Description
Figure 37.1-37.2

Relative Scale Size: small to moderate.
Position of Scales on Body: in diagonal rows below lateral line canal 44-53 (Hart, 1973)**.**
Overall Shape: the scales are generally square to rectangular with a somewhat longer lateral field with a moderately short posterior field.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth, and is approximately one-fourth of the total scale length from the outside edge of the posterior margin. The circuli are continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Radii present only in the anterior field. The outer edge of the anterior field edge is straight to convex and is slightly to moderately scalloped.

Sebastes paucispinis (Bocaccio)
(Other common names: Rock Salmon, Salmon Grouper)
Figure 38.17

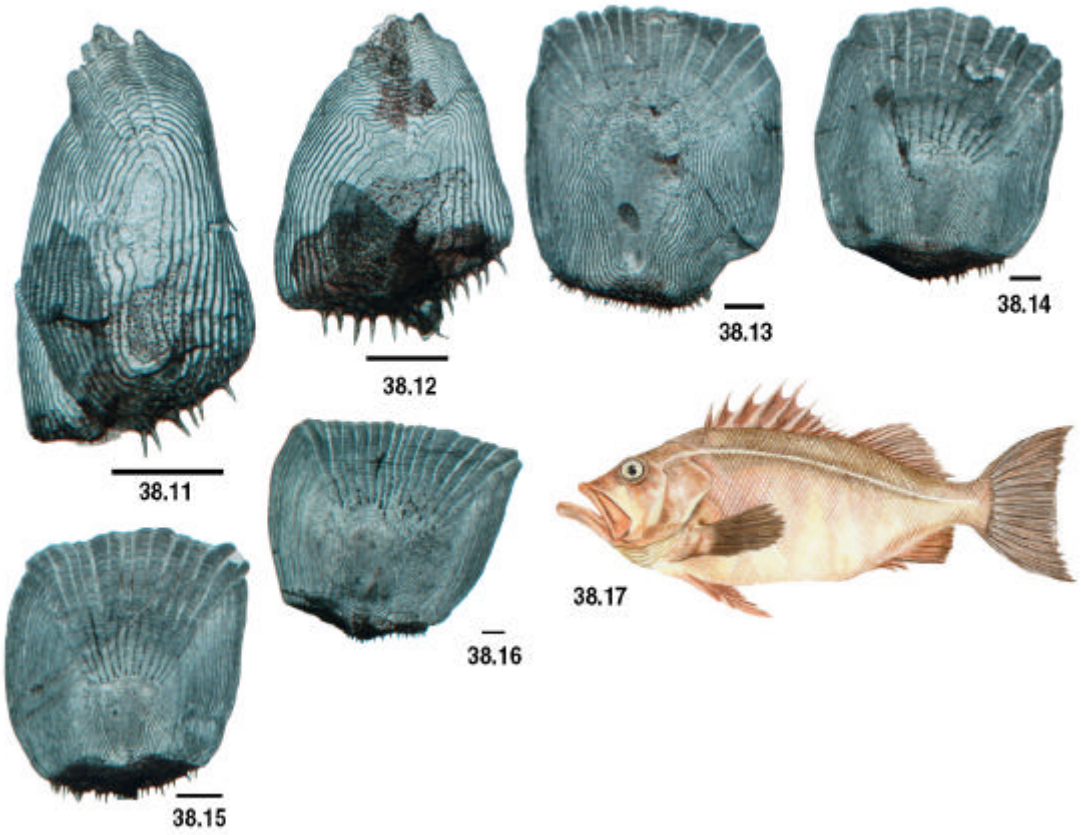


Figure 38.11 - 38.17. 38.11. Sebastes paucispinis (Boccacio Rockfish); scale bar = 1.0 mm. **38.12. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.13. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.14. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.15. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.16. Sebastes paucispinis** (Boccacio Rockfish); scale bar = 1.0 mm. **38.17. Sebastes paucispinis** (Boccacio Rockfish); sketch of living specimen; length = 91 cm.

Description

Length: 91 cm.
Mouth: very large, terminal, directed forward and up; upper jaw extends to posterior margin of orbit; lower jaw projects and enters dorsal profile; symphyseal knob absent; lower jaw thickened.
Body: head spines absent except nasals and parietals, which can be present but weak; preopercular spines well developed and strong; two opercular spines strong; cleithral and supracleithral spines present but later weak; no spine on lower gill cover; caudal fin indented; profile of snout to dorsal fin is slightly concave above the eye; interorbital space convex.
Color: light brown to olive to copper; sometimes dark red on dorsal with pinkish sides; some red-orange specimens are found.

Biology

Depth: up to 250 m; young in shallow waters for first year in schools, move to deeper waters as adults.
Habitat: rocky substrate; also open bottom areas.
Season: ovoviparous; fertilization in October; young born in November; second brood born in March.
Diet: fish (e.g., surfperch; small mackerels, young sablefish, myctophids, flatfish, pelagic schooling species), molluscs, crustaceans.
Predators: not determined.
Distribution: Baja, California to Alaska.

Scale Description
Figure 38.1-38.16

Relative Scale Size: large.
Position of Scales on Body: below lateral line canal in 72-90 rows (Hart, 1973).
Overall Shape: the scales are square, but differential elongation can make the anterior/lateral margins appear bulging. The posterior field is short.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth and is approximately one-fifth to one-sixth of the total scale length from the outside edge of the posterior margin. The circuli are continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is straight (the odd scale may be slightly convex) and is scalloped.

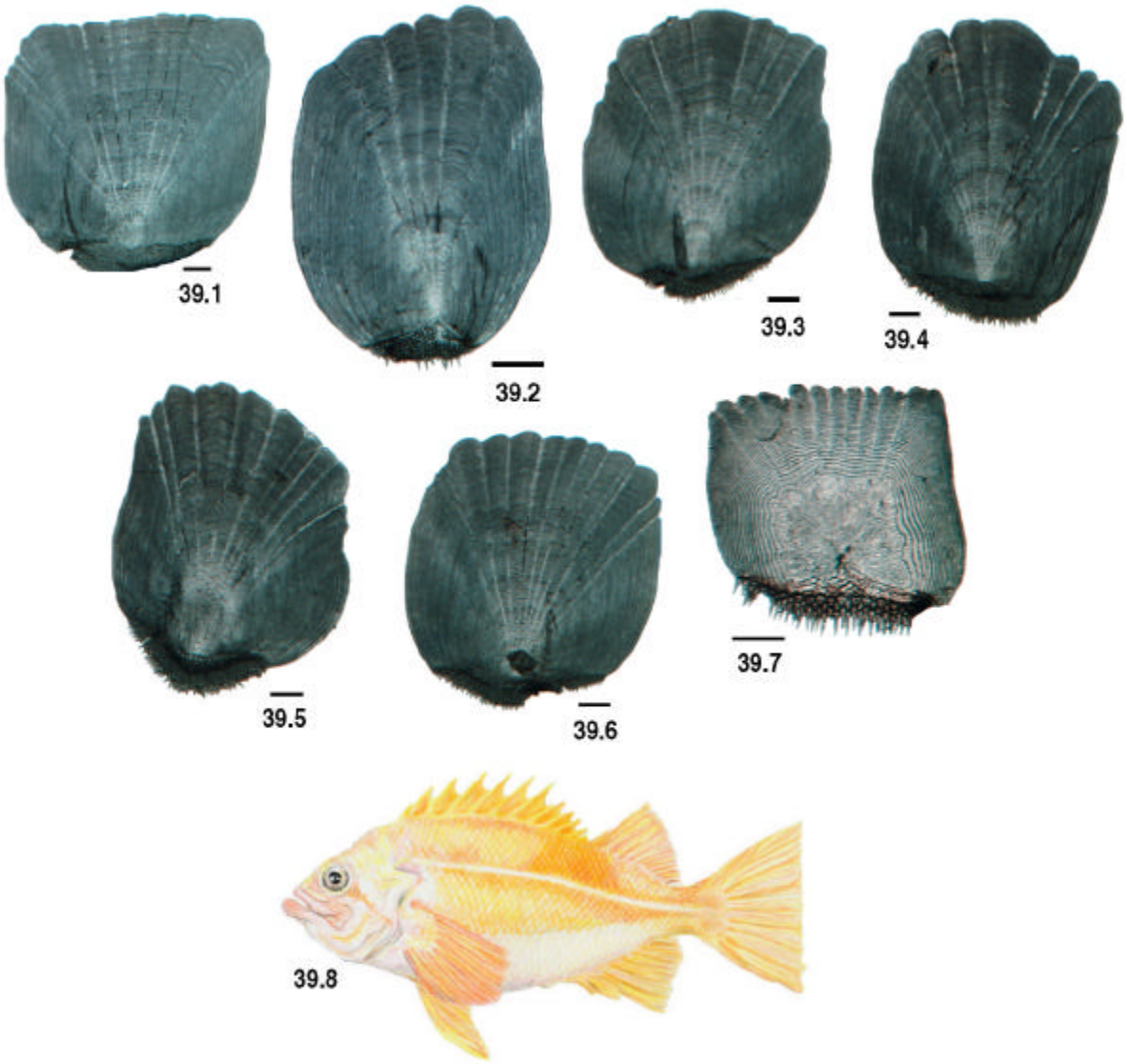


Figure 39.1 - 39.8. 39.1. Sebastes pinniger (Canary Rockfish); body region E; scale bar = 1.0 mm. **39.2. Sebastes pinniger** (Canary Rockfish); body region G; scale bar = 1.0 mm. **39.3. Sebastes pinniger** (Canary Rockfish); body region G; scale bar = 1.0 mm. **39.4. Sebastes pinniger** (Canary Rockfish); body region I; scale bar = 1.0 mm. **39.5. Sebastes pinniger** (Canary Rockfish); body region I; scale bar = 1.0 mm. **39.6. Sebastes pinniger** (Canary Rockfish); body region J; scale bar = 1.0 mm. **39.7. Sebastes pinniger** (Canary Rockfish); scale bar = 1.0 mm. **39.8. Sebastes pinniger** (Canary Rockfish); sketch of living specimen; length = 76 cm.

Sebates pinniger (Canary Rockfish)
(Other common names: Orange Rockfish, Fantail Rockfish, Red Snapper)
Figure 39.8

Description

Length: 76 cm.
Mouth: large, terminal; lower jaw projects but not into head profile; upper jaw extends to posterior of orbit; symphyseal knob weak; lower jaw had dentary elevations.
Body: coronal and nutchal spines absent; all other head spines weak; five preopercular fine and thin; opercular spines long; cleithral and supracleithral both well developed; caudal fin indented; intraorbital space convex; scales on underside of jaw are smooth.
Color: gray with orange or orange and yellow mottling; pale below; orange fin membranes; dark area on spinous dorsal fin; small individuals may have black speckling; three orange head stripes radiating to opercular slit.

Biology

Depth: 100-375 m; young in shallower waters; adults shallower in northern waters.
Habitat: hard and soft substrates; demersal schooling species.

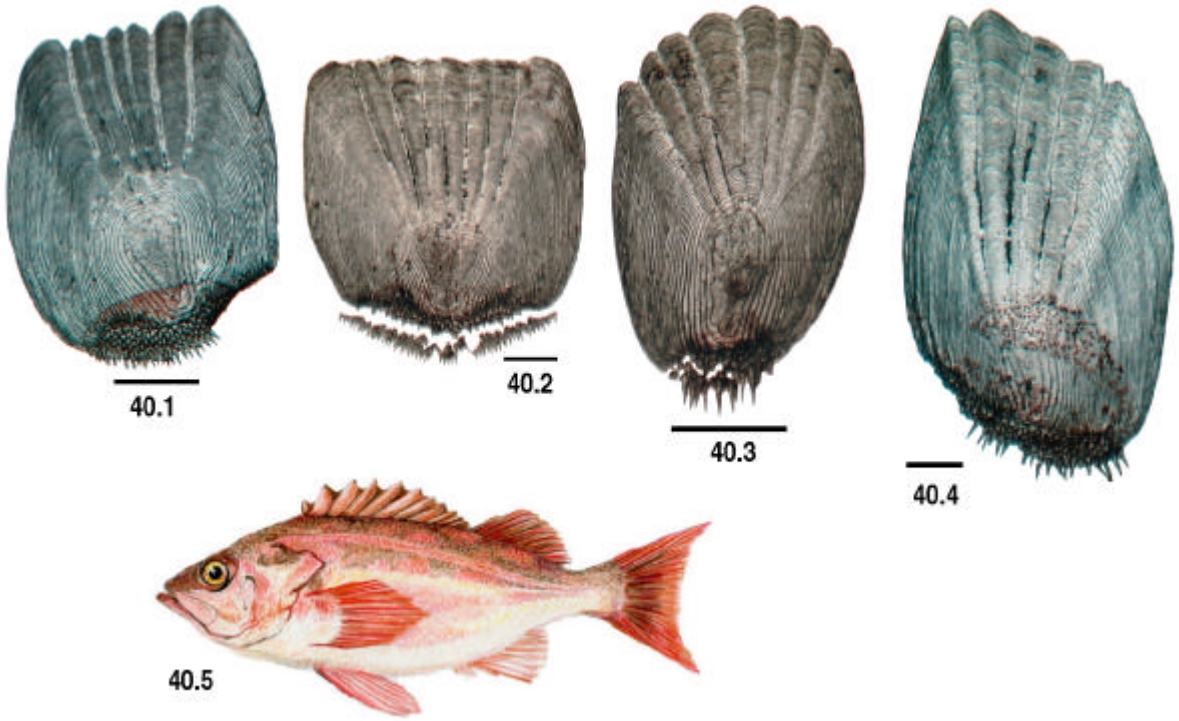


Figure 40.1 - 40.4. 40.1. Sebastes proriger (Redstripe Rockfish); scale bar = 1.0 mm. **40.2. Sebastes proriger** (Redstripe Rockfish); scale bar = 1.0 mm. **40.3. Sebastes proriger** (Redstripe Rockfish); scale bar = 1.0 mm. **40.4. Sebastes proriger** (Redstripe Rockfish); scale bar = 500 µm. **40.5. Sebastes proriger** (Redstripe Rockfish); sketch of living specimen; length = 51 cm.

Season: ovoviparous; spawn in mid-fall; young released in later winter-early spring.
Diet: small crustaceans (e.g., krill), forage fish (e.g., herring, anchovies).
Predators: not determined.
Distribution: Baja, California to Alaska; populations in British Columbia waters are separated into West Coast Vancouver Island stock and a Queen Charlotte Sound stock.

Scale Description
Figure 39.1-39.7

Relative Scale Size: large.
Position of Scales on Body: diagonal rows below lateral line canal 43-50 (Hart, 1973).
Overall Shape: the scales are generally square, but differential elongation can make the anterior/lateral margins appear bulging. The posterior field is short. The lateral fields can appear gently crenulated in some specimens.
Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth. The focus is one-seventh of the total scale. Length is from the outside edge of the posterior margin. The circuli are continuous between the lateral and anterior fields (except broken by radii).
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is straight to convex and is moderately to strongly scalloped.

Sebastes proriger (Redstripe Rockfish)
(Other common names: Redstriped Rockcod)
Figure 40.5

Description

Length: 51 cm.
Mouth: large, terminal, directed forward; lower jaw projects beyond upper jaw; upper jaw extends to mid-orbit; dentary eleveations with teeth at tip of snout; symphseal knob strong and directed upwards.
Body: supraocular, coronal and nuchal spines absent; nasal, preocular, postocular, tympanic, and parietal present but not obvious; five preopercular spines well developed; two opercular spines moderately long; cleithral and supracleithral moderate; spine on lower gill cover margin; caudal fin may or may not be indented.
Color: pale red with mottled olive on dorsal and yellow on lower sides; dusky on top of lower jaw, fins red; dorsal and caudal fins may have yellow; olive stripes radiate from eye; lateral line is light red.

Biology

Depth: 25-366 m; shallower in northern waters.
Habitat: rocky reefs and steep cliff faces over open substrate.

Figure 41.1 - 41. 12 (continued on next page). 41.1. Rockfish, core B03 S01, interval 2-7 cm; scale bar = 500 µm. **41.2.** Rockfish, core B03 S02, interval 25-30 cm; scale bar = 250 µm. **41.3.** Rockfish, core B03 S02, interval 25-30 cm; scale bar = 250 µm. **41.4.** Rockfish, core B03 S02, interval 110-120 cm; scale bar = 250 µm. **41.5.** Rockfish, core B03 S02, interval 110-120 cm; scale bar = 250 µm. **41.6.** Rockfish, core B03 S02, interval 110-120 cm; scale bar = 500 µm. **41.7.** Rockfish, core B03 S02, interval 110-120 cm; scale bar = 500 µm. **41.8.** Rockfish, core B03 S04, interval 91-96 cm; scale bar = 500 µm. **41.9.** Rockfish, core B03 S04, interval 91-96 cm. Magnified area from Fig. 41.8 showing detail of focus; scale bar = 250 µm. **41.10.** Rockfish, core B03 S04, interval 91-96 cm; scale bar = 500 µm. **41.11.** Rockfish, core B03 S04, interval 91-96 cm; scale bar = 500 µm. **41.12.** Rockfish, core B03 S04, interval 91-96 cm; scale bar = 500 µm.

Season: ovoviparous; not well determined.
Diet: juveniles each small plankton; adults eat forage fish (e.g., herring, sand lance), and crustaceans.
Predators: not determined.
Distribution: southern California to the Bering Sea.

Scale Description
Figure 40.1-40.4

Relative Scale Size: small to moderate.
Position of Scales on Body: below lateral line canal in 55-60 rows (Hart, 1973).
Overall Shape: they are generally square to rectangular with elongated lateral fields.

Figure 41.13 - 41. 19. 41.13. Rockfish, core B03 S04, interval 91-96 cm; scale bar = 250 µm. **41.14.** Rockfish, core B03 S04, interval 145-150 cm; scale bar = 1.0 mm. **41.15.** Rockfish, core B03 S04, interval 145-150 cm. Magnified area from Fig. 41.14 showing circuli detail; scale bar = 250 µm. **41.16.** Rockfish, core B03 S04, interval 145-150 cm. Magnified area from Fig. 41.14 of focus and posterior end; scale bar = 250 µm. **41.17.** Rockfish, core B03 S04, interval 145-150 cm; scale bar = 1.0 mm. **41.18.** Rockfish, core B03 S04, interval 145-150 cm. Magnified area from Fig. 41.17 showing posterior field; scale bar = 500 µm. **41.19.** Unidentified species (rockfish?), core B03 S02, interval 30-40 cm; scale bar = 500 µm.

Focus and Circuli: the focus abuts the edge of the posterior field, along the edge of ctenii growth and is approximately one-fourth of the total scale length from the outside edge of the posterior margin. The circuli are compact and continuous between the lateral and anterior fields (except broken by radii).

Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is straight to convex and is moderately scalloped.

Scale preservation
Figures 41.1-41.19

Rockfish scales preserve well in sediments. They are generally in good condition, but are susceptible to erosion, particularly along the leading edge of the anterior fields, and within the edges of the radii. Due to the presence of the cteni, the posterior field usually breaks off, truncating the circuli of the lateral fields. This truncation is one way to tell the difference between rockfish and surfperch scales. In addition, rockfish scales are generally more robust than surfperch, and the circuli are ridged and more pronounced.

Order Perciformes
Family Embiotocidae
(Surfperches)

Diagonosis:

- Small- to medium-sized fish
- All compressed and elliptical in outline
- Groove along either side of dorsal fin
- Dorsal fin continuous with 9 to 11 spines and 19 to 28 rays
- Anal fin has three spines and 15 to 35 rays
- Pelvic fins thoracic with one spine and five rays
- Caudal fin forked
- No vomerine teeth
- Lateral line continuous and high
- Viviparous
- All surfperches have cycloid scales
- Twenty-three species with nine species in British Columbia waters (one California species is freshwater, all others marine). Of British Columbia species **Amphistichus koelzi** (Calico Surfperch), **Amphistichusrhodoterus** (Redtail Surfperch), **Hyperprosopon argenteum** (Walleye Surfperch), and **Hyperprosopon ellipticum** (Silver Surfperch) are not included here.

Remarks: it is difficult to use scale morphology (including meristic measurements) to identify the Embiotocidae to the species level. The scales across species are generally the same (no distinguishing characteristic), and size is not a desirable characteristic since many of the species overlap in size. Size can be used to suggest a species (or a number of them), but with only a small degree of confidence.

Brachyistius frenatus (Kelp Perch)
(Other common names: Brown Sea-Perch, Brown Perch, Kelp Sea-Perch)
Figure 42.12

Description

Length: 20 cm.
Mouth: small, slightly pointed upward, terminal; upper jaw three-quarters of the way to the orbit; lower lip joined to jaw by frenum; teeth well developed.
Body: head slightly indented in profile at eye; lateral line parallels dorsal body contour; caudal peduncle is long and deep in comparison to head.
Color: variable; olive to brown to copper above the lateral line; sometimes blue spotted; bright below lateral line; fins pale or pinkish; may have black speckles on pectoral fins.

Biology

Depth: 27-30m.
Habitat: usually in areas with kelp beds (**Macrocystis** spp.).
Season: mating is in fall-winter; birth in late spring-summer.
Diet: crustaceans (e.g., amphipods, shrimp larvae).
Predators: Scombridae (Oliphant, 1962).
Distribution: Central Baja, California to southern British Columbia and southwest Vancouver Island.

Scale Description
Figures 42.1-42.11

Relative Scale Size: moderate to large.
Position of Scales on Body: along the lateral line canal. Large scales are found along the anterior dorsal fin furrow. Scales also along peduncle at anterior part of the anal fin (Hart, 1973).
Overall Shape: there is less variability in shape compared to other species (e.g., White surfperch). The scales are generally square with a rounded posterior field. In some cases, the leading edge of the anterior field is not as wide as the lateral fields, which are long and give the appearance of being rectangular. Hart (1973) notes dark pigmentation under each scale.
Focus and Circuli: focus is slightly off center, being closest to the posterior field. The focus and surrounding circuli are circular and concentric with the outline of the scale. Circuli are generally continuous, but depending on the condition of the scale, there is some discontinuity in the anterior field. Circuli are broken and discontinuous in the posterior field.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is scalloped.

Cymatogaster aggregata (Shiner Perch)
(Other common names: Shiner, Yellow Shiner, Gaadaa, Shiner Seaperch, Shiner Surfperch)
Figure 43.14

Description

Length: to approximately 20 cm.
Mouth: small, slightly pointed upward, terminal; upper jaw four-fifths length of the snout; lower lip free from lower jaw (no frenum); teeth are fine.
Body: head slightly concave in profile at eye; lateral line parallels dorsal body contour; caudal peduncle is compressed and slender.
Color: silvery with rows of dark spots that form stripes; these strips are crossed by three yellow bars (males only in winter); sometimes with dark spot above lip.

Biology

Depth: to 130 m; common in shallows but found deeper during the winter.
Habitat: common in bays, eel grass beds, and pilings in protected areas; euryhaline.
Season: mate year round; females gravid spring through summer and give birth from May through August; estuaries used as nursery grounds; females immigrate from nearshore coastal waters prior to giving birth. Maturing males migrate to the ocean, while most females spend their first year in nearshore bays.
Diet: zooplankton, crustaceans, polychaetes, molluscs, algae, and detritus.
Predators: sturgeon, sea bass, salmon, sharks, Cottidae, Scombridae, sea birds (cormorants); marine mammals (harbour seals; Iverson, 1962; Oliphant, 1962; Talent, 1976; Armstrong et al., 1995).
Distribution: Baja, California to southern Alaska.

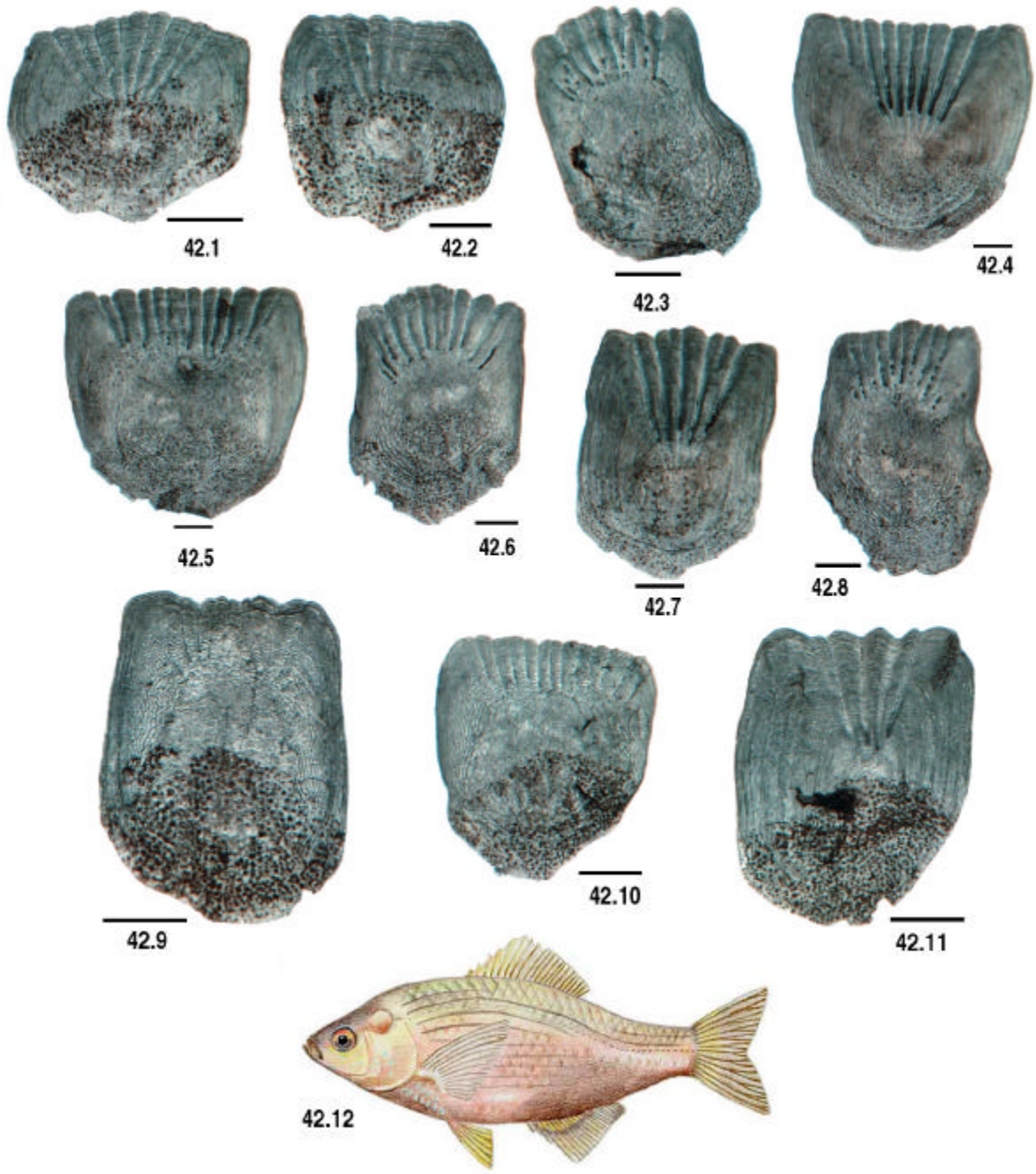


Figure 42.1 - 42.12. 42.1. Brachyistius frenatus (Kelp Perch); body region A; scale bar = 1.0 mm. **42.2. Brachyistius frenatus** (Kelp Perch); body region A; scale bar = 1.0 mm. **42.3. Brachyistius frenatus** (Kelp Perch); body region C; scale bar = 1.0 mm. **42.4. Brachyistius frenatus** (Kelp Perch); body region E; scale bar = 1.0 mm. **42.5. Brachyistius frenatus** (Kelp Perch); body region E; scale bar = 1.0 mm. **42.6. Brachyistius frenatus** (Kelp Perch); body region G; scale bar = 1.0 mm. **42.7. Brachyistius frenatus** (Kelp Perch); body region I; scale bar = 1.0 mm. **42.8. Brachyistius frenatus** (Kelp Perch); body region I; scale bar = 1.0 mm. **42.9. Brachyistius frenatus** (Kelp Perch); body region J; scale bar = 1.0 mm. **42.10. Brachyistius frenatus** (Kelp Perch); body region J; scale bar = 1.0 mm. **42.11. Brachyistius frenatus** (Kelp Perch); body region J; scale bar = 1.0 mm. **42.12. Brachyistius frenatus** (Kelp Perch); sketch of living specimen; length = 20 cm.

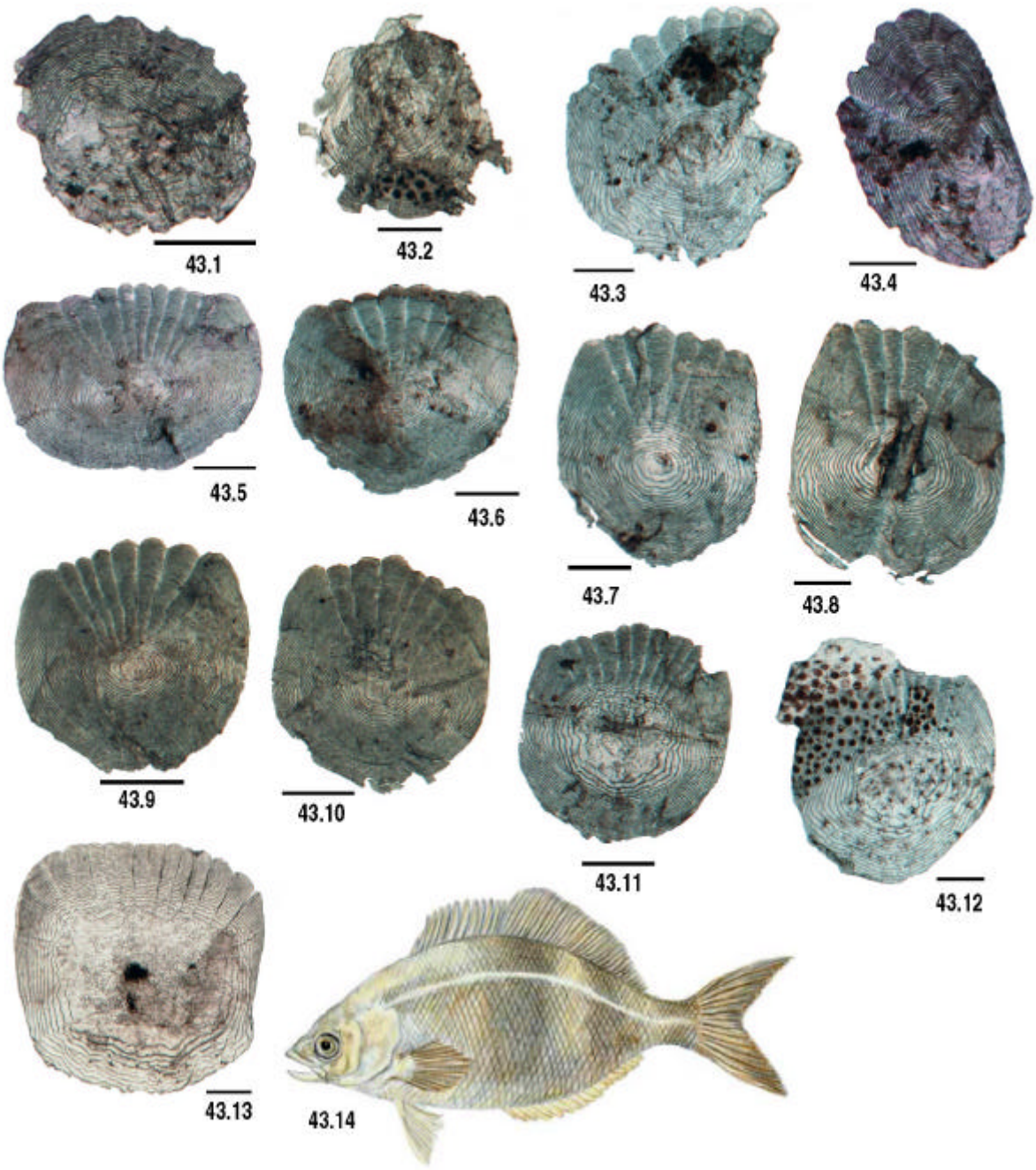


Figure 43.1 - 43.14. 43.1. Cymatogaster aggregata (Shiner Perch); body region A; scale bar = 1.0 mm. **43.2. Cymatogaster aggregata** (Shiner Perch); body region A; scale bar = 500 µm. **43.3. Cymatogaster aggregata** (Shiner Perch); body region C; scale bar = 500 µm. **43.4. Cymatogaster aggregata** (Shiner Perch); body region C; scale bar = 500 µm. **43.5. Cymatogaster aggregata** (Shiner Perch); body region E; scale bar = 1.0 mm. **43.6. Cymatogaster aggregata** (Shiner Perch); body region E; scale bar = 1.0 mm. **43.7. Cymatogaster aggregata** (Shiner Perch); body region G; scale bar = 500 µm. **43.8. Cymatogaster aggregata** (Shiner Perch); body region G; scale bar = 500 µm. **43.9. Cymatogaster aggregata** (Shiner Perch); body region I; scale bar = 500 µm. **43.10. Cymatogaster aggregata** (Shiner Perch); body region I; scale bar = 1.0 mm. **43.11. Cymatogaster aggregata** (Shiner Perch); body region I; scale bar = 1.0 mm. **43.12. Cymatogaster aggregata** (Shiner Perch); body region J; scale bar = 500 µm. **43.13. Cymatogaster aggregata** (Shiner Perch); scale bar = 500 µm. **43.14. Cymatogaster aggregata** (Shiner Perch); sketch of living specimen; length = 20 cm.

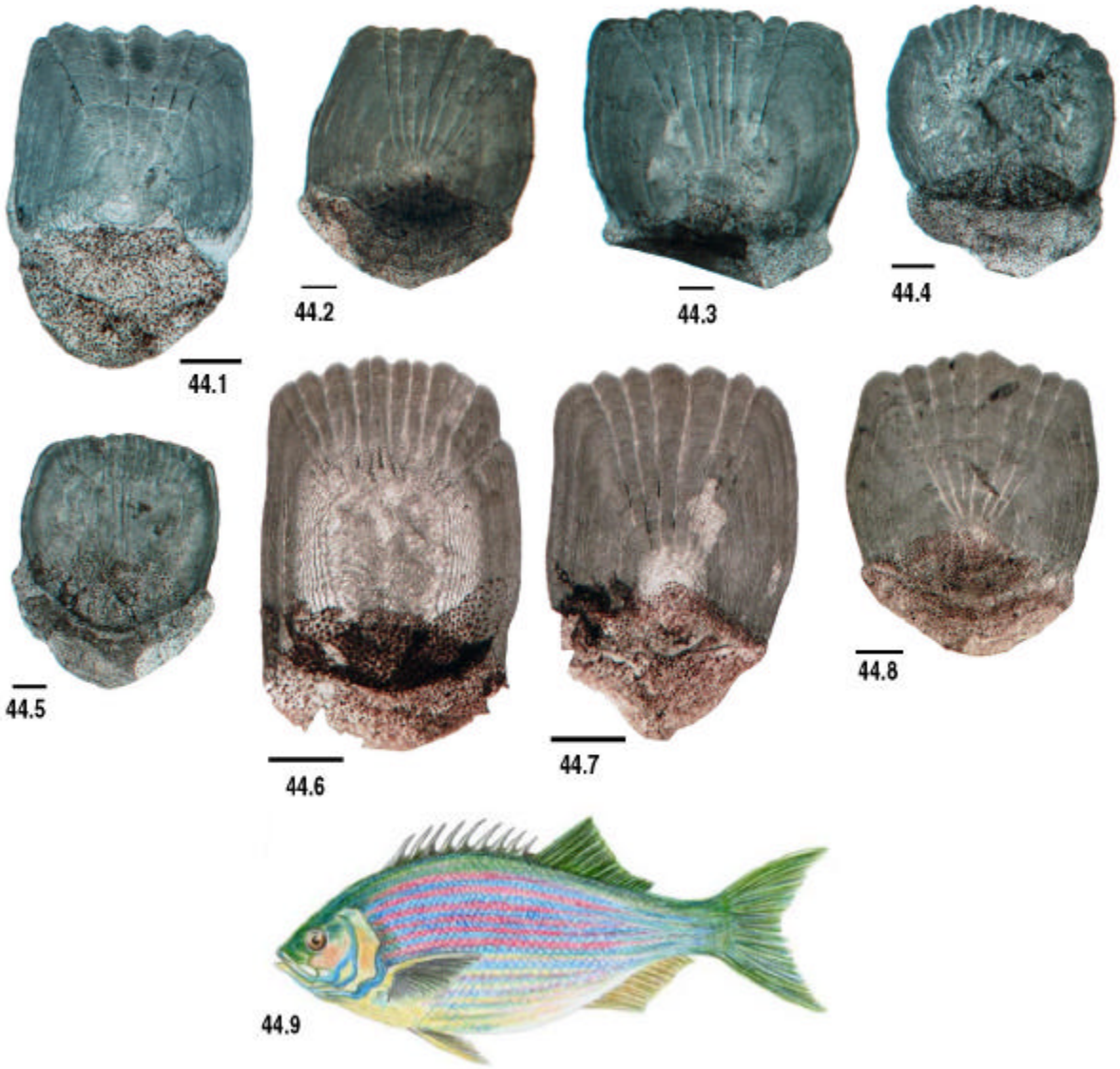


Figure 44.1 - 44.9. 44.1. Embiotoca lateralis (Striped Seaperch); body region C; scale bar = 1.0 mm. **44.2. Embiotoca lateralis** (Striped Seaperch); body region E; scale bar = 1.0 mm. **44.3. Embiotoca lateralis** (Striped Seaperch); body region G; scale bar = 1.0 mm. **44.4. Embiotoca lateralis** (Striped Seaperch); body region I; scale bar = 1.0 mm. **44.5. Embiotoca lateralis** (Striped Seaperch); body region J; scale bar = 1.0 mm. **44.6. Embiotoca lateralis** (Striped Seaperch); scale bar = 1.0 mm. **44.7. Embiotoca lateralis** (Striped Seaperch); scale bar = 1.0 mm. **44.8. Embiotoca lateralis** (Striped Seaperch); scale bar = 1.0 mm. **44.9. Embiotoca lateralis** (Striped Seaperch); sketch of living specimen; length = 38 cm.

