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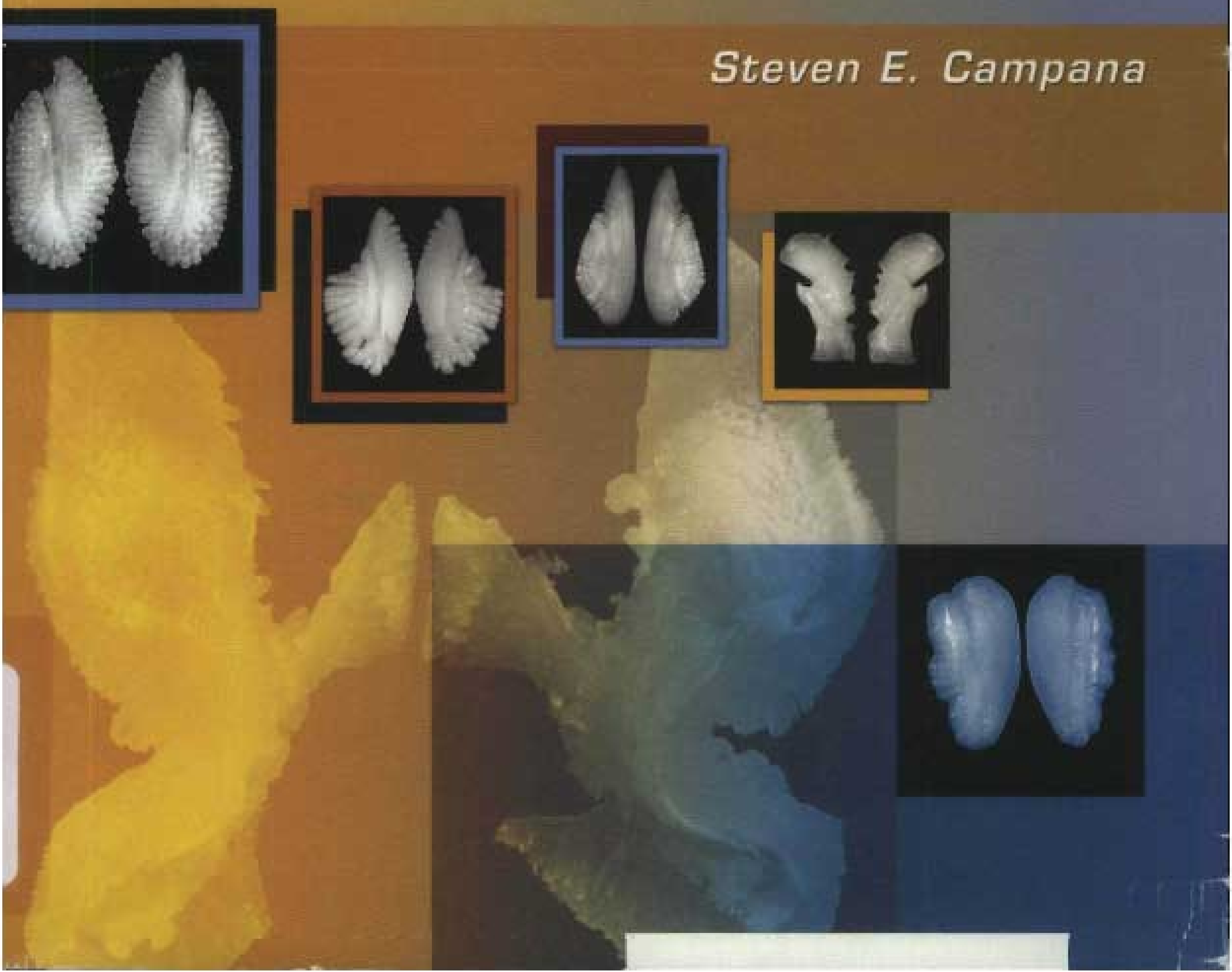
Photographic Atlas of Fish Otoliths of the Northwest Atlantic Ocean

Canadian Special Publication of Fisheries and Aquatic Sciences 133

Steven E. Campana



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Contents

Abstract/Résumé

The shape of fish otoliths is highly species specific. Since otoliths resist degradation better than most other tissues, the shape and size of preserved or undigested otoliths recovered from fossilized sediments, native middens, and the stomachs and droppings of fish predators can be used to reconstruct the species composition of the diet or fish assemblage. This photographic atlas presents light and (or) scanning electron micrographs of 580 pairs of sagittal otoliths representing 288 species, 97 families, and 27 orders of fish from the northwest Atlantic. For most species, multiple individuals across a range of sizes are presented in order to highlight changes in otolith shape with increased size. For 72 of the families, photographs of the lapillar and asteriscal otoliths are also presented.

Chez les poissons, la forme des otolithes est très particulière à chaque espèce. Puisque les otolithes résistent mieux à la dégradation que la plupart des autres tissus, la forme et la taille des otolithes, préservés ou non digérés, prélevés des sédiments fossilisés, des dépotoirs autochtones et des estomacs ou des excréments de prédateurs peuvent être utilisés pour reconstituer la composition taxinomique du régime alimentaire d'un poisson ou de l'habitat dans lequel il vit. Cet atlas photographique propose des images, obtenues à partir de microscopie optique ou de microscopie électronique à balayage, de 580 paires d'otolithes sagittaux, représentant 288 espèces, 97 familles et 27 ordres de poissons de l'Atlantique Nord-Ouest. Pour la plupart des espèces, plusieurs spécimens d'une gamme de tailles variées sont présentés pour mettre en évidence les changements dans la forme des otolithes en fonction de la taille du poisson. Des photographies des asteriscii et des lapilli sont également offertes pour 72 familles.

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Introduction

Otoliths ("earstones") are small, white structures found in the head of all fishes other than sharks, rays, and lampreys. Although they are located within the skull adjacent to the brain, they are not attached to the skull, but are retained within the transparent tubular canals of the inner ear. Otoliths provide a sense of balance to fish in much the same way that the inner ear provides balance in humans. Fish otoliths also aid in hearing (Popper and Lu 2000).

To the fisheries biologist, the otolith is one of the most important tools for understanding the life of fish and fish populations. Growth rings (annuli) not unlike those of a tree record the age and growth of a fish from the date of hatch to the time of death (Casselman 1987). Daily growth increments formed in the first year of life record daily age and growth patterns in surprising, albeit microscopic, detail (Campana and Neilson 1985). In addition, chemical and elemental assays allow the reconstruction of everything from the year of hatch, to migration pathways, to population identity, to the temperature of the water (Campana 1999). Indeed, virtually the entire lifetime of the fish is recorded in the otolith. For that reason, otoliths are used and studied in almost every fisheries laboratory in the world, and form the basis for most age-structured analyses of fish populations around the world (Summerfelt and Hall 1987; Secor et al. 1995; Fossum et al. 2000). Recent estimates indicate that more than 800 000 otoliths were aged worldwide in 1999, with many more analyzed for shape, chemical composition, and other applications (Campana and Thorrold 2001).