Scale Description
Figures 43.1-43.13

Relative Scale Size: moderate to large.
Position of Scales on Body: on lateral line canal, and the anterior three-quarters of the dorsal fin marked by the dorsal furrow (Hart, 1973).
Overall Shape: the posterior field is rounded, but the anterior field is round to square (more so in the larger scales giving the appearance of a rounded rectangle).
Focus and Circuli: the focus is centralized between the four fields and the circuli extending from the focus are somewhat pyriform-shaped in the direction of the lateral fields (giving it an elongated appearance). The circuli are generally continuous in all fields (except where broken by radii).
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is scalloped.

Embiotoca lateralis (Striped Seaperch)
(Other common names: Blue Perch, Perch, Striped Surfperch)
Figure 44.9

Description

Length: 38 cm.

Mouth: small, slightly pointed upward, terminal; upper jaw close to, but not reaching anterior edge of orbit; teeth moderate and pointed; lower lip attached to lower jaw by broad frenum; upper lip often black.
Body: lateral line follows dorsal profile; caudal peduncle is compressed and deep.
Color: fifteen blue strips (curved above lateral line; horizontal below it) on dark copper or reddish background; bright blue strip on head and operculum; fins copper; juveniles are bright golden; spiny front of dorsal fin (back fin) is short; soft rear half is taller and darker.

Biology

Depth: surface to 15 m; generally shallow waters but retreats to deeper waters during late winter to early spring.
Habitat: coastal waters in kelp beds and rocky areas; generally schooling.
Season: mate in October with birthing in June and July.
Diet: small crustaceans, worms, mussels, and forage fish (e.g., herring).
Predators: not determined.
Distribution: northern Baja, California to southern Alaska.

Scale Description
Figures 44.1-44.8

Relative Scale Size: large
Position of Scales on Body: along lateral line canal; row at anterior end of base of each dorsal fin (Hart, 1973).
Overall Shape: the A scale, being smaller, is rectangular in appearance with the lateral fields being longer than the width of the anterior/posterior axis. The larger scales are more square.
Focus and Circuli: the focus is not centralized between the four fields and is approximately one-third of the total length from the posterior margin. The focus and surrounding circuli are circular and concentric with the scale outline. The circuli are continuous from lateral to anterior fields. They are broken and discontinuous in the posterior field.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is scalloped.

Phanerodon furcatus (White Seaperch)
(Other common names: White Perch; Silver Seaperch)
Figure 45.12

Description

Length: to approximately 30 cm.
Mouth: small, slightly pointed upward, terminal; upper jaw slightly less than half way to orbit; lower lip attached to lower jaw by a frenum; teeth are fine.
Body: caudal fin is deeply forked; long dorsal fin base with long rays; spinous portion of dorsal fin shorter than soft-rayed portion; the transition from spinous region to soft-rayed region runs in a smooth curve; lateral line parallels dorsal body contour; caudal peduncle is slender.
Color: greenish to silvery above; dark line at the base of the posterior portion of the dorsal fin; fins yellowish; dark edge on caudal fin; dark spot on anterior end of anal fin.

Biology

Depth: 43 m.
Habitat: sandy shallow bays; pier areas, offshore near rocky areas.
Season: young born May-August.
Diet: small crustaceans, worms, and mussels.
Predators: not determined.
Distribution: northern Baja, California to Vancouver Island, B.C. (less common in northern waters).

Scale Description
Figures 45.1-45.11

Relative Scale Size: moderate.
Position of Scales on Body: on lateral line canal; also as a sheath of scales on the sides of the dorsal fin (Hart, 1973).
Overall Shape: there are some similarities to the Shiner Perch, but there seems to be a greater degree of variability. The smaller scales are circular to rectangular, while the larger scales are more squared.
Focus and Circuli: the focus is centralized between the four fields. The focus and surrounding circuli are circular and concentric with the outline of the scale. Circuli are continuous from lateral to anterior fields. They are broken and discontinuous in the posterior field.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is scalloped.

Rhacochilus vacca (Pile Perch)
(Other common names: Silver Perch, Forktail Perch, Porgy)
Figure 46.7

Description

Length: 44 cm.
Mouth: small, slightly pointed upward, terminal; upper jaw and snout are the same length; lower lip attached to lower jaw by a frenum; teeth are fine.
Body: short and compressed; lateral line flatter than dorsal profile; dorsal fin with low spinous portion with front end of the soft-rayed portion much higher; deeply forked tail; thick, drooping folds around the mouth.
Color: silvery on sides and belly with darky grey or brown above; dark blotches on back and sides, juveniles have vertical bars; dusky fins; sometimes there is a dark spot below the eye.

Biology

Depth: shallow waters to 46 m; retreat to deeper waters in winter months.
Habitat: rocky shoreline areas around pilings; prefers complex substrate; schooling species.
Season: mate in winter, October-December with birth in June-October depending on geographical location (in BC in August [Hart, 1973]).
Diet: crustaceans, polychaetes, and mollusks.

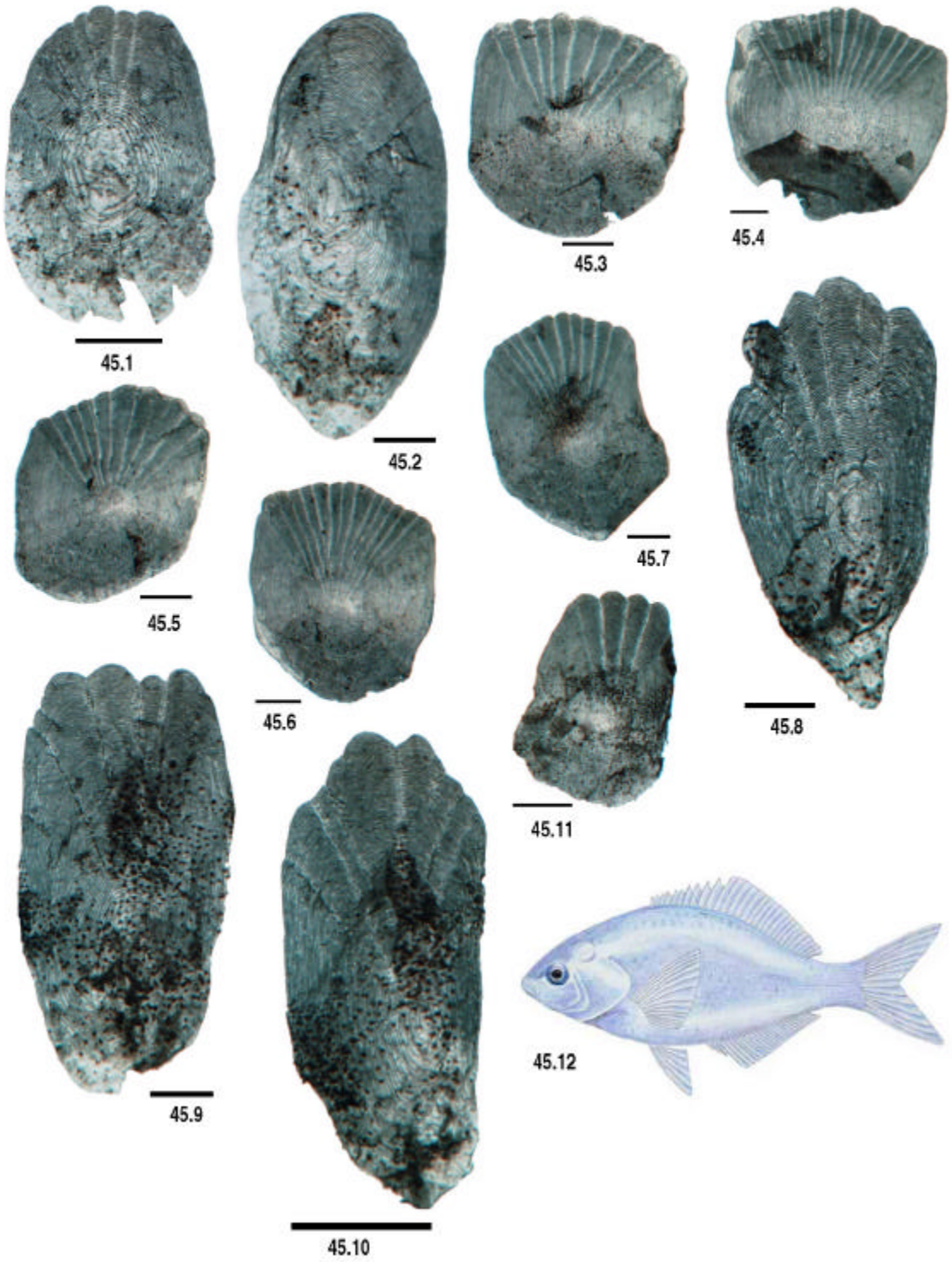


Figure 45.1 - 45.12. 45.1. Phanerodon furcatus (White Surfperch); body region A; scale bar = 1.0 mm. **45.2. Phanerodon furcatus** (White Surfperch); body region A; scale bar = 500 µm. **45.3. Phanerodon furcatus** (White Surfperch); body region C; scale bar = 1.0 mm. **45.4. Phanerodon furcatus** (White Surfperch); body region E; scale bar = 1.0 mm. **45.5. Phanerodon furcatus** (White Surfperch); body region G; scale bar = 1.0 mm. **45.6. Phanerodon furcatus** (White Surfperch); body region I; scale bar = 1.0 mm. **45.7. Phanerodon furcatus** (White Surfperch); body region I; scale bar = 1.0 mm. **45.8. Phanerodon furcatus** (White Surfperch); body region J; scale bar = 500 µm. **45.9. Phanerodon furcatus** (White Surfperch); body region J; scale bar = 500 µm. **45.10. Phanerodon furcatus** (White Surfperch); body region J; scale bar = 1.0 mm. **45.11. Phanerodon furcatus** (White Surfperch); body region J; scale bar = 1.0 mm. **45.12. Phanerodon furcatus** (White Surfperch); sketch of living specimen; length = 30 cm.

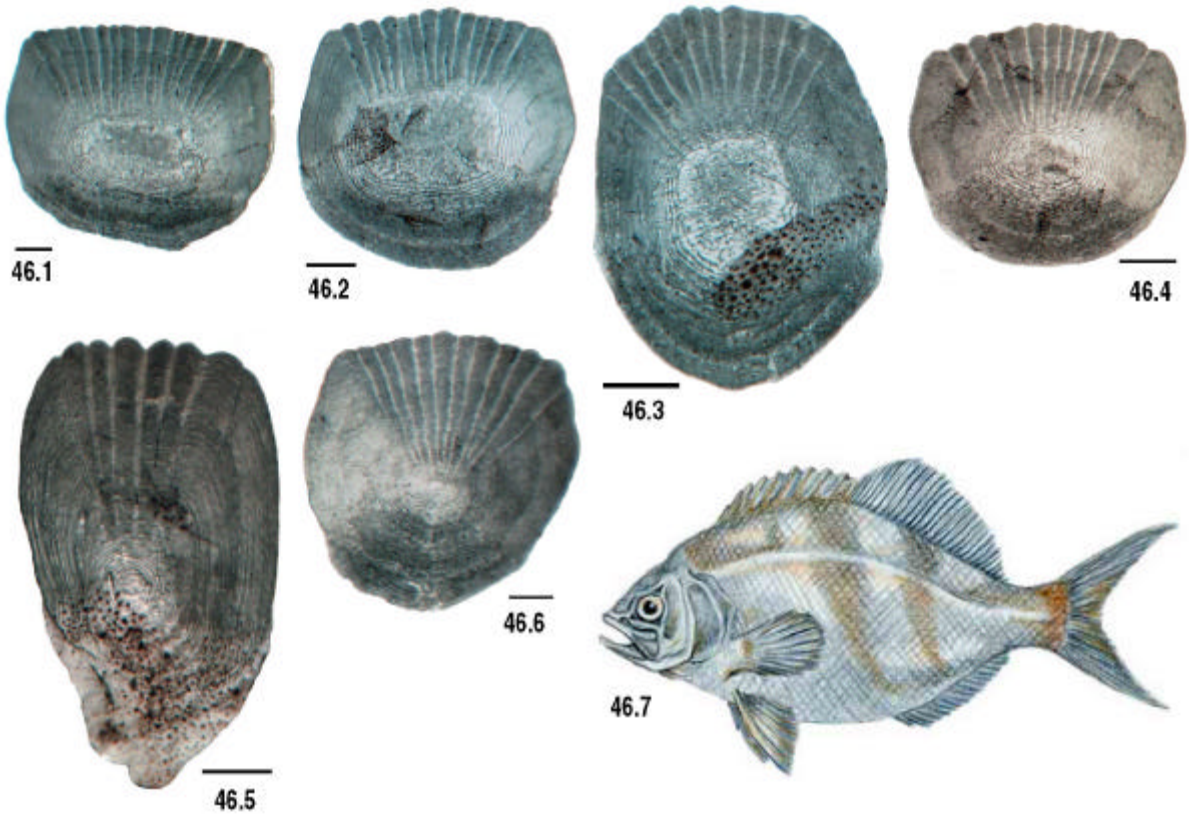


Figure 46.1 - 46.7. 46.1. Rhacochilus vacca (Pile Perch); large size; scale bar = 1.0 mm. **46.2. Rhacochilus vacca** (Pile Perch); medium size; scale bar = 1.0 mm. **46.3. Rhacochilus vacca** (Pile Perch); small size; scale bar = 1.0 mm. **46.4. Rhacochilus vacca** (Pile Perch); scale bar = 1.0 mm. **46.5. Rhacochilus vacca** (Pile Perch); scale bar = 1.0 mm. **46.6. Rhacochilus vacca** (Pile Perch); scale bar = 1.0 mm. **46.7. Rhacochilus vacca** (Pile Perch); sketch of living specimen; length = 44 cm.

Predators: not determined.
Distribution: central Baja, California to southeast Alaska.

Scale Description
Figures 46.1-46.6

Relative Scale Size: moderate to large.
Position of Scales on Body: scales in lateral line canal; there is a sheath of scales on each side of the dorsal fin for the first two-thirds of the length (Hart, 1973).
Overall Shape: the scales of this species are very similar to the Shiner Perch, but there is some degree of variation in the shape of the posterior field such that it appears bulbous (this could be atypical, environmentally induced, or happen in regenerated scales). In the A scales, the anterior edge of the lateral field can also appear more bulbous than the neighboring anterior field, but this is not consistent.

Focus and Circuli: the focus is centralized between the four fields, and the focus and surrounding circuli are circular and concentric with the outline of the scale. Circuli are continuous in the lateral to anterior fields (except where broken by radii), and some circuli are continuous in the posterior field and others are discontinuous.
Radii: numbers are variable and not diagnostic. Present only in the anterior field. The outer edge of the anterior field is scalloped.

Scale Preservation
Figures: 47.1-47.7

The scales seem to preserve well and maintain a degree of flexibility, although some conditions can make them brittle and difficult to handle. The posterior field seems susceptible to erosion, as do the edges of the radii, often making the radii appear wider and more fan-like. Scalloped edges are also easily eroded. They are generally white/transparent although some are amber.

Figure 47.1 - 47.7. 47.1. Surfperch, core B03 S01, interval 16-21 cm; scale bar = 1.0 mm. **47.2.** Surfperch, core B03 S01, interval 16-21 cm; scale bar = 1.0 mm. **47.3.** Surfperch, core B03 S02, interval 25-30 cm; scale bar = 500 µm. **47.4.** Surfperch, core B03 S02, interval 25-30 cm; scale bar = 500 µm. **47.5.** Surfperch, core B03 S04, interval 73-78 cm; scale bar = 500 µm. **47.6.** Surfperch, core B03 S04, interval 91-96 cm; scale bar = 1.0 mm. **47.7.** Surfperch, core B03 S04, interval 91-96 cm. Magnified area from Fig. 47.6 showing detail of focus and circuli; scale bar = 250 µm.

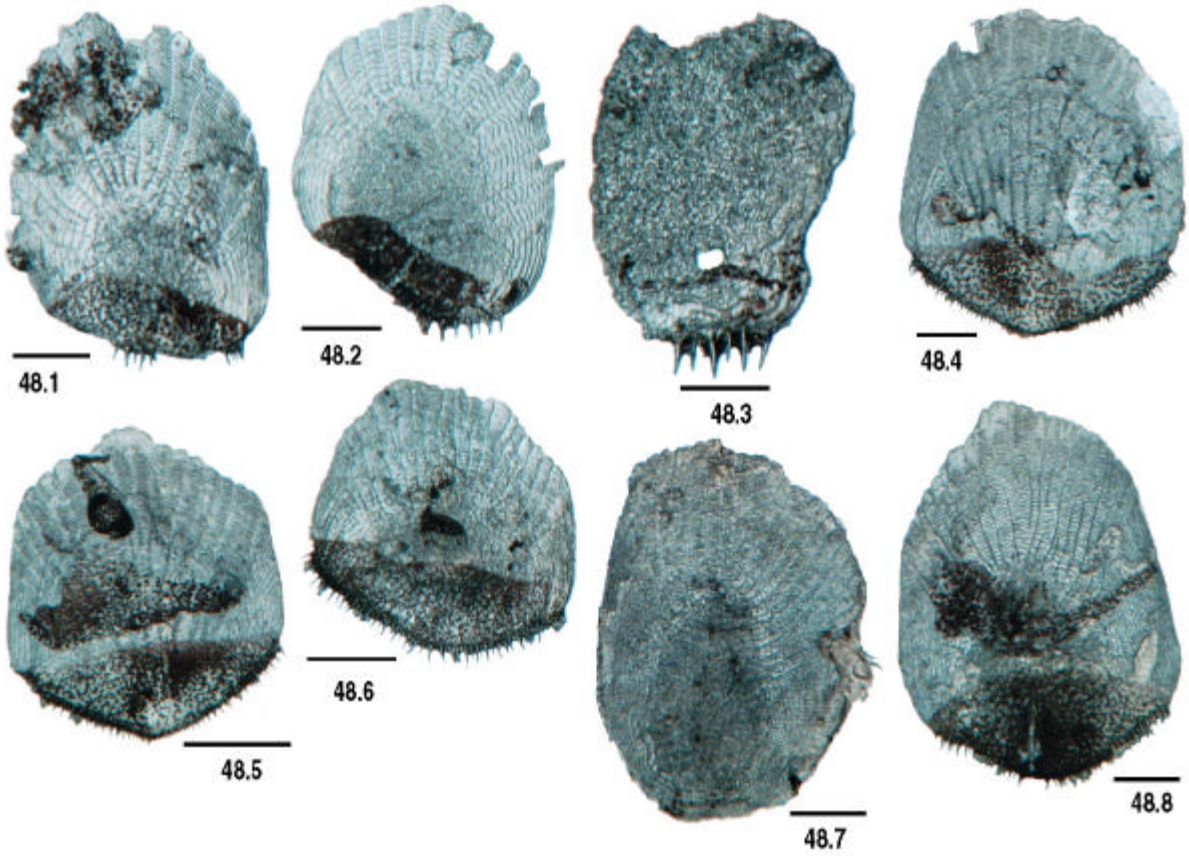


Figure 48.1 - 48.8 (continued on next page). 48.1. Citharichthys stigmaeus (Speckled Sanddab); body region A; scale bar = 500 µm. **48.2. Citharichthys stigmaeus** (Speckled Sanddab); body region A; scale bar = 500 µm. **48.3. Citharichthys stigmaeus** (Speckled Sanddab); body region C, note this scale is heavily regenerated; scale bar = 250 µm. **48.4. Citharichthys stigmaeus** (Speckled Sanddab); body region C; scale bar = 500 µm. **48.5. Citharichthys stigmaeus** (Speckled Sanddab); body region C; scale bar = 1.0 mm. **48.6. Citharichthys stigmaeus** (Speckled Sanddab); body region E; scale bar = 1.0 mm. **48.7. Citharichthys stigmaeus** (Speckled Sanddab); body region E; scale bar = 500 µm. **48.8. Citharichthys stigmaeus** (Speckled Sanddab); body region G; scale bar = 500 µm.

Order Pleuronectiformes

Diagnosis:

- Adults have asymmetrical skulls with both eyes on same side
- Larvae are symmetrical and free-swimming in plankton until metamorphosis, which involves migration of one eye to the other
- Color on blind side usually pale
- Fins usually spineless
- Pelvic fins have less than seven rays
- Base of pelvic fin attached to cleithrum
- Gas bladder present
- Usually demersal
- Ctenoid scales on the eyed side; cycloid scales on blind side

Remarks: Batts (1964) published a dichotomous key for the scale characteristics of adult flatfish of Puget Sound, Washington. However, some characteristics used by Batts are not applicable to preserved material. For example, the number, angles, and orientation of ctenii are not particularly useful characteristics since the ctenii are generally lost, or at the least, damaged during sediment burial. Characteristics reported that are also stated by Batts are noted with a citation.

Family Bothidae (Lefteye Flounders)

Diagnosis:

- Eyes and colour on left side
- Pelvic fin on eyed side is located on abdominal ridge
- Generally small
- Single lateral line with no dorsal branch
- Three species found in BC waters. **Citharichthys sordidus** (Pacific Sanddab) and **Paralichthys californicus** (California Halibut) are not included here.

Citharichthys stigmaeus (Speckled Sanddab)
(Other common names: Catalina sand dab)
Figure 48.16

Description

Length: 15 cm.
Mouth: moderate, terminal; jaws symmetrical; median knob on tip of lower jaw; maxillary extends to from on

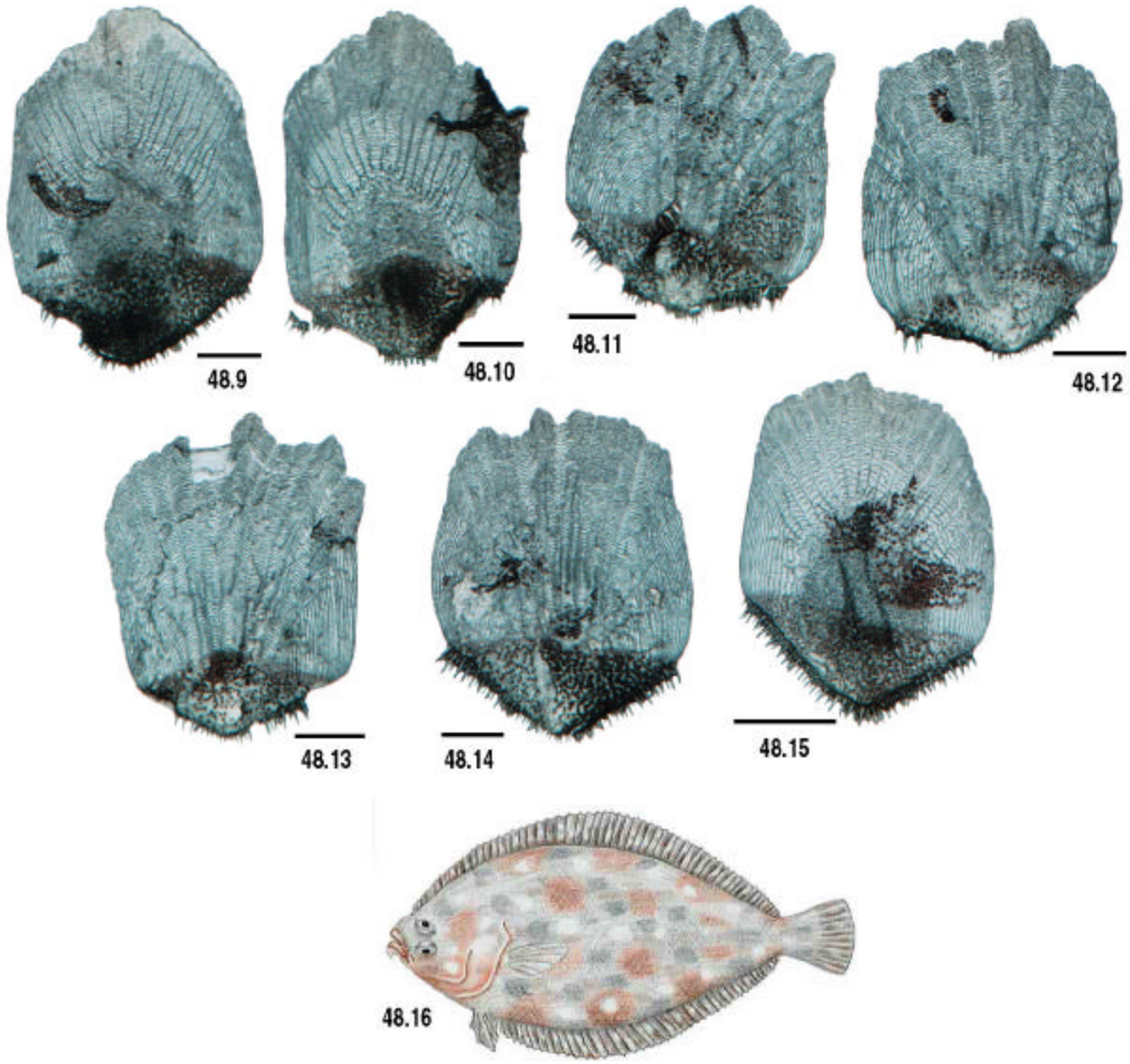


Figure 48.9 - 48.16. 48.9. Citharichthys stigmaeus (Speckled Sanddab); body region G; scale bar = 500 µm. **48.10. Citharichthys stigmaeus** (Speckled Sanddab); body region I; scale bar = 500 µm. **48.11. Citharichthys stigmaeus** (Speckled Sanddab); body region J; scale bar = 500 µm. **48.12. Citharichthys stigmaeus** (Speckled Sanddab); body region J; scale bar = 500 µm. **48.13. Citharichthys stigmaeus** (Speckled Sanddab); body region J; scale bar = 1.0 mm. **48.14. Citharichthys stigmaeus** (Speckled Sanddab); body region J; scale bar = 500 µm. **48.15. Citharichthys stigmaeus** (Speckled Sanddab); body region J; scale bar = 1.0 mm. **48.16. Citharichthys stigmaeus** (Speckled Sanddab); sketch of living specimen; length = 15 cm.

lower eye; snout is shorter than the length of the lower eye.
Body: head is deep and blunt; left pectoral fin shorter than head; caudal peduncle slender; caudal fin rounded; ridge around lower eye absent; lateral line straight.
Color: olive brown with black speckles; creamy on blind side; young can be gray with black speckles.

Biology

Depth: up to 550 m (usually shallower).
Habitat: sandy substrates; from nearshore to deep.
Season: spawning occurs in winter month with larvae appearing in the spring and summer; spawning takes place in shallow water.
Diet: small crustaceans (e.g., amphipods, copepods), polychaetes.
Predators: fish, marine mammals, sea birds.
Distribution: Mexico to Alaska.

Scale Description
Figure 48.1-48.15

Relative Scale Size: moderate to large.
Position of Scales on Body: on lateral line canal; 52-58 scales; imbricated pattern; deciduous; ctenoid on both sides of body (Hart, 1973).
Overall Shape: both ctenoid and cycloid scales are circular; ctenoid pattern is weak.

Focus and Circuli: the focus abuts the region of ctenoid growth and is approximately one-tenth of the total length of from the posterior field's outer edge. The posterior field is short and the anterior field is wider than the lateral fields are long. The circuli are tightly compacted and generally continuous between the lateral and anterior fields. They appear to truncate at the ctenoid interface. Regeneration appears common. The outer edge of the anterior field is scalloped.
Radii: radii not present in all fields; intermarkings present and are uniform in lateral and anterior field (Batts, 1964).

Family Pleuronectidae (Righteye Flounders)

Diagnosis:

- Eyes and color on right side
- Pelvic fin symmetrical
- Large and small species
- Single lateral line with a dorsal branch that runs along the base of the dorsal fin
- Lateral line is straight in some species; curved over the pectoral fin in others
- Nineteen species found in BC waters. **Clidoderma asperrimum** (Roughscale Sole); **Embassichthys bathybius** (Deepsea sole); **Eopsetta jordani** (Petrale Sole); **Inopsetta ischyra** (Hybrid Sole); **Limanda aspera** (Yellowfin Sole); **Pleuronicthys decurrens** (Curlfin Sole); and **Reinhardtius hippologssoides** (Greenland Halibut) are not included here.

Atheresthes stomias (Arrowtooth Flounder)
(Other common names: Long-Jawed Flounder, Needle-Toothed Halibut, French Sole)
Figure 49.4

Description

Length: 84 cm (females larger than males).
Mouth: very large, terminal; near symmetrical with wide gape; maxillary extends beyond posterior margin of lower orbit; snout is pointed; teeth well developed on both sides of jaws and are arrow-shaped.
Body: compressed; caudal penduncle long; caudal fin slightly lunate; dorsal fin originals over middle of upper eye; left eye on upper margin of head; dorsal branch absent on lateral line.
Color: brown to olive on eyed side; white with fine black spots on blind; darker margins on scales.

Biology

Depth: up to 900 m (generally shallower).
Habitat: soft substrate.
Season: spawning occurs December through February; larvae in the water column in summer.
Diet: larvae eat small crustaceans (e.g., copepods, shrimp); adults also crustaceans and other forage fish species (e.g., herring, anchovy, sand lance, pollock)
Predators: not determined.
Distribution: southern California to the Bering Sea.

Scale Description
Figure 49.1-49.3

Note: no ctenoid scales are illustrated.
Relative Scale Size: moderate.
Position of Scales on Body: on lateral line canal; approximately 135 scales; unevenly imbricated pattern; deciduous; ctenoid on eyed side, cycloid on blind side (Hart, 1973).
Overall Shape: circular to square; regenerated scales tend to be more circular. The lateral fields are slightly longer than the anterior is wide. The posterior field can be straight to slightly curved.
Focus and Circuli: the focus is distinct and falls within the anterior portion of the posterior field. It is approximately one-fifth to one-sixth of the total scale length from the edge of the posterior field. The circuli are compact and continuous in all fields.
Radii: numbers are variable and not diagnostic. Presently only in the anterior field (radii not present in all fields; Batts, 1964). Intermarkings present and are not brick-like (Batts, 1964); they are not perpendicular to the circuli. The outer edge of the anterior field is convex to slightly fluted (is not scalloped).

Glyptocephalus zachirus (Rex Sole)
(Other common names: Long-Finned Sole, Witch Sole, Pacific Sole)
Figure 50.25

Description

Length: 59 cm.
Mouth: small, terminal, narrow gape; asymmetrical; maxillary extend to below the anterior margin of the orbit; snout round; teeth on lower side of jaw.
Body: caudal peduncle short; caudal fin V-shaped being longest in the central region of the fin; pectoral fin on eyed side elongated; straight laternal line with no dorsal branch; well developed anal spine.
Color: light brown on eyed side; white to dusky on blind side; young are translucent.

Biology

Depth: up to 366 m; juveniles in shallower waters; adults deeper in the northern range.
Habitat: sandy-muddy substrate.
Season: spawning in spring.
Diet: crustaceans, molluscs (e.g., squid), and fish.
Predators: not determined.
Distribution: Mexico to the Bering Sea.

Scale Description
Figure 50.1-50.24

Scale Type: uniformly cycloid over the body.
Relative Scale Size: small to moderate.
Position of Scales on Body: uniform over the body; imbricated (Hart, 1973).
Overall Scale Shape: circular to oval. In the larger scales the lateral fields are longer than anterior/posterior is wide giving it an elongated appearance; in G, I, and J the posterior field is V-shaped; regenerated scales are less defined in shape.

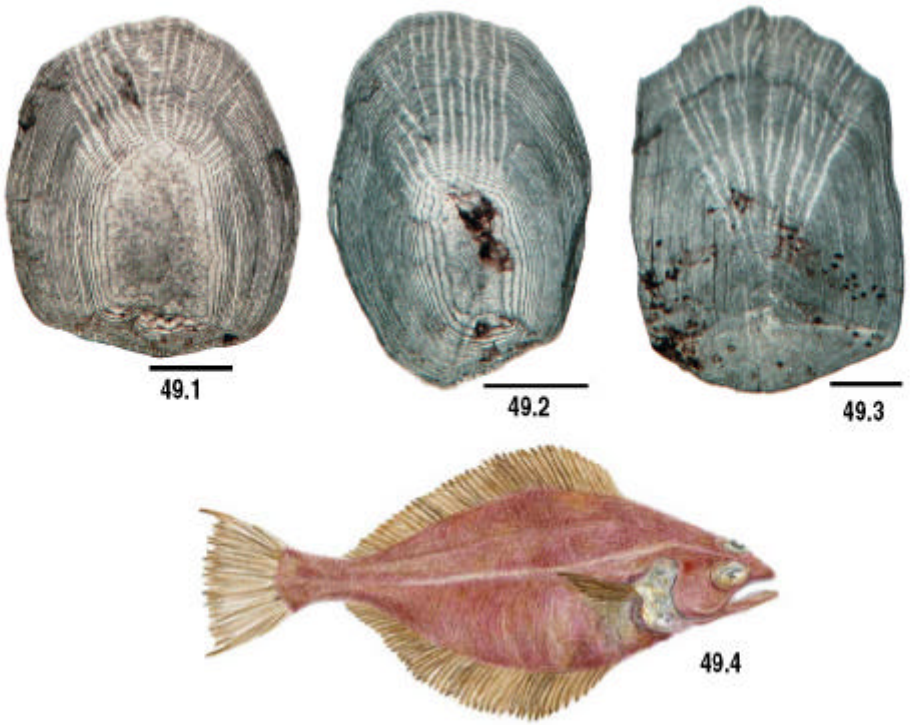


Figure 49.1 - 49.4. 49.1. Atheresthes stomias (Arrowtooth Flounder); scale bar = 1.0 mm. **49.2. Atheresthes stomias** (Arrowtooth Flounder); scale bar = 1.0 mm. **49.3. Atheresthes stomias** (Arrowtooth Flounder); scale bar = 1.0 mm. **49.4. Atheresthes stomias** (Arrowtooth Flounder); sketch of living specimen; length = 84 cm.

Focus and Circuli: the focus is not central between the fields, is approximately one-third to one-fourth of the total scale length from the edge of the posterior field. In small scales the circuli are both continuous and discontinuous (both between and within a field), but in larger, well-developed scales, the circuli are generally continuous (but tend to be somewhat discontinous in the leading edges of the fields). In smaller scales, the circuli do not go into the posterior field, but rather appear as protruberances. The circuli are tightly compacted.
Radii: numbers are variable and not diagnostic. Generally, radii are in the anterior field only (radii not present in all fields; Batts, 1964). The outer edge of the anterior field is convex and smooth. Intermarkings absent (Batts, 1964).

Hippoglossoides elassodon (Flathead Sole)
(Other common names: Paper Sole, Cigarette Sole)
Figure 51.11

Description

Length: 46-50 cm.
Mouth: large, terminal; wide gape; near symmetrical; lower jaw protrudes; teeth in both jaws and well developed; teeth in upper jaw in a single row; maxillary extending to a point below pupil.
Body: compressed/thin; narrow raised interorbit space between two large eyes; caudal peduncle slender; caudal fin truncate with small V-shaped extension; small pores below the lower eye; well developed anal spine at base of anal fin; dorsal branch of lateral line absent; pectorals large and tips are rounded.
Color: grey to olive brown on eyed side; white on blind side, dusky blotches on dorsal and anal fins; sometimes dusky blotches on body.

Biology

Depth: up to 550, but most common 275-366 m; young in shallower water with adults generally below 180 m; over-winter along the outer shelf and move to shallower water in the spring.
Habitat: silty-muddy substrate.
Season: spawns in spring (March- April).
Diet: molluscs, echinoderms, fish, and polychaetes.
Predators: not determined.
Distribution: central California to the Bering Sea to the Sea of Japan.