Otoliths have a distinctive shape which is highly species specific, but varies widely among species (Maisey 1987). Thus fish, seal, and seabird biologists, as well as taxonomists and archaeologists, often rely on the shape and size of preserved or undigested otoliths to reconstruct the species and size composition of the diet of fish predators (Murie and Lavigne 1985; Jobling and Breiby 1986; Barrett et al. 1990). Preserved otoliths may also serve to identify fossil fish assemblages for phylogenetic or climatological studies (Nolf 1985; Andrus et al. 2002). Identification is aided by the fact that otoliths resist degradation better than most other tissues (Cottrell et al. 1996), and are often the only identifiable animal remains recovered from stomachs and droppings, as well as from Indian middens.

Reference collections of otoliths now exist for several locations around the world, although none claim to be comprehensive. The best published descriptions are those of Smale et al. (1995) for South African fishes, Harkonen (1986) for northeast Atlantic fishes, Morrow (1976) for the Bering Sea, and Nolf (1985) for fossil fishes. Regional collections also exist for Argentina (Volpedo and Echeverria 2000), Antarctica (Hecht 1987; Williams and McEldowney 1990), and the northeastern Pacific (Harvey et al. 2000). There are no published reference collections for the northwest Atlantic, nor do any of the published works contain photographs of the non-sagittal otoliths (the lapilli and asteriscii).

The intention of this book is to provide a photographic reference book for those using or studying the otoliths of fishes of the northwest Atlantic. This work will be of particular interest to those who reconstruct the diet of fish, seals, seabirds, and other fish predators, as well as archaeologists, paleontologists, and taxonomists. Biologists preparing to age previously unstudied fish species will also find the book of value.

This otolith atlas presents light and (or) scanning electron micrographs (SEM) of 580 pairs of sagittal otoliths representing 288 species, 97 families, and 28 orders of fish. Although the species coverage in this book is extensive, it does not include all of the 538 species which have been documented in the northwest Atlantic (although many of these species are considered rare or transient). For most species, multiple individuals across a range of sizes are presented in order to highlight changes in otolith shape with increased size. However, the presentation is limited to post-juvenile stages on account of the relative absence of distinguishing features among larval fish otoliths. For 72 of the families, photographs of the lapillar and asteriscal otoliths are also presented.

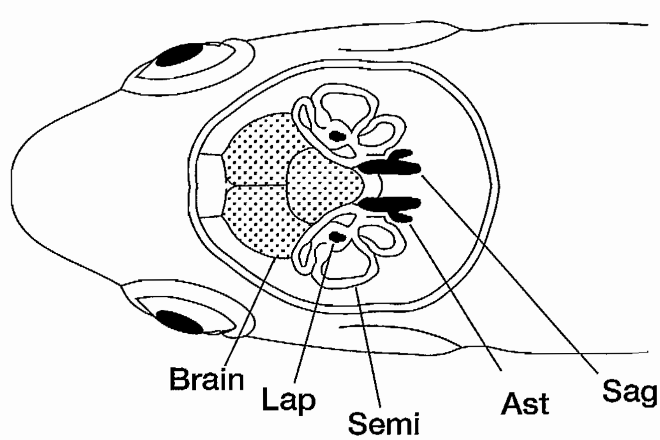
Otolith location and function

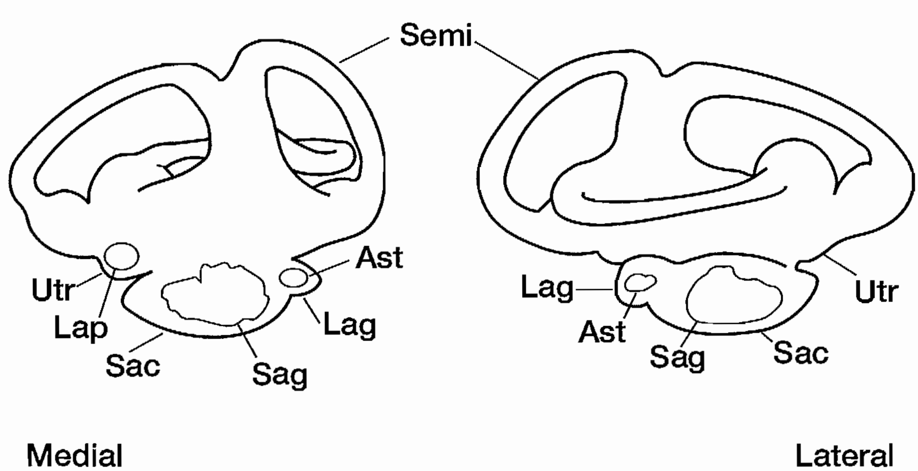
The inner ear is the primary vestibular organ in fishes and other vertebrates, responsible for balance and orientation in three dimensions (Popper and Lu 2000). The inner ear also aids in sound detection in most fishes. The inner ear is located adjacent to the brain, within and occasionally invaginated in the neurocranium (Fig. 1). Composed of a series of interconnecting semi-circular canals, the fluid-filled inner ear looks delicate and translucent but is surprisingly tough. Inner ear architecture varies somewhat among species, but a common feature is the presence of three pairs of chambers, each of which contains an otolith (Fig. 1). Since otoliths are the only solid bodies within the endolymph fluid, changes in orientation and acceleration are detected by slight shifts in the location of the otoliths relative to the surrounding chamber. A sensory epithelium in the form of a macula lies on one wall of the chamber, coupled to the otolith via an otolithic membrane (Popper and Platt 1993). This sensory epithelium is thought to be responsible for the detection of both sound and changes in posture. Thus all otoliths appear to share a vestibular and sound detection function, although the balance between the two functions may vary with the otolith. In general, the lapilli appear to be more associated with posture and the sagittae with sound detection.

The three pairs of otoliths tend to have a size and shape representative of the chamber within which they are held (Fig. 1). Each sacculus contains a sagitta (plural: sagittae), which is often the largest otolith in all but the ostariophysian fishes. The sacculus and sagitta on a given side are usually ventral to the posterior part of the brain, lateral to but close to the midline of the brain. Slightly posterior to each sacculus is a lagena, containing an asteriscus (plural: asteriscii). The asteriscus is so close to the sagitta in many fishes that they are often removed together when the sacculus is pulled out. Considerably more anterior and dorsal on each side is the utriculus containing the lapillus (plural: lapilli). The lapillus is often the smallest of the otoliths.