Scale Description
Figure 51.1-51.10

Scale Type: predominately ctenoid on eyed side and cycloid on blind side.
Relative Scale Size: small.
Position of Scales on Body: in a band across the lateral line and in a diagonal row between the dorsal fin and the lateral line at widest part of body; also on caudal peduncle; imbricated; decidous (Hart, 1973).
Overall Scale Shape: variable; some circular, others semi-circular with the posterior fields being short and the edge being straight; leading edges can be uneven.

Figure 50.1 - 50.13 (continued on next page). 50.1. Glyptocephalus zachirus (Rex Sole); body region A; scale bar = 1.0 mm. **50.2. Glyptocephalus zachirus** (Rex Sole); body region A; scale bar = 250 µm. **50.3. Glyptocephalus zachirus** (Rex Sole); body region A; scale bar = 500 µm. **50.4. Glyptocephalus zachirus** (Rex Sole); body region C; scale bar = 1.0 mm. **50.5. Glyptocephalus zachirus** (Rex Sole); body region C; scale bar = 500 µm. **50.6. Glyptocephalus zachirus** (Rex Sole); body region C; scale bar = 500 µm. **50.7. Glyptocephalus zachirus** (Rex Sole); body region C; scale bar = 500 µm. **50.8. Glyptocephalus zachirus** (Rex Sole); body region E; scale bar = 500 µm. **50.9. Glyptocephalus zachirus** (Rex Sole); body region E; scale bar = 500 µm. **50.10. Glyptocephalus zachirus** (Rex Sole); body region E; scale bar = 1.0 mm. **50.11. Glyptocephalus zachirus** (Rex Sole); body region G; scale bar = 1.0 mm. **50.12. Glyptocephalus zachirus** (Rex Sole); body region G; scale bar = 1.0 mm. **50.13. Glyptocephalus zachirus** (Rex Sole); body region G; scale bar = 1.0 mm.

Figure 50.14 - 50.25. 50.14. Glyptocephalus zachirus (Rex Sole); body region G; scale bar = 1.0 mm. **50.15. Glyptocephalus zachirus** (Rex Sole); body region I; scale bar = 1.0 mm. **50.16. Glyptocephalus zachirus** (Rex Sole); body region I; scale bar = 1.0 mm. **50.17. Glyptocephalus zachirus** (Rex Sole); body region I; scale bar = 1.0 mm. **50.18. Glyptocephalus zachirus** (Rex Sole); body region I; scale bar = 1.0 mm. **50.19. Glyptocephalus zachirus** (Rex Sole); body region J; scale bar = 1.0 mm. **50.20. Glyptocephalus zachirus** (Rex Sole); body region J; scale bar = 500 µm. **50.21. Glyptocephalus zachirus** (Rex Sole); body region J; scale bar = 1.0 mm. **50.22. Glyptocephalus zachirus** (Rex Sole); body region J; scale bar = 1.0 mm. **50.23. Glyptocephalus zachirus** (Rex Sole); scale bar = 500 µm. **50.24. Glyptocephalus zachirus** (Rex Sole); scale bar = 500 µm. **50.25. Glyptocephalus zachirus** (Rex Sole); sketch of living specimen; length = 59 cm.

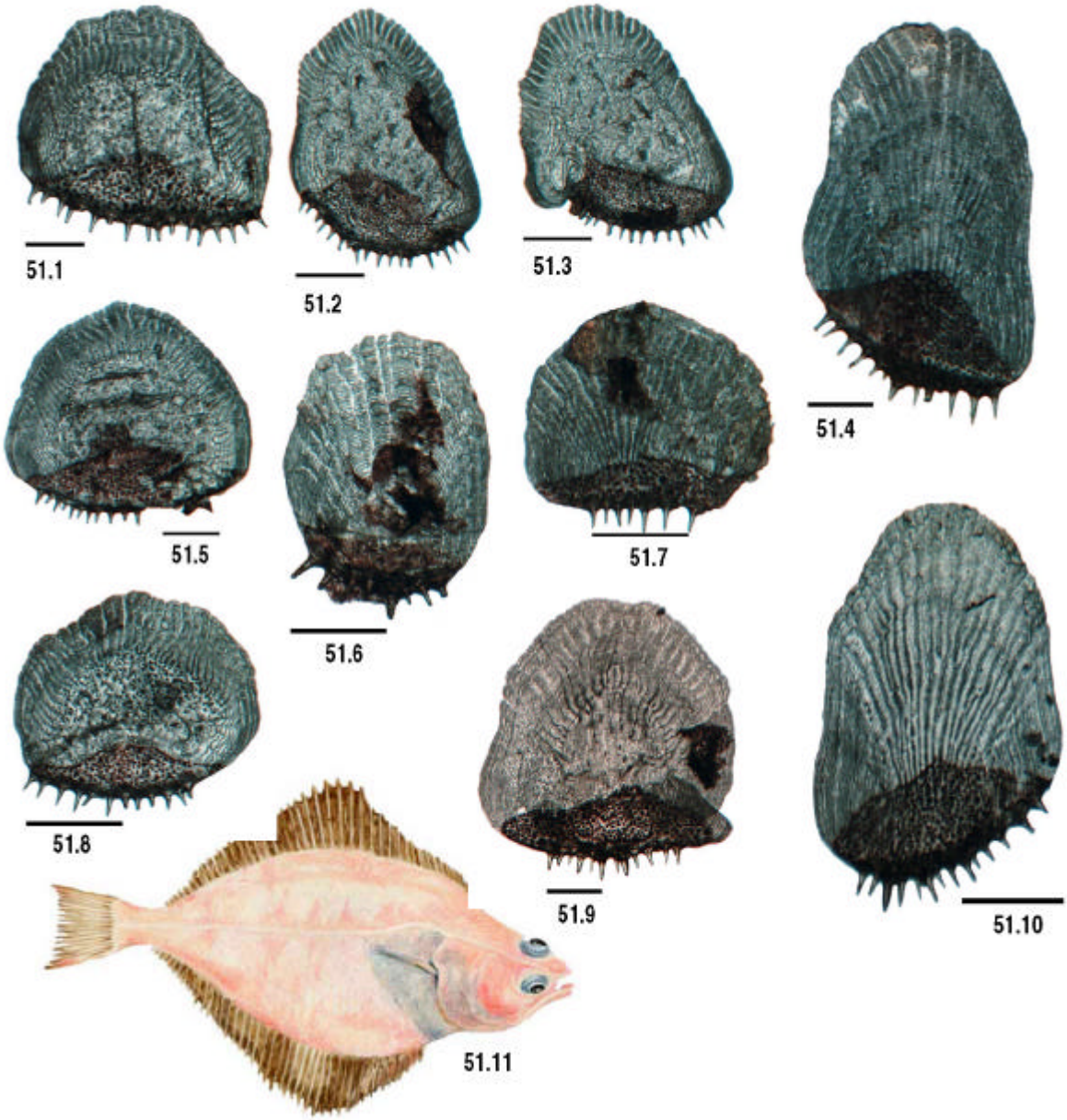


Figure 51.1 - 51. 11. 51.1. Hippoglossoides elassodon (Flathead Sole); scale bar = 500 µm. **51.2. Hippoglossoides elassodon** (Flathead Sole); scale bar = 1.0 mm. **51.3. Hippoglossoides elassodon** (Flathead Sole); scale bar = 1.0 mm. **51.4. Hippoglossoides elassodon (**Flathead Sole); scale bar = 500 µm. **51.5. Hippoglossoides elassodon** (Flathead Sole); scale bar = 500 µm. **51.6. Hippoglossoides elassodon** (Flathead Sole); scale bar = 500 µm. **51.7. Hippoglossoides elassodon** (Flathead Sole); scale bar = 1.0 mm. **51.8. Hippoglossoides elassodon** (Flathead Sole); scale bar = 1.0 mm. **51.9. Hippoglossoides elassodon** (Flathead Sole); scale bar = 500 µm. **51.10. Hippoglossoides elassodon** (Flathead Sole); scale bar = 1.0 mm. **51.11. Hippoglossoides elassodon** (Flathead Sole); sketch of living specimen; length = 46-50 cm.

Focus and Circuli: the focus abuts the inside edge, approximately one-sixth of the total scale length from leading edge of the posterior field (Batts, 1964). The circuli are tightly packed and generally appear continuous (except where broken by radii). In the posterior field, the circuli are truncated by ctenii region.

Radii: numbers are variable and not diagnostic. The radii are primarily in the anterior field, but in some regenerated scales, they also appear in the lateral fields (radii not present in all fields, Batts, 1964). The leading edge of the radii are slightly scalloped. Intermarkings absent (Batts, 1964). Area of anterior field larger than area of combined lateral fields (Batts, 1964). There is no bar-like thickening anterior to base of ctenii (Batts, 1964).

Note: Batts (1964) stated that the posterior field is not well demarcated and that some normal circuli do extend into the posterior field. This does not appear to be the case with our reference collection. It is not certain if this is a plastic feature, or due to desiccation of the reference material.

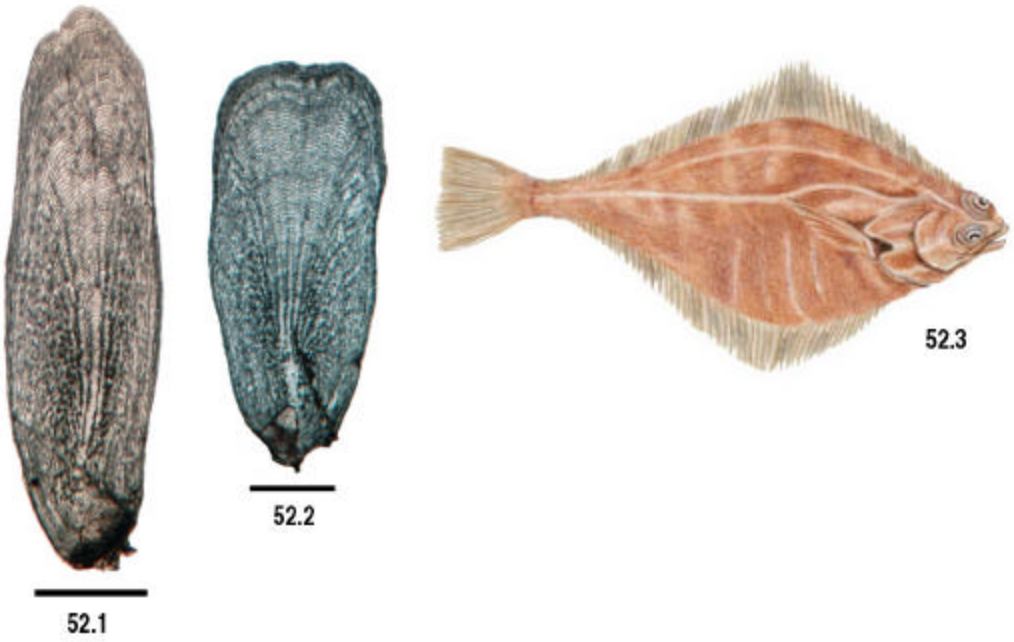


Figure 52.1 - 52.3. 52.1. Hippoglossus stenolepsis (Pacific Halibut); scale bar = 1.0 mm. **52.2. Hippoglossus stenolepsis** (Pacific Halibut); scale bar = 1.0 mm. **52.3. Hippoglossus stenolepsis** (Pacific Halibut); sketch of living specimen; length = 267 cm.

Hippoglossus stenolepis (Pacific Halibut)
(Other common names: Halibut, Northern Halibut, Right Halibut)
Figure 52.3

Description

Length: 267 cm (males generally smaller than females).
Mouth: large, terminal; wide gape; nearly symmetrical; directed forward and up; upper jaw extends to mid orbit of lower eye; lower jaw protrudes; teeth conical and well developed with a double row in the upper jaw and a single row in the lower jaw.
Body: caudal peduncle compressed; caudal fine slightly forked; interorbital space narrow and concave; lateral line highly arched over pectoral region; lateral line dorsal branch absent.
Color: gray marble to dark brown on eyed side; white on blind side.

Biology

Depth: up to 1100 m; mainly between 55-422 m; young in shallower waters, move deeper as they age.
Habitat: variety of substrates.
Season: spawn in winter (November-January) in deep waters; mature adults can have significant migrations.
Diet: crustaceans, molluscs (e.g., clams, squid, octopus), and fish.
Predators: not determined.
Distribution: southern California to the Bering Sea to the Sea of Japan.

Scale Description
Figure 52.1-52.2

Type of Scale: cycloid on both sides (Batts, 1964).
Relative Scale Size: small.
Position of Scales on Body: approximately 150 scales along the lateral line canal; imbricated (Hart, 1973).
Overall Scale Shape: ovoid with elongated lateral fields with a narrow and short posterior field. Area of anterior field larger than area of combined lateral fields (Batts, 1964).
Focus and Circuli: focus is approximately one-fourth to one-fifth of the total scale length from the edge of the posterior field. The circuli can be followed but can appear somewhat broken. Circuli are more dense in the lateral fields than the anterior field and are irregularly spaced in the anterior field (Batts, 1964).
Radii: numbers are variable and not diagnostic. The radii are primarily in the anterior field (radii not present in all fields, Batts, 1964). The outer edge of the anterior field is convex and scalloped. Intermarkings absent (Batts, 1964).

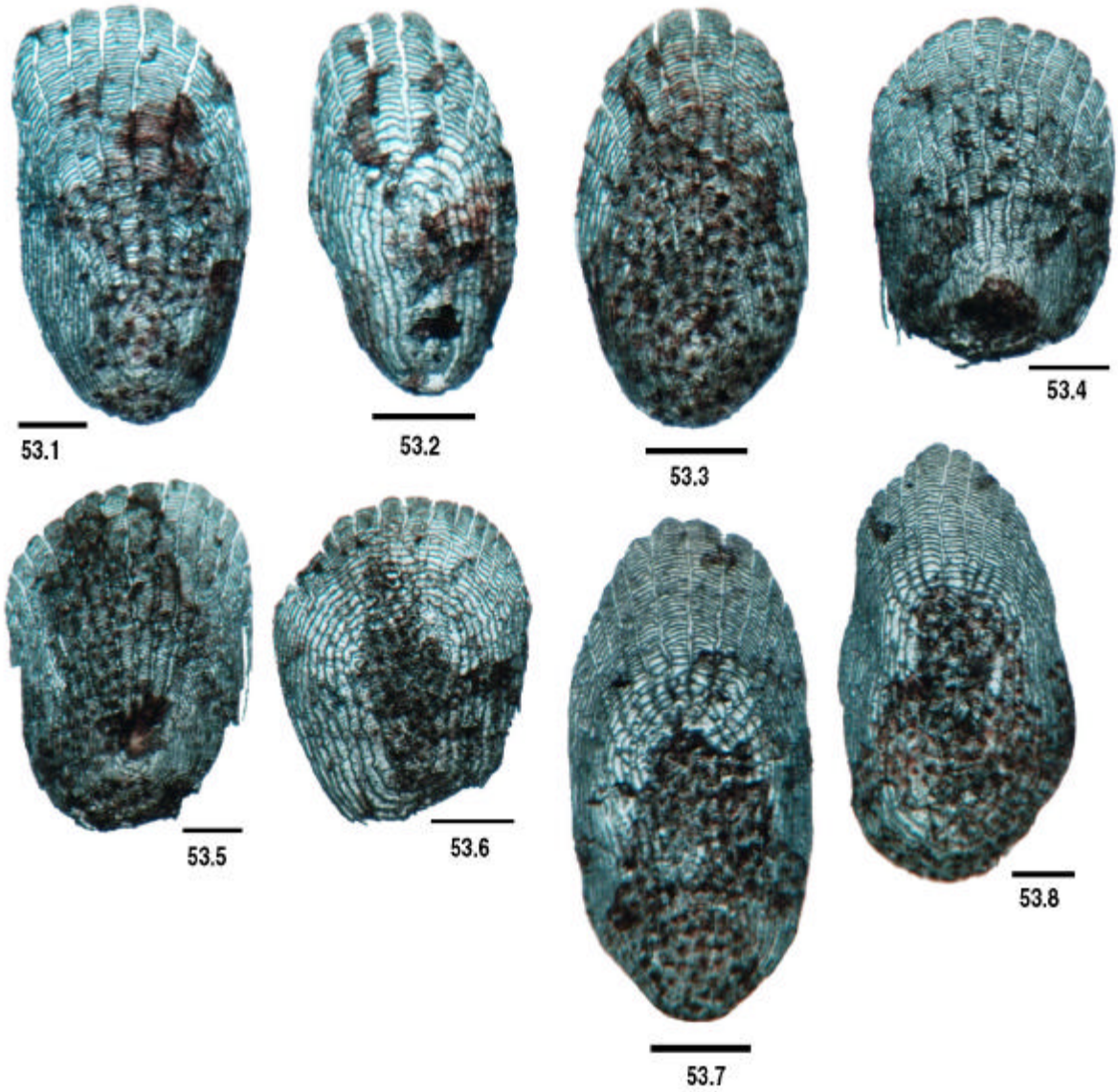


Figure 53.1 - 53.8 (continued on next page). 53.1. Isopsetta isolepsis (Butter Sole); body region A; scale bar = 250 µm. **53.2. Isopsetta isolepsis** (Butter Sole); body region A; scale bar = 250 µm. **53.3. Isopsetta isolepsis** (Butter Sole); body region A; scale bar = 250 µm. **53.4. Isopsetta isolepsis** (Butter Sole); body region C; scale bar = 250 µm. **53.5. Isopsetta isolepsis** (Butter Sole); body region C; scale bar = 250 µm. **53.6. Isopsetta isolepsis** (Butter Sole); body region E; scale bar = 250 µm. **53.7. Isopsetta isolepsis** (Butter Sole); body region G; scale bar = 250 µm. **53.8. Isopsetta isolepsis** (Butter Sole); body region G; scale bar = 250 µm.

Isopsetta isolepis (Butter Sole)
(Other common names: Scalyfin, Bellingham Sole, Skidegate Sole)
Figure 53.13

Description

Length: 55 cm.
Mouth: small, terminal; narrow gape; asymmetrical; maxillary extends to point below anterior edge of lower eye; jaws with teeth strongest on blind side; snout round and pointed.
Body: caudal peduncle moderate; caudal fin rounded; pectorals small with blunt points; anal fin with small sharp spine; lateral line canal is slightly arched over the pectoral fin; dorsal accessory branch present.
Color: gray with irregular blotches on eyed side; white on blind spots, bright yellow on tips of dorsal and anal fin.

Biology

Depth: up to 366 m; usually shallower.
Habitat: soft silty substrate; in shallow waters in summer and deeper waters in winter.
Season: spawn in late winter-spring (February to late April; as cited in Hart, 1973).