In ostariophysian (otophysan) fishes, a chain of Weberian ossicles connecting the swimbladder to the inner ear enhances sound detection. In these fishes, the asteriscii are usually larger than the sagittae.

Fig. 1. Schematic of the location of the inner ear and three pairs of otoliths in the skull of a generalized teleost. *Top,* Dorsal view of the inner ear and otoliths in relation to the brain in a cutaway of a fish skull (modified from Secor et al. 1992). *Bottom,* Position of otoliths and otolith chambers in the inner ear of the teleost *Trichogaster* (modified from Popper and Hoxter 1981). Ast, asteriscus; Lag, lagena; Lap, lapillus; Sac, sacculus; Sag, sagitta; Semi, semi-circular canal of labyrinth; Utr, utriculus.





Otolith composition

Otoliths are very pure compared to most biological and mineralogical structures, with the composition being dominated by calcium carbonate in an organic matrix. Most otoliths contain more than 95% by weight of calcium carbonate, with 3–5% in the form of an organic matrix, and less than 1% as non-organic trace impurities. The trace element and stable isotope composition of the otolith has been given extensive study, owing to numerous applications in reconstructing the environmental history, migration, and population identity of fishes (Campana 1999).

Calcium carbonate can crystallize as any one of three crystal polymorphs: calcite, aragonite, or vaterite. However, the vast majority of sagittal and lapillar otoliths are composed of aragonite, which has a milky white appearance (Carlström 1963; Oliveira et al. 1996; Campana 1999). This is unlike the otoconia of mammals, which are composed of calcite.

Curiously, different polymorphs of calcium carbonate appear to be linked to the different otolith organs. While aragonite is the norm for sagittae and lapilli, most asteriscii are made of vaterite, thus accounting for their glassy appearance (Oliveira et al. 1996). Vaterite is also the principal polymorph in many aberrant, or "crystalline", otoliths (Mugiya 1972). Calcitic regions in otoliths are much rarer.

The implications of an otolith composition dominated by calcium carbonate lie most clearly with otolith preservation and stability. Both calcium carbonate and otoliths are stable for many years when stored dry. However, calcium carbonate is acid soluble, so preservation in even weakly acidic solutions will result in dissolution of the otolith.

Otolith morphology

The three pairs of otoliths differ markedly in shape and appearance. In most adult fishes, the sagittae are the largest pair and the lapilli the smallest (Fig. 2). In contrast, asteriscii are larger than sagittae in ostariophysian fishes (a group which includes the minnows and catfish). Sagittal shape differs substantially among species, while lapillar shape is more uniform. The shape of the asteriscii shows intermediate inter-specific variability. Within an otolith pair, the left and right otoliths are very similar, but not identical, mirror images of each other. Interestingly, the left and right asteriscii can differ considerably more in shape than the other otolith pairs (Campana and Casselman 1993).

The orientation and major landmarks of a typical sagitta are shown in the labelled scanning electron microscope (SEM) photo of Fig. 3. The rostrum, antirostrum, and postrostrum are consistent features of all sagittae, although their size and extension varies substantially among species. The sulcus, which represents the point of attachment of the sensory macula, is also a consistent feature of sagittae. Although the fine details of sulcus morphology are not documented here, those details are defined elsewhere and can prove helpful in some species identifications (Nolf 1985; Smale et al. 1995). An intricate morphology is also evident in the SEM images of asteriscii, but less so in the case of the lapilli (Fig. 4). It is possible that inter-specific differences in the shape of asteriscii and lapilli could be used to complement the differences observed in the sagittae. However, in light of the relatively small size of the lapilli and sagittae, SEM would probably be required by the end user to observe all but the most gross of morphological differences.

In any given species, otolith size and shape often changes substantially with fish growth (Fig. 5). In virtually all young fish larvae, otoliths tend to be relatively featureless: spherical or smoothly oblate in most species, and discoid in species (such as salmonids) which hatch at a larger size. In most species, the sagittae and lapilli are present at hatch, while the asteriscii first appear at an age of 2–3 weeks. At this early stage of fish development, relative otolith sizes can be inverted, with lapilli being larger than sagittae (Campana 1989). Otoliths first acquire the main features of their mature shape in the juvenile stage. As the size-specific photos of this atlas demonstrate, otolith shape can remain diagnostic but still change in later life as the fish (and otolith) grows. As a result, otolith size must be taken into consideration, as well as shape, when identifying a species from an otolith. In particular, the otolith shape of very large fish can differ substantially from those of average-sized adults.

Because of their function in maintaining the balance of the fish, otoliths tend to grow as the fish grows. Therefore, there is almost always a strong relationship between otolith size and fish size (Hunt 1992). Given a measurement of otolith size (whether in terms of length or weight), it is possible to estimate the length of the fish from which the otolith was obtained (Fig. 6). These estimates provide useful approximations of fish length, but cannot be interpreted too strictly, since the fish-otolith regression often differs among populations or groups of fish with different growth rates (Campana 1990). It is also important to note that the relationship between fish and otolith length is not necessarily linear, and that the relationship for larvae is often very different from that for adults.

Fig. 2. Light micrograph of the three pairs of otoliths from a 23-cm adult white perch (*Morone americana*). The left-hand otolith of each pair is shown on the left side.

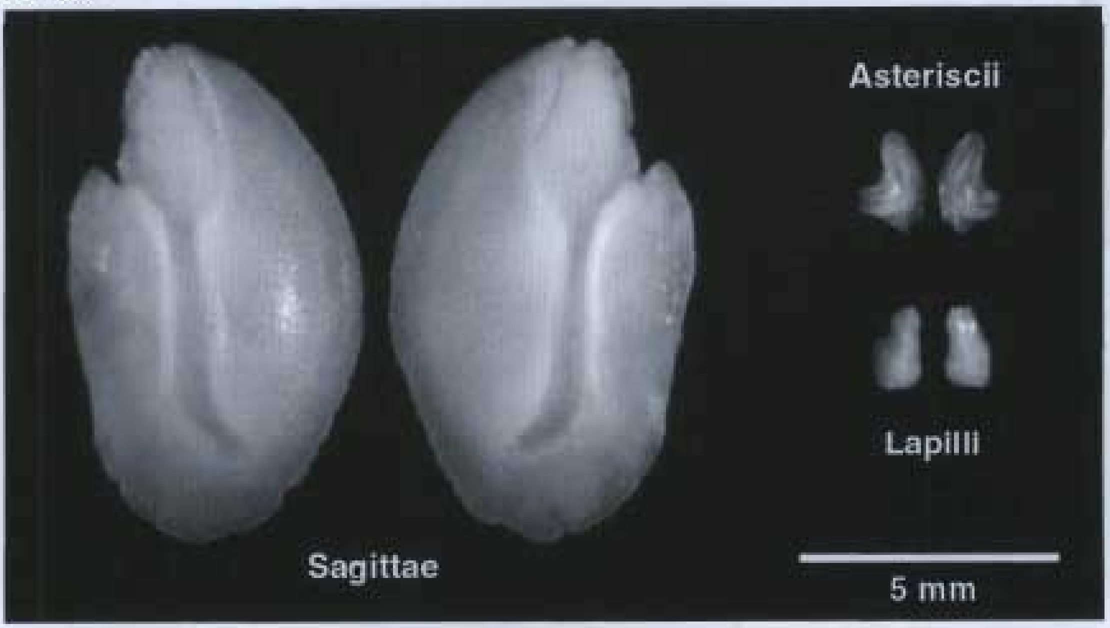


Fig. 3. Morphology of a haddock (*Melanogrammus aeglefinus*) sagitta evident in proximal (top sagitta) and distal (bottom sagita) views with SEM.

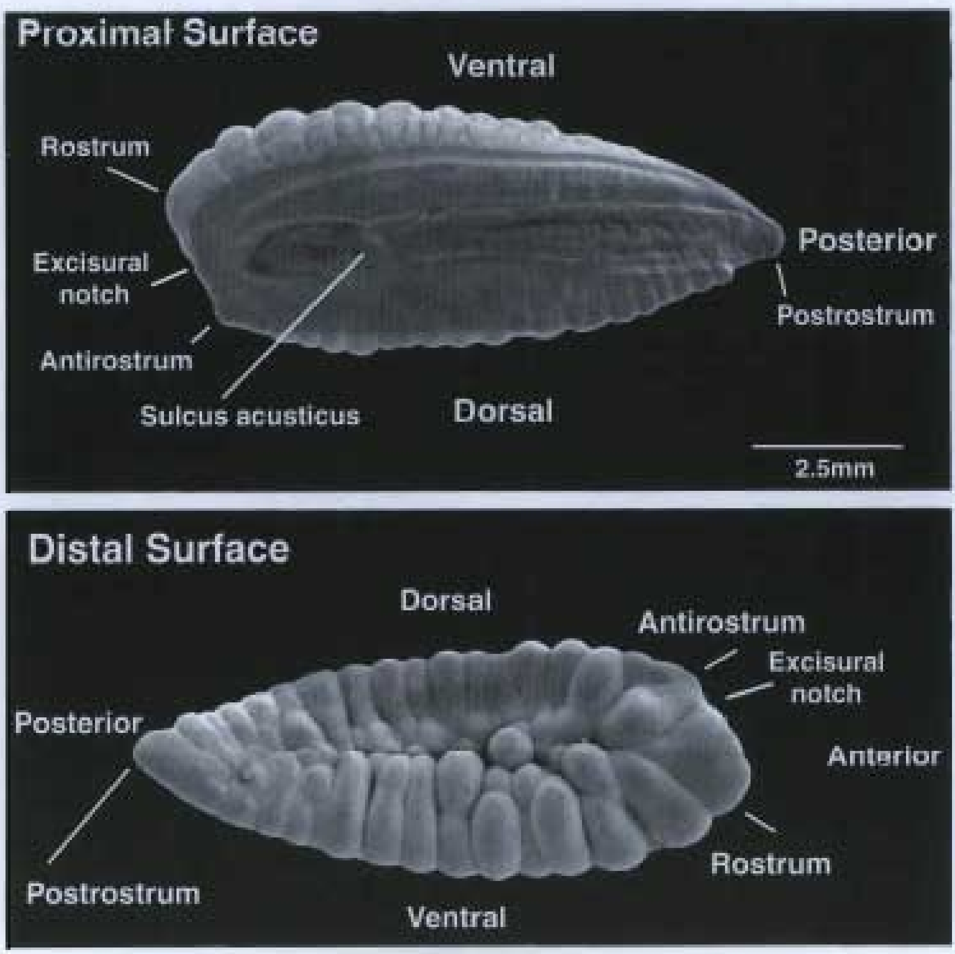


Fig. 4. Morphology of a cod (*Gadus morhua*) asteriscus (left panel) and lapillus (right panel) evident in top and bottom views with SEM.

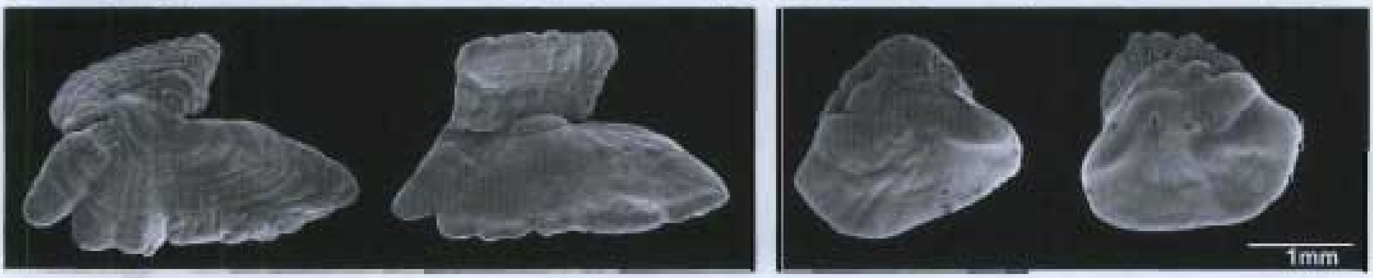


Fig. 5. Ontogenetic sequence showing the change in size and shape of a haddock sagitta from the larval stage (37 days old) to that of a 6-year-old adult. Note that the individual images have been re-scaled to allow presentation in a single figure; use scale bars for correct size.