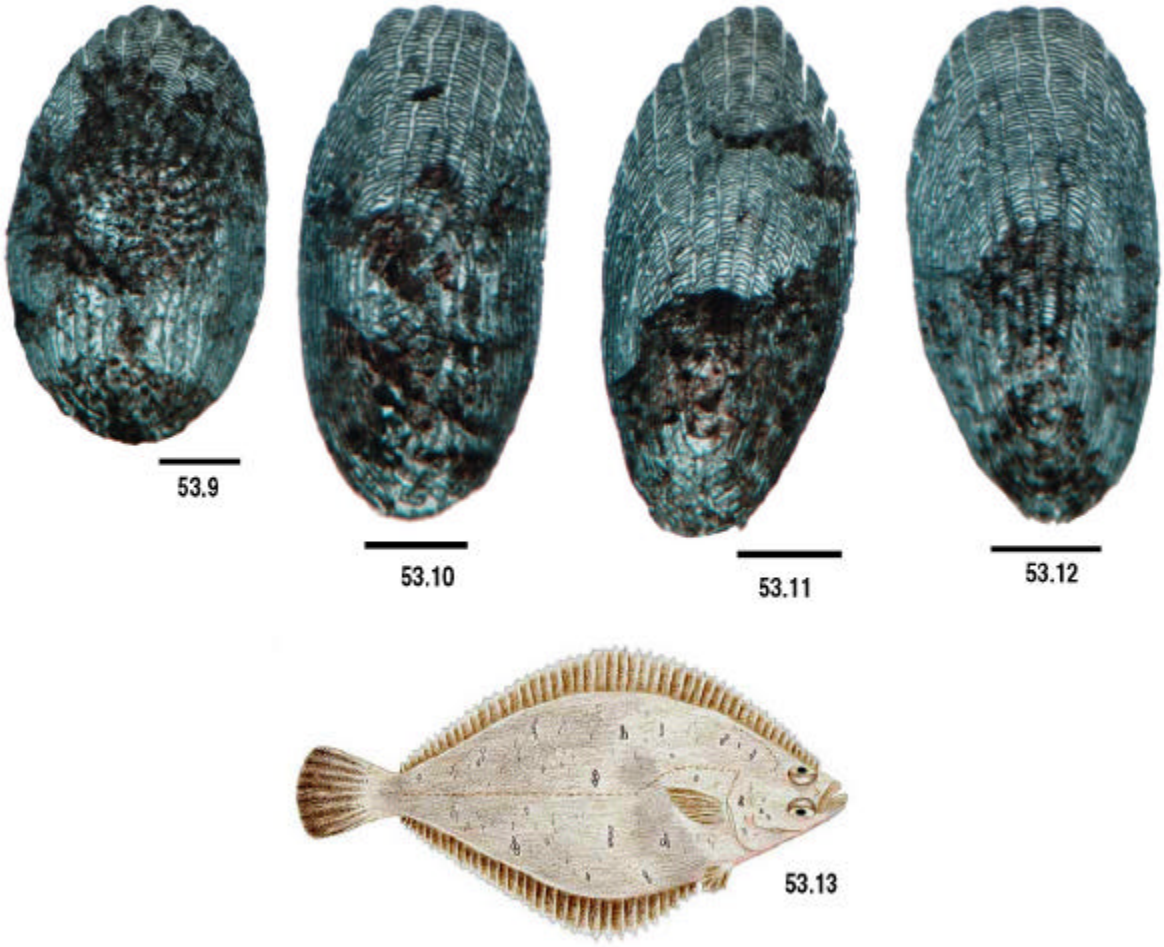


Figure 53.9 - 53.13. 53.9. Isopsetta isolepsis (Butter Sole); body region I; scale bar = 250 µm. **53.10. Isopsetta isolepsis** (Butter Sole); body region J; scale bar = 250 µm. **53.11. Isopsetta isolepsis** (Butter Sole); body region J; scale bar = 250 µm. **53.12. Isopsetta isolepsis** (Butter Sole); body region J; scale bar = 500 µm. **53.13. Isopsetta isolepsis** (Butter Sole); sketch of living specimen; length = 55 cm.

Diet: molluscs, worms, crustaceans, and forage fish (e.g., herring).
Predators: not determined.
Distribution: southern California to Alaska.

Scale Description
Figure 53.1-53.12

Scale Type: ctenoid on eyed side; ctenoid on head and fin rays; partly cycloid on blind side (Batts, 1964).
Relative Scale Size: large.
Position of Scales on Body: along lateral line; on head and fins; also on blind side; imbricated (Hart, 1973).
Overall Scale Shape: oval with elongated lateral fields that are 2:1 the width of the anterior field (Batts, 1964).
Focus and Circuli: the focus is approximately one-quarter of the total scale length from the outside edge of the posterior field (Batts, 1964). The circuli are compact and generally continuous between all fields, but are more compacted in the posterior field (Batts, 1964).
Radii: numbers are variable and not diagnostic. The radii are in the anterior field and may also be present in the anterior portion of the lateral fields (radii not present in all fields; Batts, 1964). The outer edge of the anterior field is smooth to slightly scalloped, depending on the spread of the radii. Intermarkings absent (Batts, 1964).

Lepidopsetta bilineata (Rock Sole)
(Other common names: Broadfin Sole, Whitebellied Sole, Two-Lined Dab)
Figure 54.14

Description

Length: 60 cm (females larger than males).
Mouth: small, terminal; small gape; asymmetrical; directed upwards; maxillary extends to anterior part of the lower eye; teeth and jaws most developed on the blind side.
Body: caudal peduncle moderate; caudal fin rounded to V-shaped; lateral line is prominently arched over the pectoral region; accessory branch present and short.
Colour: gray to brown with either mottled dark or light areas; dorsal, anal, and caudal fins have dark mottling; blind side white; yellow towards caudal region.

Figure 54.1 - 54.8 (continued on next page). 54.1. Lepidopsetta bilineata (Rock Sole); body region A; scale bar = 500 µm. **54.2. Lepidopsetta bilineata** (Rock Sole); body region A; scale bar = 1.0 mm. **54.3. Lepidopsetta bilineata** (Rock Sole); body region C; scale bar = 1.0 mm. **54.4. Lepidopsetta bilineata** (Rock Sole); body region C; scale bar = 1.0 mm. **54.5. Lepidopsetta bilineata** (Rock Sole); body region E; scale bar = 1.0 mm. **54.6. Lepidopsetta bilineata** (Rock Sole); body region E; scale bar = 1.0 mm. **54.7. Lepidopsetta bilineata** (Rock Sole); body region G; scale bar = 1.0 mm. **54.8. Lepidopsetta bilineata** (Rock Sole); body region G; scale bar = 1.0 mm.

Biology

Depth: up to 366 m, but generally shallower.
Habitat: soft substrate areas, but also pebbly substrate; moves to shallow waters in the summer and deeper during the winter.
Season: spawns in spring (February to April).
Diet: molluscs, worms, crustaceans (e.g., shrimp, crabs), and forage fish (e.g., sand lance).
Predators: not determined.
Distribution: southern California to the Bering Sea to the Sea of Japan.

Scale Description
Figure 54.1-54.13

Type of Scale: ctenoid on eyed side; some tuberculate on eyed side; cycloid on blind.
Relative Scale Size: moderate.
Position of Scales on Body: along lateral line, caudal peduncle region and extends to the dorsal, anal, and caudal fins (Hart, 1973).
Overall Scale Shape: circular to oval with the edge of the posterior field being straight to slightly convex. Bar-like thickening just anterior to the bases of the ctenii (Batts, 1964). Area of the lateral fields is approximately equal to the area of anterior field.
Focus and Circuli: the focus is not centralized and is approximately one-quarter the total scale length from the edge of the posterior field. The circuli are compact and generally continuous between all fields (Batts, 1964). Regeneration appears common.
Radii: numbers are variable and not diagnostic. The radii are in the anterior field and may extend into the anterior portion of the lateral fields. (Radii not present in all fields; Batts, 1964). Intermarkings absent (Batts, 1964).

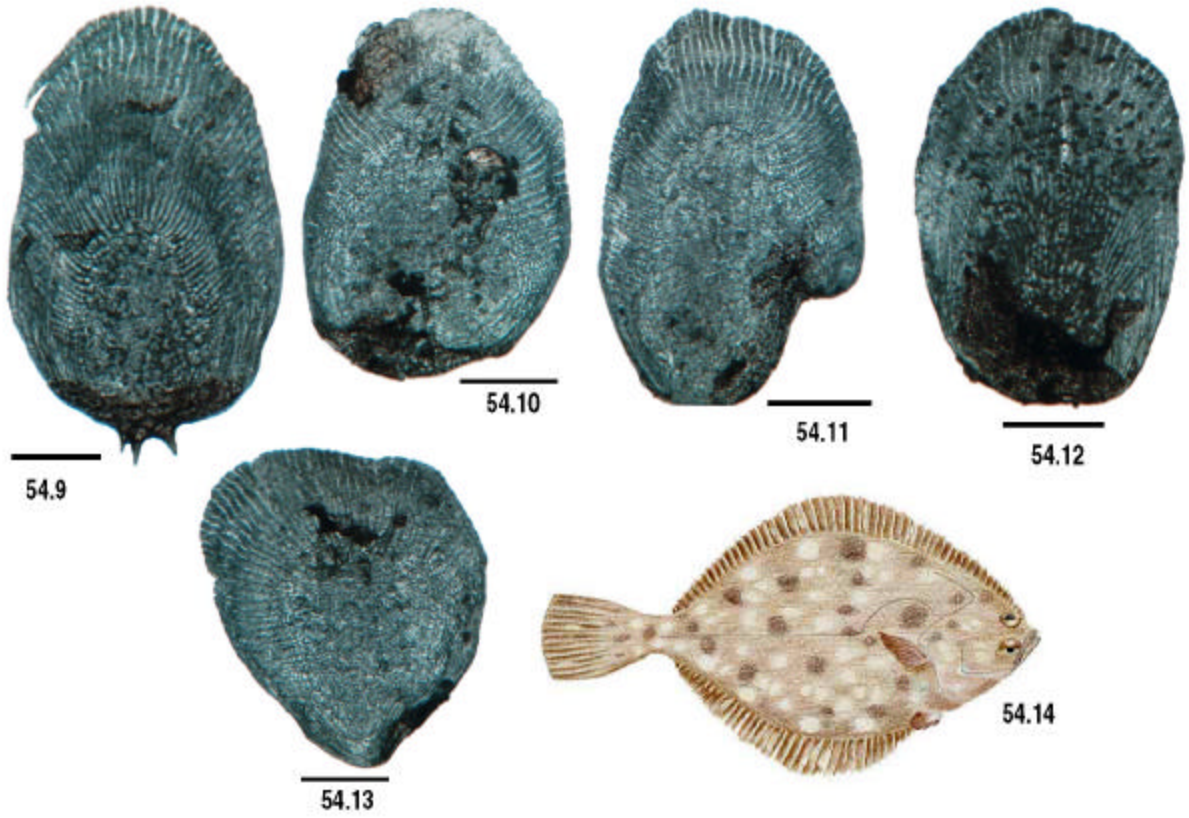


Figure 54.9 - 54.14. 54.9. Lepidopsetta bilineata (Rock Sole); body region I; scale bar = 1.0 mm. **54.10. Lepidopsetta bilineata** (Rock Sole); body region I; scale bar = 1.0 mm. **54.11. Lepidopsetta bilineata** (Rock Sole); body region I; scale bar = 1.0 mm. **54.12. Lepidopsetta bilineata** (Rock Sole); body region J; scale bar = 1.0 mm. **54.13. Lepidopsetta bilineata** (Rock Sole); body region J; scale bar = 1.0 mm. **54.14. Lepidopsetta bilineata** (Rock Sole); sketch of living specimen; length = 60 cm.

Lyopsetta exilis (Slender Sole)
(Other common names: Rough Sole)
Figure 55.18

Description

Length: 35 cm.
Mouth: large, terminal; wide gape; asymmetrical; jaws extend to middle of lower eye; maxillary extends to anterior edge of the lower eye; teeth well developed in both jaws; lower jaw has two rows of teeth; snout blunt and pointed.
Body: caudal peduncle moderate; caudal fin rounded; lateral line gently slopes from head to pectoral region and then horizontal; accessory branch absent.
Color: pale brown on eyed side with dark margins in scales; pale orange to white on blind side; fins dusky.

Biology

Depth: up to 500 m.
Habitat: soft substrate but will also move into shallow sandy/rocky areas.
Season: spawns in spring (April).
Diet: crustaceans, worms, and molluscs.
Predators: not determined.
Distribution: southern California to Alaska.

Scale Description
Figure 55.1-55.17

Type of Scale: ctenoid on eyed side and mostly ctenoid on blind, but some cycloid on central area under dorsal fin.
Relative Scale Size: large.
Position of Scales on Body: along lateral line to dorsal fin; on dorsal, caudal, and anal fins; on blind side; imbricated; deciduous and easily shed (Hart, 1973).
Overall Scale Shape: generally oval (some regenerated scales are more circular) with elongated lateral fields. Area of the anterior field is smaller than area of combined lateral fields (Batts, 1964).
Focus and Circuli: the focus is positioned approximately one-sixth to one-seventh of the total scale length from the outside margin of the posterior field, abuting the edge of ctenii growth. The circuli are generally continuous between the lateral and anterior fields (except where broken by radii) but the circuli in the shorter posterior field are compacted (Batts, 1964). Exposed field extends anterior to the focus, a distance greater than the distance from the posterior edge of the ctenii to anterior edge of the bases of the ctenii (Batts, 1964).

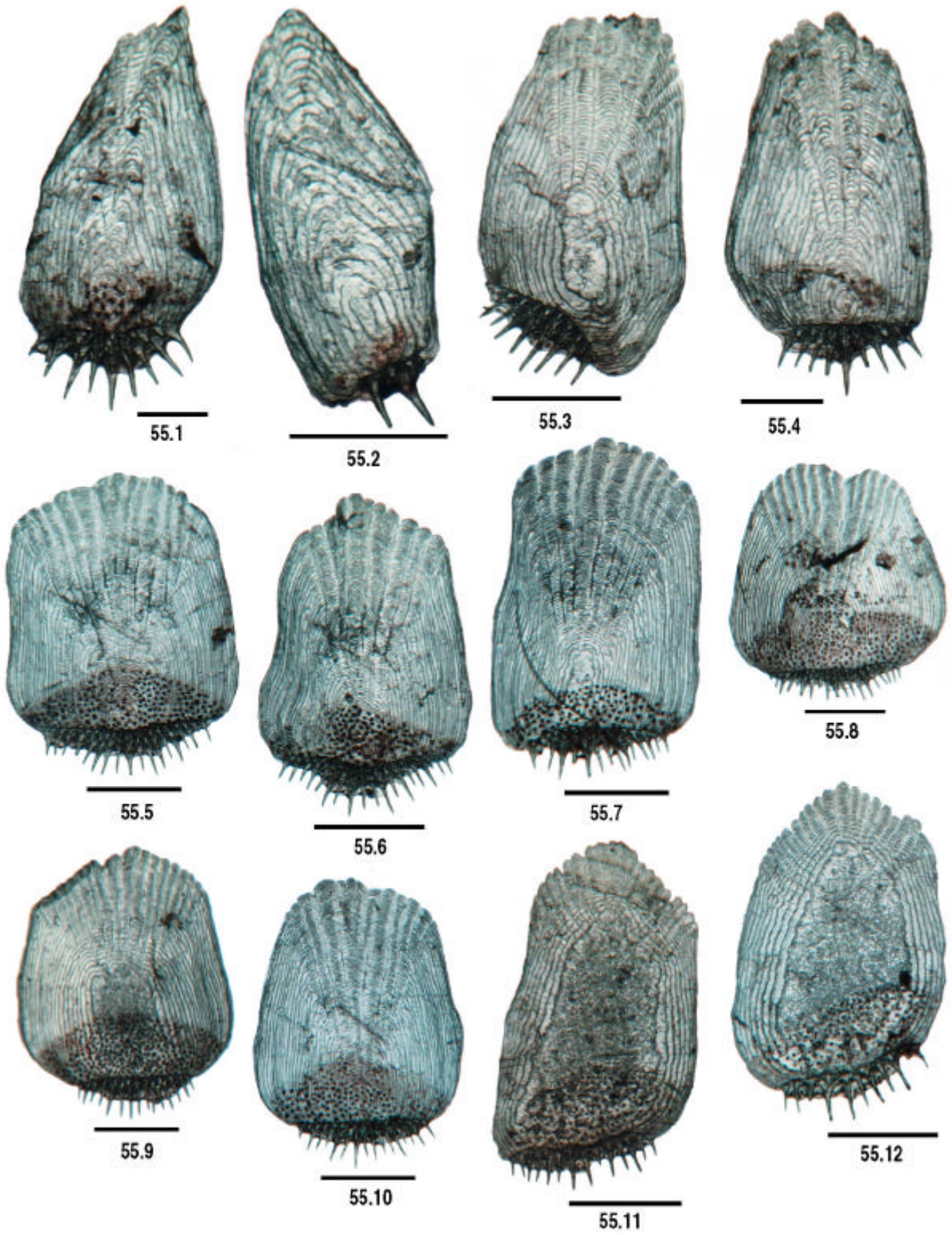


Figure 55.1 - 55.12 (continued on next page). 55.1. Lyopsetta exilis (Slender Sole); body region A; scale bar = 500 µm. **55.2. Lyopsetta exilis** (Slender Sole); body region A; scale bar = 500 µm. **55.3. Lyopsetta exilis** (Slender Sole); body region A; scale bar = 1.0 mm. **55.4. Lyopsetta exilis** (Slender Sole); body region A; scale bar = 500 µm. **55.5. Lyopsetta exilis** (Slender Sole); body region C; scale bar = 1.0 mm. **55.6. Lyopsetta exilis** (Slender Sole); body region C; scale bar = 1.0 mm. **55.7. Lyopsetta exilis** (Slender Sole); body region C; scale bar = 1.0 mm. **55.8. Lyopsetta exilis** (Slender Sole); body region E; scale bar = 1.0 mm. **55.9. Lyopsetta exilis** (Slender Sole); body region E; scale bar = 1.0 mm. **55.10. Lyopsetta exilis** (Slender Sole); body region E; scale bar = 1.0 mm. **55.11. Lyopsetta exilis** (Slender Sole); body region G; scale bar = 1.0 mm. **55.12. Lyopsetta exilis** (Slender Sole); body region G; scale bar = 1.0 mm.

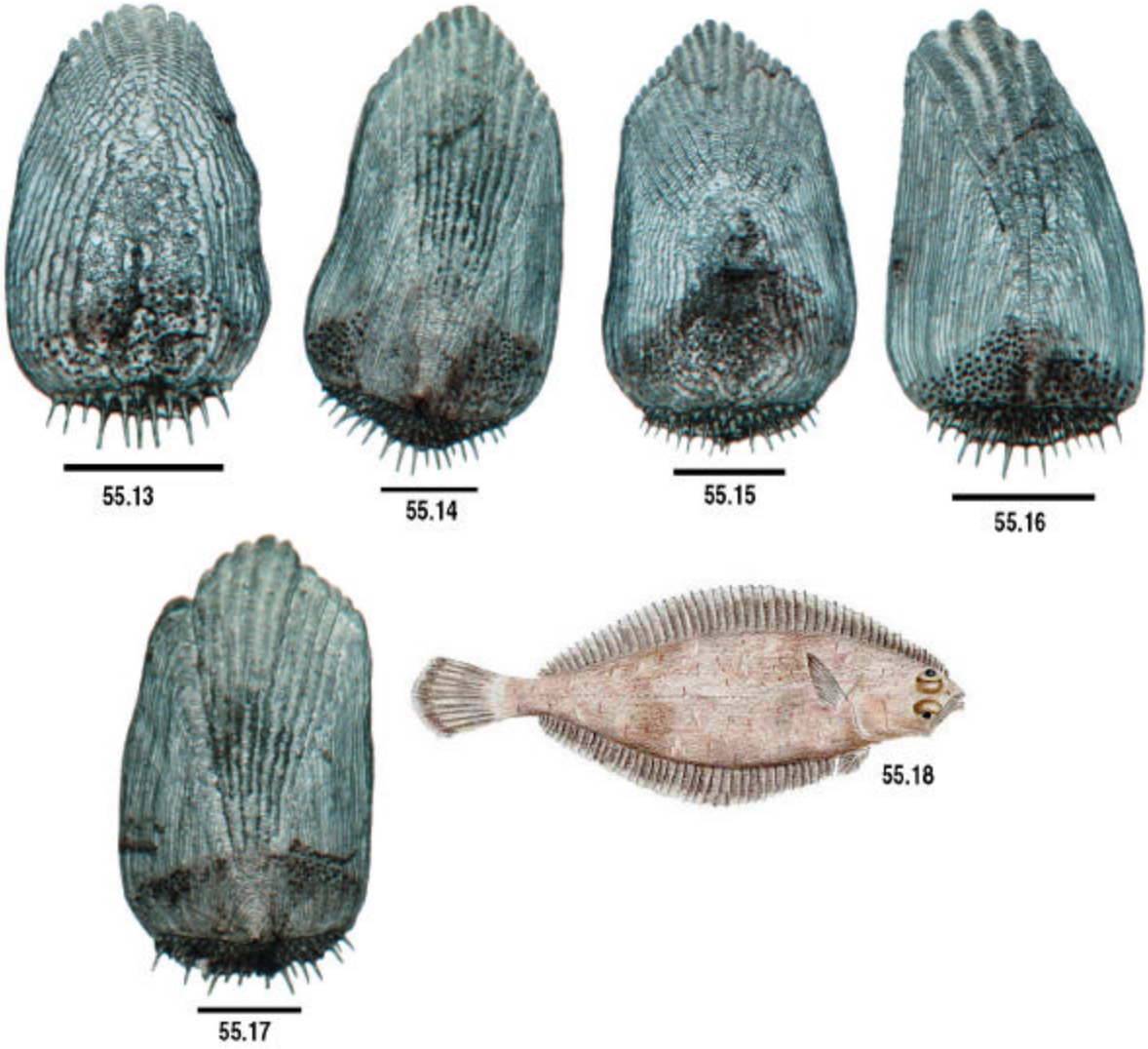


Figure 55.13 - 55.18. 55.13. Lyopsetta exilis (Slender Sole); body region G; scale bar = 1.0 mm. **55.14. Lyopsetta exilis** (Slender Sole); body region I; scale bar = 1.0 mm. **55.15. Lyopsetta exilis** (Slender Sole); body region I; scale bar = 1.0 mm. **55.16. Lyopsetta exilis** (Slender Sole); body region J; scale bar = 1.0 mm. **55.17. Lyopsetta exilis** (Slender Sole); body region J; scale bar = 1.0 mm. **55.18. Lyopsetta exilis** (Slender Sole); sketch of living specimen; length = 35 cm.

Radii: numbers are variable and not diagnostic, but the reference collection suggests that there are at least one (rarely two) secondary radii before the first primary on both sides of the anterior field. Radii are present only in the anterior field (Batts, 1964). Intermarkings are absent (Batts, 1964). The outer edge of the anterior field is slightly scalloped and convex (not expressed in regenerated scales).

Parophrys (re: Pleuronectes) vetulus (English Sole)
(Other common names: Lemon Sole, Pointed-Nose Sole, California Sole)
Figure 56.12

Description

Length: 57 cm.

Mouth: small, terminal; narrow gape; asymmetrical; maxillary extends to forward edge of lower eye; jaws and teeth strongest on blind side; snout pointed.
Body: slender; caudal peduncle moderate; caudal fin truncate; upper eye visible from blind side; lateral line only slightly arched and with a long accessory branch; pointed pectorals fins.
Color: uniformly brown on eyed side; yellow-white on blind side, with head region being tinged red-brown; fin tips dark.

Biology

Depth: up to 550 m.
Habitat: silty to sandy substrates; young can be found in the intertidal regions and shallow waters and move into deeper waters as they grow.

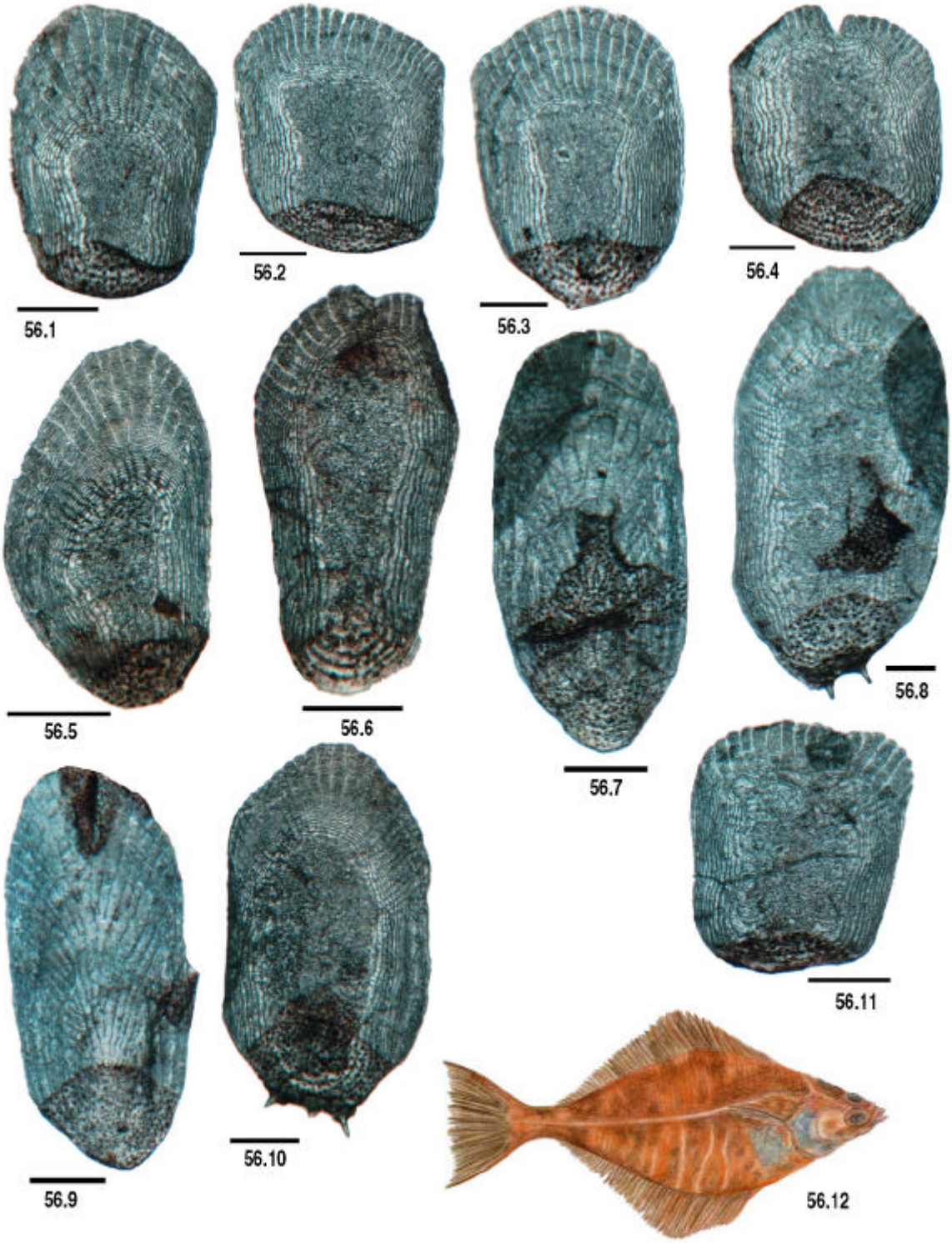


Figure 56.1 - 56.12. 56.1. Parophyrus vetulus (English Sole/Lemon Sole); body region A; scale bar = 500 µm. **56.2. Parophyrus vetulus** (English Sole/Lemon Sole); body region C; scale bar = 500 µm. **56.3. Parophyrus vetulus** (English Sole/ Lemon Sole); body region C; scale bar = 500 µm. **56.4. Parophyrus vetulus** (English Sole/ Lemon Sole); body region C; scale bar = 500 µm. **56.5. Parophyrus vetulus** (English Sole/Lemon Sole); body region E; scale bar = 500 µm. **56.6. Parophyrus vetulus** (English Sole/ Lemon Sole); body region E; scale bar = 500 µm. **56.7. Parophyrus vetulus** (English Sole/ Lemon Sole); body region G; scale bar = 500 µm. **56.8. Parophyrus vetulus** (English Sole/Lemon Sole); body region G; scale bar = 500 µm. **56.9. Parophyrus vetulus** (English Sole/Lemon Sole); body region I; scale bar = 1.0 mm. **56.10. Parophyrus vetulus** (English Sole/Lemon Sole); body region I; scale bar = 500 µm. **56.11. Parophyrus vetulus** (English Sole/Lemon Sole); body region J; scale bar = 500 µm. **56.12. Parophyrus vetulus** (English Sole/ Lemon Sole); sketch of living specimen; length = 57 cm.

Season: spawn in winter to early spring (December to April).
Diet: crustaceans, molluscs, and polychaetes.
Predators: larger fish species, marine birds (especially on young).
Distribution: central Baja to Alaska.

Scale Description
Figure 56.1-56.11

Scale Type: cycloid on both sides of the eyed region and on cheeks; ctenoid posteriorly (Batts, 1964).
Relative Scale Size: small to moderate.
Position of Scales on Body: uniform over the body and on cheeks; absent on fins; imbricated (Hart, 1973).
Overall Scale Shape: mostly oval (elongated lateral fields), but regenerated scales are often circular to square. Area of anterior field is larger than the area of the combine lateral fields (Batts, 1964). There is no bar-like thickening at the base of the ctenii (Batts, 1964).
Focus and Circuli: the focus is positioned approximately 1/4th or greater from the outside margin of the posterior field (Batts, 1964). The circuli are generally continuous between the all the fields in cycloid scales (except where broken by radii) and only continuous in lateral/anterior fields in ctenoid scales (discontinuous in the posterior field for ctenoid scales, Batts, 1964). The circuli are compact and regeneration appears to be more common in ctenoid scales than cycloid scales.
Radii: numbers are variable and not diagnostic. Radii are presently only in the anterior field (Batts, 1964). The outer edge of the anterior field is smooth. Intermarkings absent (Batts, 1964).

Platichthys stellatus (Starry Flounder)
(Other common names: Grindstone, Leatherjacket)
Figure 57.16

Description

Length: 91 cm.
Mouth: small, terminal; narrow gape; asymmetrical; maxillary reaches to a point below the anterior edge of the lower orbit; teeth on blind side jaw; snout blunt.
Body: caudal fin arched with a heavy first haemal spine; pectorals fins bluntly pointed; dorsal fin originates over the upper eye; lateral line slightly curved over pectoral region and then straight; no accessory branch; distinct bony plates or tubercle plates over the body; there is a tendency for this species to also be left-handed.
Color: dark brown to black with blotches on the eyed side; white to cream on the blind side; unpaired fins (anal, dorsal, and caudal) have black bands separated by orange-white stripes.

Biology

Depth: up to 275 m.
Habitat: generally soft substrates; generally an inshore species that can tolerate low salinities, moving into estuaries to spawn; move into deeper waters during the winter.
Season: spawn in early spring (February-April); earlier in southern waters; young are common in estuaries and low salinity rivers.
Diet: young feed on crustaceans such as copepods and cladocerans; adults feed on polychaetes; mussels and larger crustaceans (e.g., crabs, shrimps).
Predators: marine birds, marine mammals (Simstead et al., 1979).
Distribution: southern California to Alaska to the Bering Sea to Korea.

Scale Description
Figures 57.1-57.15

Type of Scale: stellate plates without circuli (not illustrated) predominately on the eyed side; cycloid scales on the blind side.
Relative Scale Size: small.
Position of Scales on Body: stellate plates irregularly distributed on the body; cycloid scales along the bases of the dorsal and anal fins (Hart, 1973).
Overall Scale Shape: circular to ovoid with slightly elongated lateral fields.
Focus and Circuli: focus is not centralized and is approximately one-quarter of the total scale length from the edge of the posterior field. The circuli are tightly compacted in the lateral fields and somewhat less so in the anterior. The circuli are continuous in the anterior and lateral fields and in the posterior field are discontinuous (almost protruberances).
Radii: numbers are variable and not diagnostic. Present in the anterior field only (radii not present in all fields, Batts, 1964). The outer edge of the anterior field is convex and slightly scalloped. Intermarkings absent (Batts, 1964).

Pleuronichthys coenosus (C-O Sole)
(Other common names: Spotflounder, Popeye Sole, Muddy Flounder)
Figure 58.18

Description

Length: 36 cm.
Mouth: small, terminal; narrow gape; asymmetrical; maxillary extends to below the forepoint of the lower eye; thickened lips; teeth mainly on the blind side of jaws.
Body: caudal peduncle deep; caudal fin rounded; dorsal and anal fins high; the first five to six dorsal rays begin on the blind side; small spine before anal fin; pectorals bluntly pointed; lateral line slightly curved over pectoral region then straight; accessory dorsal branch long.
Color: dark brown to black on the eyed side; creamy white on the blind side; dark spot mid-body on eyed side; similar spot on mid-caudal fin; dark curved bar at the base of the caudal fin (last two features look like a ‘C’ and an ‘O’).
Biology
Depth: up to 350 m.
Habitat: both soft and hard substrates; eelgrass habitats; young are more common in shallow waters; can adjust colouration to substrate.

Figure 57.1 - 57.11 (continued on next page). 57.1. Platichthys stellatus (Starry flounder); body region A; scale bar = 500 µm. **57.2. Platichthys stellatus** (Starry flounder); body region A; scale bar = 250 µm. **57.3. Platichthys stellatus** (Starry flounder); body region A; scale bar = 500 µm. **57.4. Platichthys stellatus** (Starry flounder); body region A; scale bar = 250 µm. **57.5. Platichthys stellatus** (Starry flounder); body region C; scale bar = 250 µm. **57.6. Platichthys stellatus** (Starry flounder); body region C; scale bar = 250 µm. **57.7. Platichthys stellatus** (Starry flounder); body region C; scale bar = 250 µm. **57.8. Platichthys stellatus** (Starry flounder); body region E; scale bar = 250 µm. **57.9. Platichthys stellatus** (Starry flounder); body region G; scale bar = 500 µm. **57.10. Platichthys stellatus** (Starry flounder); body region G; scale bar = 500 µm. **57.11. Platichthys stellatus** (Starry flounder); body region G; scale bar = 1.0 mm.

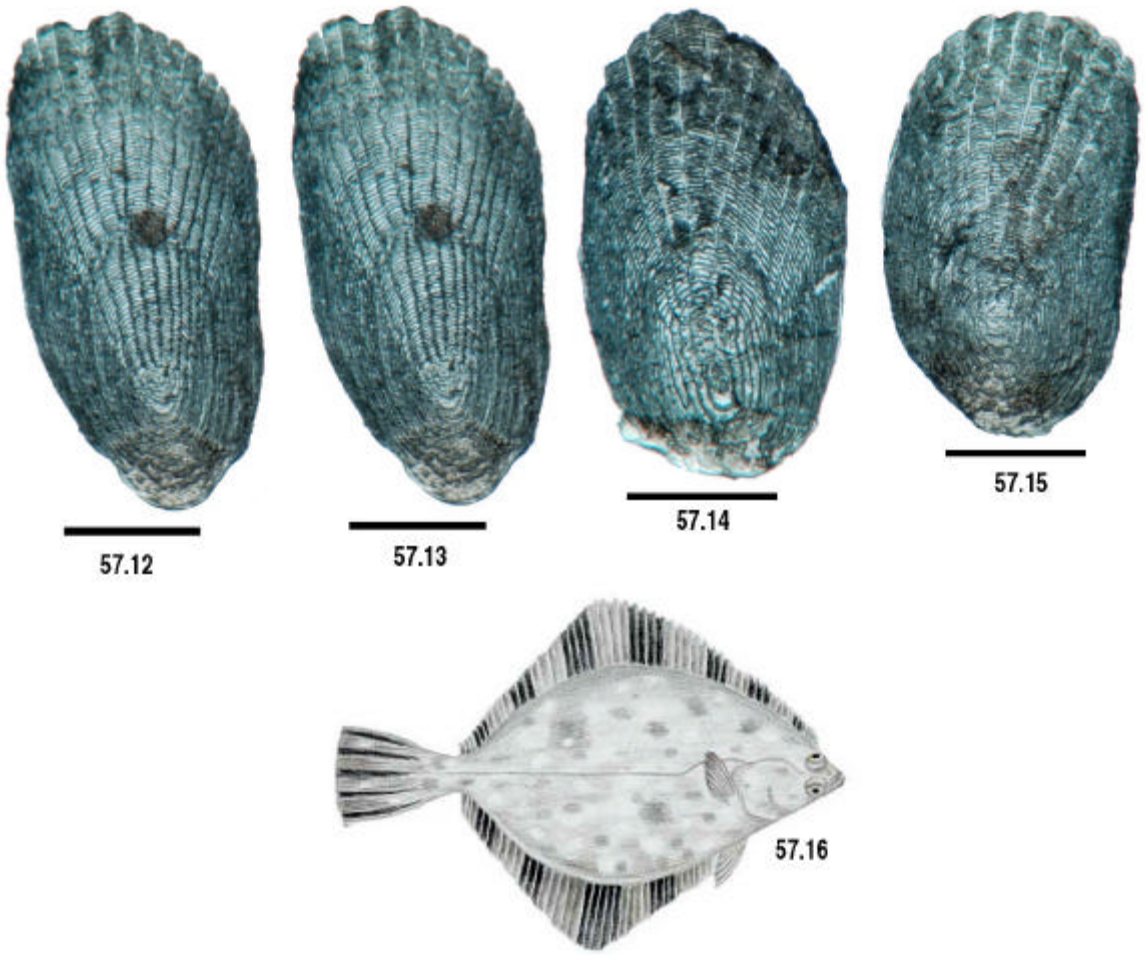


Figure 57.12 - 57.16. 57.12. Platichthys stellatus (Starry flounder); body region I; scale bar = 500 µm. **57.13. Platichthys stellatus** (Starry flounder); body region I; scale bar = 500 µm. **57.14. Platichthys stellatus** (Starry flounder); body region J; scale bar = 500 µm. **57.15. Platichthys stellatus** (Starry flounder); body region J; scale bar = 500 µm. **57.16. Platichthys stellatus** (Starry flounder); sketch of living specimen; length = 91 cm.