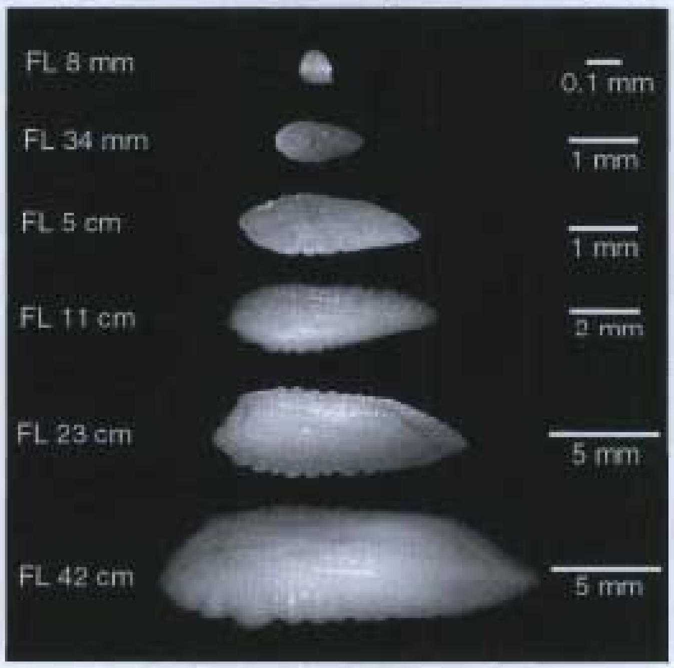
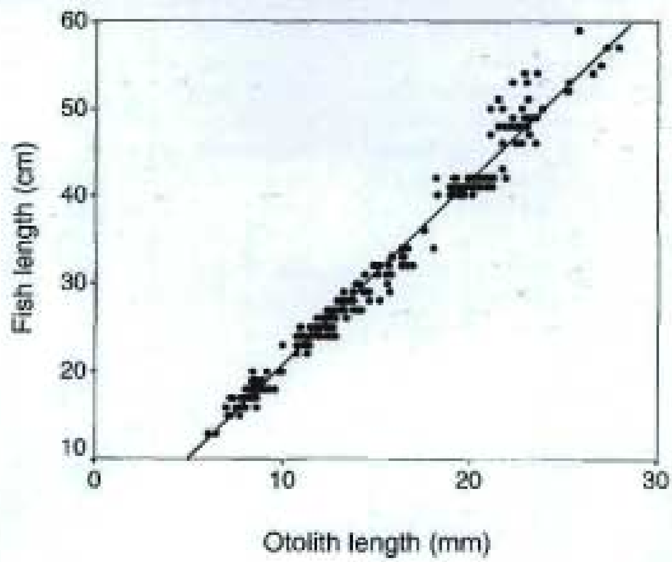


Fig. 6. Relationship between fish length and sagittal length in silver hake (*Merluccius bilinearis*; $n = 235$; $r^2 = 0.97$), which could be used to predict fish length based on the size of the recovered otolith. A linear relationship between fish and otolith size is characteristic of the juvenile and adult stages of most fish species, but the same relationship seldom applies to the larval stage.



Biological factors affecting otolith morphology

There are a broad range of biological factors which influence or moderate otolith shape. These factors can operate at a range of scales, from that of general phylogeny to the individual level. Few of these factors are well understood, but those that are known or suspected are mentioned here.

There are no broad phylogenetic principles which are known to guide otolith shape (Maisey 1987). Although family- or genus-level otolith characteristics are often present, it is often impossible to predict otolith shape for any given species. There may be functional relationships however. Based on numerous observations, I have noted that fast-swimming fishes capable of rapid acceleration and turning tend to have smaller otoliths than their slower swimming counterparts. The tunas and swordfish are good examples of this phenomenon, whereby the sagittal otolith of a 400-kg bluefin tuna (*Thunnus thynnus*) is smaller than that of a 1-kg cod. Species capable of good sound production (and presumably good sound detection) can also be expected to have large saggital otoliths. Members of the Sciaenidae (grunts and drums) are characteristic of this group; species such as the black drum (*Pogonias cromis*) have sagittae which are among the largest observed. In contrast, the families within the group Ostariophysii (such as cyprinids and catfishes), which possess a chain of Weberian ossicles to enhance sound detection, have somewhat smaller sagittae and larger asteriscii than normal.

Within a species, otolith shape can vary with the sex, population, and growth rate, as well as the stage of ontogeny described in the previous section. The magnitude of shape differences due to ontogeny and fish size is considerably larger than that due to sex, population, and growth rate, since the effect of the latter factors may be detectable only through statistical analysis (Campana and Casselman 1993; Cardinale et al. 2003).

In general, otoliths within an otolith pair are very similar but non-identical mirror images of each other. However, left versus right asymmetry is common in flatfish, a fish in which the eyes migrate to the same side of the head at around the time of metamorphosis to the settled juvenile. The presence or degree of asymmetry seems to vary among individuals, and is most evident in large individuals. In general, however, the sagitta found on the upper side of the fish (the right otolith in right-eyed flatfish) is irregularly shaped or occasionally shorter and thicker than the sagitta which faces down in the adult fish. The functional significance of this otolith asymmetry is unknown, but is presumably related to a reduced or altered function in one of the two otoliths.

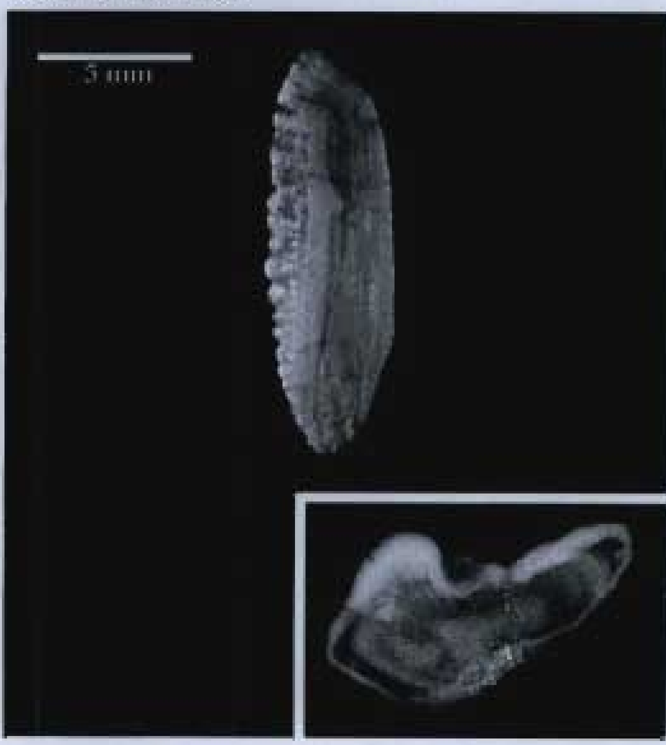
Effects of preservation on otolith morphology

The shape and size of otoliths recovered from the stomach or feces of fish predators has long been used to reconstruct the species and size composition of the predator's diet (Murie and Lavigne 1985; Jobling and Breiby 1986; Barrett et al. 1990; Pierce et al. 1991; Bowen et al. 1993; Dolloff 1993; Burns et al. 1998). In many cases, there are few alternatives, since otoliths are often the only animal remains that are recovered, let alone identified to species. Nevertheless, there are limitations to this application. Several studies have fed fish of known species and size composition to seals, and then recovered the ingested otoliths from the stomachs or feces (Dellinger and Trillmich 1988; Cottrell et al. 1996; Tollit et al. 1997; Bowen 2000). In all cases, sources of bias have been noted, associated primarily with the relatively rapid dissolution of small and (or) fragile otoliths in the acidic stomach environment. As a result, it seems likely that any dietary reconstruction could underestimate the contribution from fish species with small otoliths, or from smaller individuals. Even where complete otolith dissolution does not occur, partial dissolution can leave an otolith unrecognizable to species, or perhaps smaller than its original size. Examples of partial dissolution of otoliths recovered from seal droppings are shown in Fig. 7.

Preserved otoliths may also serve to identify fossil fish assemblages (Elder et al. 1996), date sedimentary strata (Gaemers 1984), reconstruct historical populations (Hales and Reitz 1992), prepare phylogenies (Nolf 1995), reconstruct ancient climates (Ivany et al. 2000; Andrus et al. 2002), and provide indicators of seasonal occupation for ancient peoples (Van Neer et al. 1993). Such otoliths may be recovered from aquatic sediments, fossil grounds, or archaeological middens, where they have been exposed to possibly acidic conditions or chemical leaching. Such conditions have the potential to bias reconstructions of past assemblages, if otoliths have been dissolved, or to alter climatic reconstructions if chemical leaching has occurred. However, other indicators can often be used to determine if otolith alteration has occurred. In the case of archaeological applications, bias is not usually a problem, since the growth increments used to determine seasonality are either present or absent. For reasons not fully understood, otoliths in some fossil middens may sustain little damage after thousands of years of preservation, while others are rendered illegible after only a few hundred years (Fig. 8).

Fig. 7. Morphology of silver hake (*Merluccius bilinearis*) sagittae recovered from seal droppings, reflecting increasing effects of digestion from left to right. The image on the far left is that of an undigested silver hake sagitta.

Fig. 8. Photo of an Atlantic tomcod (*Microgadus tomcod*) otolith recovered from a midden after about 600 years of burial. The otolith surface retains most of its detail, and thus can be used for species identification. However, a transverse section (inset) indicates that diagenesis has occurred, obscuring much of the age and seasonality information.



Methods

All identifications of common species were confirmed with established keys for the region (Scott and Scott 1988; Bigelow and Schroeder 1953). For unusual species, or for any fish where there was the slightest uncertainty concerning species identity, identification was confirmed by fish taxonomists. Uncertainty concerning the validity of existing classifications for the liparids, including the probable presence of undescribed species in the northwest Atlantic, suggest that caution should be used in the interpretation of this family (Lou Van Guelpen, Huntsman Marine Science Centre, St. Andrews, NB, personal communication). The taxonomic status of Ammodytes spp. is also unknown. All family associations and phylogenies were based on Nelson (1994).

Source fish used to provide otoliths were either frozen or preserved in 95% ethanol, so as to insure complete preservation of the otoliths. In the few instances where fish were fixed in formalin for a few days prior to otolith removal, the formalin was first made basic to a pH of 8–9 through addition of sodium carbonate. All three pairs of otoliths were removed wherever possible; removal of the inner ear canals made it easier to identify left and right pairs. Adhering tissue was removed immediately after removal. Otoliths were then stored dry until the time of examination.

The default method of photography for all otolith pairs was with reflected light under a dissecting microscope at a magnification of 3–40 times. Previous otolith atlases have used either SEM photography or line drawings, both of which provide excellent representations of otolith shape, but neither of which make the otolith appear as it would to the atlas user. Since most users rely on reflected light microscopy for otolith examination, light microscopic images can be particularly helpful in an atlas. Oblique lighting with a dual fibre optic light source helped provide visual contrast to the images. Sagittal otolith pairs were first photographed on the medial side, then turned over and photographed on the distal side. Lapillar and asteriscal pairs were photographed from a single side only. Images were captured with a digital video camera at a resolution of 1280 × 1024. All images were automatically digitally enhanced to improve contrast or sharpen edges, but not at the expense of making the images appear artificial. Optimas software was used for image capture and automated enhancement, while Photoshop was used for any subsequent enhancements.

SEM images were prepared for sagittae of most species in order to capture morphological detail in and around the sulcus. Sagittae were prepared for SEM by coating with carbon in a vacuum evaporator. Photographs were taken at a magnification of 18–35 times.

Using the atlas

Fish systematics is an evolving science; hence species affiliations within a family are not necessarily stable. For this reason, this atlas is arranged alphabetically by order, rather than phylogenetically. Within each order, families are presented alphabetically, as are species within families. A key to identify unknown otoliths to the order or family level was attempted but was discontinued, owing to the difficulty of providing diagnostic keys which take into account the changing shape of many otoliths with increasing size. However, outlines of "representative" sagittae for each order are provided in Fig. 9. It is important to note that there can be wide variations in otolith shape within orders and families, and that "representative" outlines are not necessarily representative. This is particularly true for the Perciformes, which comprises dozens of families.