Season: Hart (1973) lists hatching of eggs at 13.8ºC after 12 days; suggesting that spawning occurs late spring to summer.
Diet: polychates, molluscs, and crustaceans.
Predators: not determined.
Distribution: Mexico, to Baja, California to Alaska.

Scale Description
Figure 58.1-58.17

Scale Type: cycloid on both sides.
Relative Size of Scale: moderate.
Scale Position: imbedded in the skin on the fins (Hart, 1973).
Overall Scale Shape: circular to slightly ovoid.
Focus and Circuli: the focus is not centralized and is approximately one-fourth to one-fifth of the total scale length from the edge of the posterior field. The circuli are discontinuous in all fields (Batts, 1964).
Radii: numbers are variable and not diagnostic. Present in the anterior field and may extend into the anterior edges of the lateral fields (radii not present in all fields, Batts, 1964). The outer edge of the anterior fields is convex and smooth with only a slight scalloping. Intermarkings absent (Batts, 1964).

Psettichthys melanostictus (Sand Sole)
(Other common names: Fringe Sole; Sand Flounder, Spotted Flounder)
Figure 59.19

Description

Length: 63 cm.
Mouth: large, terminal; wide gape; almost symmetrical; maxillary extends to point below pupil of eye.
Body: caudal peduncle deep and flat; caudal fin rounded; first eight (or more) rays on dorsal fin elongated and not attached to fin membrane; anal fin spine directed anteriorly; pectorals small; lateral line slightly arched over pectoral region then straight; accessory dorsal branch present.
Color: variable; green to brown with black points on eyed side; yellow on the tips of the dorsal and anal rays.

Figure 58.1 - 58.14 (continued on next page). 58.1. Pleuronichthys coenosus (C-O Sole); body region A; scale bar = 500 µm. **58.2. Pleuronichthys coenosus** (C-O Sole); body region A; scale bar = 1.0 mm. **58.3. Pleuronichthys coenosus** (C-O Sole); body region C; scale bar = 500 µm. **58.4. Pleuronichthys coenosus** (C-O Sole); body region E; scale bar = 500 µm. **58.5. Pleuronichthys coenosus** (C-O Sole); body region E; scale bar = 500 µm. **58.6. Pleuronichthys coenosus** (C-O Sole); body region G; scale bar = 500 µm. **58.7. Pleuronichthys coenosus** (C-O Sole); body region G; scale bar = 500 µm. **58.8. Pleuronichthys coenosus** (C-O Sole); body region G; scale bar = 500 µm. **58.9. Pleuronichthys coenosus** (C-O Sole); body region I; scale bar = 500 µm. **58.10. Pleuronichthys coenosus** (C-O Sole); body region I; scale bar = 500 µm. **58.11. Pleuronichthys coenosus** (C-O Sole); body region I; scale bar = 500 µm. **58.12. Pleuronichthys coenosus** (C-O Sole); body region I; scale bar = 500 µm. **58.13. Pleuronichthys coenosus** (C-O Sole); body region J; scale bar = 500 µm. **58.14. Pleuronichthys coenosus** (C-O Sole); body region J; scale bar = 500 µm.

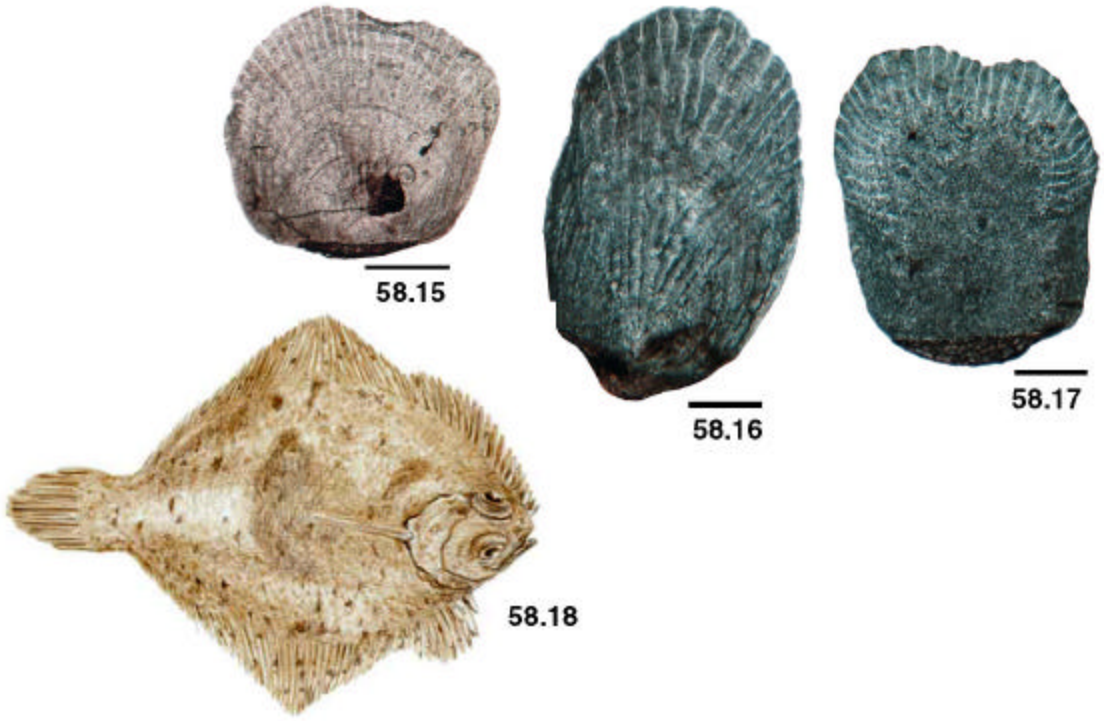


Figure 58.15 - 58.18. 58.15. Pleuronichthys coenosus (C-O Sole); scale bar = 1.0 mm. **58.16. Pleuronichthys coenosus** (C-O Sole); scale bar = 500 µm. **58.17. Pleuronichthys coenosus** (C-O Sole); scale bar = 500 µm. **58.18. Pleuronichthys coenosus** (C-O Sole); sketch of living specimen; length = 36 cm.

Biology

Depth: up to 183 m.
Habitat: sandy substrate; generally in shallow waters.
Season: spawning occurs winter-early spring (January-March).
Diet: forage fish species (e.g., anchovies, herring, speckled sanddab), crustaceans, worms, and molluscs.
Predators: not determined.
Distribution: southern California to Alaska to the Bering Sea.

Scale Description
Figure 59.1-59.18

Type of Scale: ctenoid on eyed side; cycloid on blind side, except on ventral edge where there are some ctenoid scales.
Relative Scale Size: small.
Position of Scales on Body: base of dorsal, anal, and caudal fins; 98-112 scales along the lateral line; imbricated (Hart, 1973).
Overall Scale Shape: generally oval with elongated lateral sides; the C and E scales are more squared. Area of anterior field is larger than area of combined lateral fields (Batts, 1964). Bar-like thickening is anterior to the base of the ctenii. Ratio of base of ctenii to the length of the longest ctenium is approximately 1:2 (Batts, 1964).
Focus and Circuli: the focus is not centralized, and is positioned approximately one-fourth to one-fifth (Batts, 1964) from the outside margin of the posterior field (in both ctenoid and cycloid scales), is close to but does not abut ctenii basal area. The circuli are compact and continuous in the anterior-lateral fields (Batts, 1964); discontinuous in the posterior field (both cycloid and ctenoid).
Radii: numbers are variable and not diagnostic. The radii are present only in the anterior field (Batts, 1964). The outer edge of the anterior field is smooth, not scalloped. Intermarkings absent (Batts, 1964).

Scale Preservation

To date, no flatfish scales have been found in our core analyses. The scales of both groups of flatfish are sufficiently robust to withstand the preservation process, but since Effingham Inlet bottom waters are anoxic, it is unlikely that flatfish would inhabit that part of the basin and hence, scales do not show up in the laminated regions. Sediments deposited during oxygenation episodes in these basins have yet to be examined so representatives of the flatfish may be present in these portions of the cores.

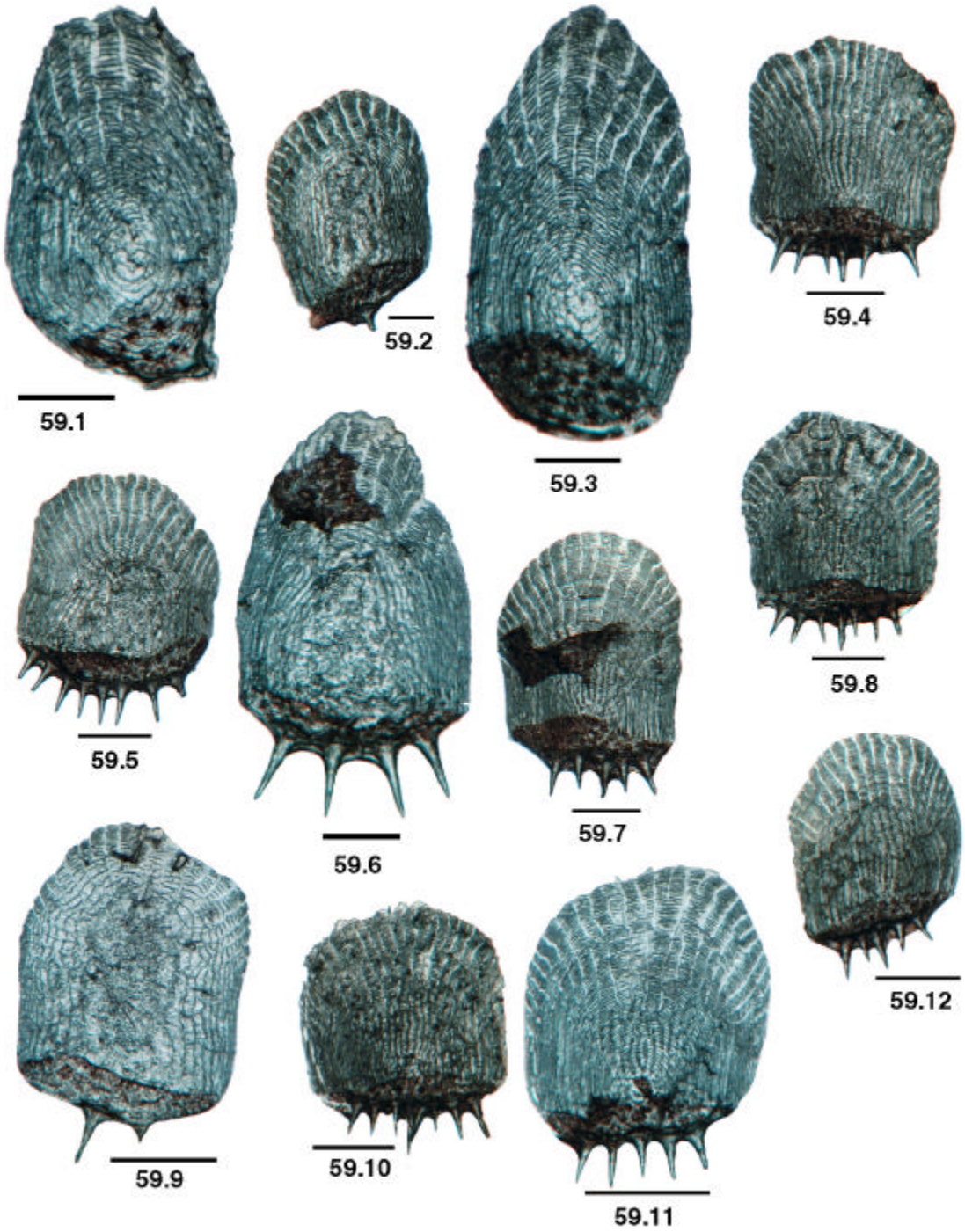


Figure 59.1 - 59.12 (continued on next page). 59.1. Psettichthys melanostictus (Sand Sole); body region A; scale bar = 250 µm. **59.2. Psettichthys melanostictus** (Sand Sole); body region A; scale bar = 250 µm. **59.3. Psettichthys melanostictus** (Sand Sole); body region A; scale bar = 250 µm. **59.4. Psettichthys melanostictus** (Sand Sole); body region C; scale bar = 500 µm. **59.5. Psettichthys melanostictus** (Sand Sole); body region C; scale bar = 500 µm. **59.6. Psettichthys melanostictus** (Sand Sole); body region C; scale bar = 250 µm. **59.7. Psettichthys melanostictus** (Sand Sole); body region C; scale bar = 500 µm. **59.8. Psettichthys melanostictus** (Sand Sole); body region E; scale bar = 500 µm. **59.9. Psettichthys melanostictus** (Sand Sole); body region E; scale bar = 500 µm. **59.10. Psettichthys melanostictus** (Sand Sole); body region E; scale bar = 500 µm. **59.11. Psettichthys melanostictus** (Sand Sole); body region E; scale bar = 500 µm. **59.12. Psettichthys melanostictus** (Sand Sole); body region E; scale bar = 500 µm.

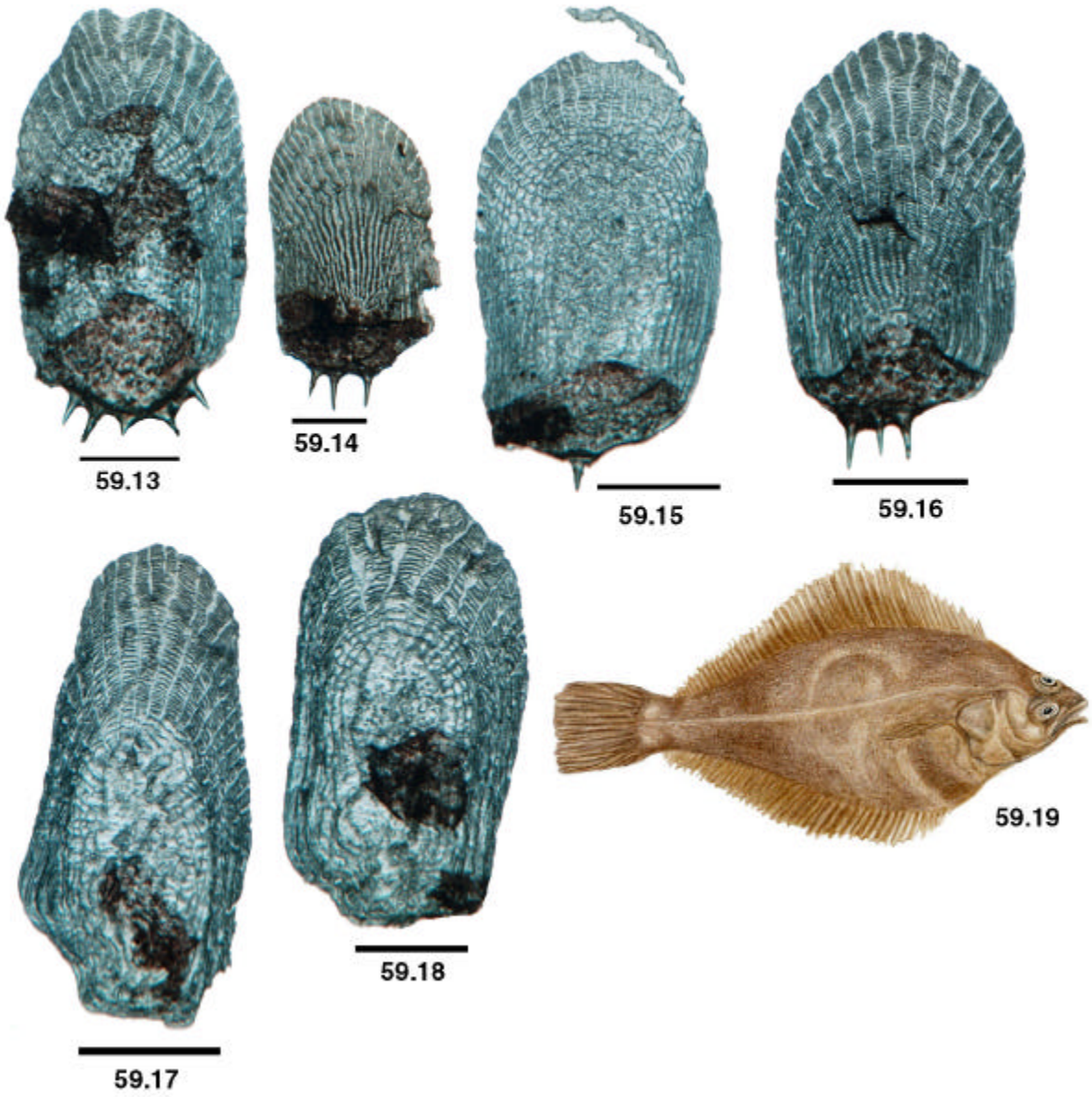


Figure 59.13 - 59.19. 59.13. Psettichthys melanostictus (Sand Sole); body region G; scale bar = 500 µm. **59.14. Psettichthys melanostictus** (Sand Sole); body region I; scale bar = 500 µm. **59.15. Psettichthys melanostictus** (Sand Sole); body region I; scale bar = 500 µm. **59.16. Psettichthys melanostictus** (Sand Sole); body region I; scale bar = 500 µm. **59.17. Psettichthys melanostictus** (Sand Sole); body region J; scale bar = 500 µm. **59.18. Psettichthys melanostictus** (Sand Sole); body region J; scale bar = 500 µm. **59.19. Psettichthys melanostictus** (Sand Sole); sketch of living specimen; length = 63 cm.

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