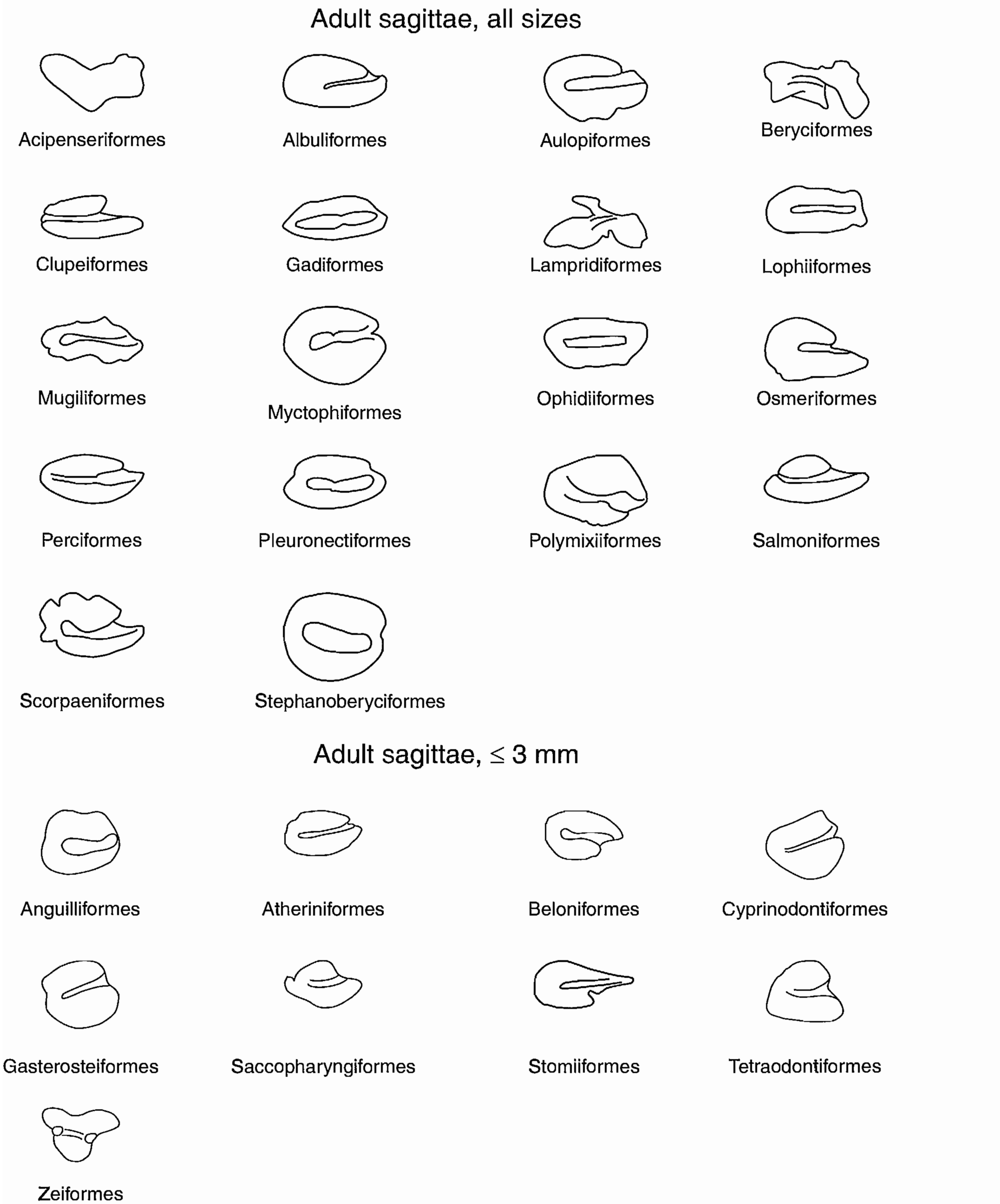
For most species, representative otolith images occupy the entire page. Where available, an SEM image of the sagitta heads the page in order to highlight details of the sulcus. For at least one species of each family, an accompanying pair of light microscopic images to the right of the SEM image shows the lapilli and asteriscii (note, however, that left- and right-side identifications of these two otolith pairs are not neccesarily correct). Below these images are a series of light microscopic images showing multiple pairs of sagittae from fish of different sizes, arranged from smallest to largest. Image scales often vary across the images, so the accompanying scale bar should be used to estimate otolith size. Each sagittal pair is shown both medial side up (sulcus side) and distal side up, with the left otoliths arranged on the left side of the image panel wherever possible. In most cases, the rostrum and antirostrum are oriented up. However, it was not always possible to identify the rostrum in some sagittae; hence caution is required in interpreting the otolith orientations too strictly.

In most cases, external profile will be sufficient to identify an otolith to species. The key features include the relative size of the rostrum, antirostrum, postrostrum, and excisural notch. The length of the sulcus can also be diagnostic. Where morphological details of the sulcus are required, it can be difficult to view these details with a light microscope. However, use of oblique lighting is often helpful in providing visual contrast. Further contrast can be provided by sprinkling powdered graphite over the medial surface of the sagitta, and then lightly tapping the otolith on its side to remove any excess. Alternatively, a graphite pencil can rubbed over the sulcus region. If this is not sufficient, SEM may be required.

Clearly, intact and well-preserved otoliths will be easier to identify than will those which have been degraded or eroded. Although freshly removed otoliths provide excellent samples, otoliths which have been stored dry after removal remain in excellent condition almost indefinitely. Fish which have remained frozen after capture also provide well-preserved otoliths, as will those which have been preserved in 95% ethanol. Note, however, that ethanol becomes increasingly acidic as concentration drops, and that otoliths will dissolve in concentrations below about 70–80%. In addition, ethanol concentration declines soon after the fish carcass is added, owing to dilution from the water in the fish tissues. Complete ethanol replacement after 12–24 hours helps keep concentrations high. Formalin is not a recommended preservative for fish otoliths, since even buffered formalin is slightly acidic and will dissolve otoliths. However, short-term storage in formalin is possible if the formalin is first made basic with sodium carbonate to a pH of at least 8.

It is often possible to identify the characteristics of otolith dissolution or degradation. Rounded edges, particularly at the tips of the rostrum and postrostrum, often occur during digestion in an acidic stomach, and can signify an overall loss of material and size. Discolouration (usually brown or black) is a sign of degradation seen in both formalin-preserved material and in otoliths from archaeological sites. A chalky white appearance is a sign of exposure to mildly acidic conditions. None of these conditions should be confused with the irregular glassy appearance of "crystalline" otoliths, which are uncommon but natural occurrences in most species of fishes.

Fig. 9. Schematic outlines of adult sagittae representing each of the 27 orders of fish found in this atlas. The two sections of the figure separate orders in which the sagittae span a broad range of sizes (*top*) from those where the sagittae are typically ≤3 mm in diameter (*bottom*). Note that "representative" outlines are difficult to provide for orders such as the Perciformes, which contains many families.



References

Andrus, C.F., Crowe, D.E., Sandweiss, D.H., Reitz, E.J., and Romanek, C.S. 2002. Otolith $\delta^{18}O$ record of mid-Holocene sea surface temperatures in Peru. Science, **295**: 1508–1511.

Barrett, R.T., Rov, N., Loen, J., and Montevecchi, W.A. 1990. Diets of shags *Phalacrocorax aristotelis* and cormorants *P. carbo* in Norway and possible implications for gadoid stock recruitment. Mar. Ecol. Prog. Ser. **66**: 205–218.

Bigelow, H.B., and Schroeder, W.C. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv. Fish. Bull. 74. Vol. 53. 577 p.

Bowen, W.D. 2000. Reconstruction of pinniped diets: accounting for complete digestion of otoliths and cephalopod beaks. Can. J. Fish. Aquat. Sci. **57**: 898–905.

Bowen, W.D., Lawson, J.W., and Beck, B. 1993. Seasonal and geographic variation in the species composition and size of prey consumed by grey seals (*Halichoerus grypus*) on the Scotian Shelf. Can. J. Fish. Aquat. Sci. **50**: 1768–1778.

Burns, J.M., Trumble, S.J., Castellini, M.A., and Testa, J.W. 1998. The diet of Weddell seals in McMurdo Sound, Antarctica as determined from scat collections and stable isotope analysis. Polar Biol. **19**: 272–282.

Campana, S.E. 1989. Otolith microstructure of three larval gadids in the Gulf of Maine, with inferences on early life history. Can. J. Zool. **67**: 1401–1410.

Campana, S.E. 1990. How reliable are growth backcalculations based on otoliths? Can. J. Fish. Aquat. Sci. **47**: 2219–2227.

Campana, S.E. 1999. Chemistry and composition of fish otoliths: pathways, mechanisms and applications. Mar. Ecol. Prog. Ser. **188**: 263–297.

Campana, S.E., and Casselman, J.M. 1993. Stock discrimination using otolith shape analysis. Can. J. Fish. Aquat. Sci. **50**: 1062–1083.

Campana, S.E., and Neilson, J.D. 1985. Microstructure of fish otoliths. Can. J. Fish. Aquat. Sci. **42**: 1014–1032.

Campana, S.E., and Thorrold, S.R. 2001. Otoliths, increments and elements: keys to a comprehensive understanding of fish populations? Can. J. Fish. Aquat. Sci. **58**: 30–38.

Cardinale, M., Doering-Arjes, P., Kastowsky, M., and Mosegaard, H. 2003. Effects of sex, stock and environment on the shape of Atlantic cod (*Gadus morhua*) otoliths. Can. J. Fish. Aquat. Sci. In press.

Carlström, D. 1963. A crystallographic study of vertebrate otoliths. Biol. Bull. **124**: 441–463.

Casselman, J.M. 1987. Determination of age and growth. *In* The Biology of Fish Growth. Chap. 7. *Edited by* A.H. Weatherley and H.S. Gill. Academic Press, New York. p. 209–242.

Cottrell, P.E., Trites, A.W., and Miller, E.H. 1996. Assessing the use of hard parts in faeces to identify harbour seal prey: results of captive feeding trials. Can. J. Zool. **74**: 875–880.

Dellinger, T., and Trillmich, F. 1988. Estimating diet composition from scat analysis in otariid seals (*Otariidae*): is it reliable? Can. J. Zool. **66**: 1865–1870.

Dolloff, C.A. 1993. Predation by river otters (Lutra canadensis) on juvenile coho salmon (*Oncorhynchus kisutch*) and Dolly Varden (*Salvelinus malma*) in southeast Alaska. Can. J. Fish. Aquat. Sci. **50**: 312–315.

Elder, K.L., Jones, G.A., and Bolz, G. 1996. Distribution of otoliths in surficial sediments of the U.S. Atlantic continental shelf and slope and potential for reconstructing Holocene fish stocks. Paleoceanography, **11**: 359–367.

Fossum, P., Kalish, J., and Moksness, E. 2000. 2nd International Symposium on Fish Otolith Research and Application, Bergen, Norway, 20–25 June 1998. Fish. Res. **46**: 1–371.

Gaemers, P.A.M. 1984. Fish otoliths from the Bassevelde sand (Late Tongrian) of Ruisbroek, Belgium, and the stratigraphy of the early Oligocene of Belgium. Meded. Werkgr. Tert. Kwart. Geol. **46**: 237–267.

Hales, Jr., L.S., and Reitz, E.J. 1992. Historical changes in age and growth of Atlantic croaker, *Micropogonias undulatus* (Perciformes: Sciaenidae). J. Archaeol. Sci. **19**: 73–99.

Harkonen, T. 1986. Guide to the otoliths of the bony fishes of the northeast Atlantic. Danbiu ApS. Biological Consultants, Hellerup, Denmark. 256 p.

Harvey, J.T., Loughlin, T.R., Perez, M.A., and Oxman, D.S. 2000. Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean. NOAA Tech. Rep. NMFS, **150**: 1–36.

Hecht, T. 1987. A guide to the otoliths of southern ocean fishes. S. Afr. T. Nav. Antarkt. **17**: 1–87.

Hunt, J.J. 1992. Morphological characteristics of otoliths for selected fish in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. **13**: 63–75.

Ivany, L.C., Patterson, W.P., and Lohmann, K.C. 2000. Cooler winters as a possible cause of mass extinctions at the Eocene/Oligocene boundary. Nature (London), **407**: 887–890.

Jobling, M., and Breiby, A. 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. Sarsia, **71**: 265–274.

Maisey, J.G. 1987. Notes on the structure and phylogeny of vertebrate otoliths. Copeia, **2**: 495–499.

Morrow, J.E. 1976. Preliminary keys to otoliths of some adult fishes of the Gulf of Alaska, Bering Sea, and Beaufort Sea. NOAA Tech. Rep. NMFS Circ. **420**: 1–32.

Mugiya, Y. 1972. On aberrant sagittas of teleostean fishes. Jpn. J. Ichthyol. **19**: 11–14.

Murie, D.J., and Lavigne, D.M. 1985. Interpretation of otoliths in stomach content analyses of phocid seals: quantifying fish consumption. Can. J. Zool. **64**: 1152–1157.

Nelson, J.S. 1994. Fishes of the world. John Wiley and Sons, Toronto. 600 p.

Nolf, D. 1985. Otolithi Piscium. *In* Handbook of Paleoichthylogy. Vol. 10. *Edited by* H.-P. Schultze. Gustav Fischer Verlag, New York. 145 p.

Nolf, D. 1995. Studies on fossil otoliths — the state of the art. *In* Recent Developments in Fish Otolith Research. *Edited by* D.H. Secor, J.M. Dean, and S.E. Campana. University of South Carolina Press, Columbia, SC. p. 513–544.

Oliveira, A.M., Farina, M., Ludka, I.P., and Kachar, B. 1996. Vaterite, calcite and aragonite in the otoliths of three species of piranha. Naturwissenschaften, **83**: 133–135.

Pierce, G.J., Boyle, P.R., and Diack, J.S.W. 1991. Identification of fish otoliths and bones in faeces and digestive tracts of seals. J. Zool. (London), **224**: 320–328.

Popper, A.N., and Hoxter, B. 1981. The fine structure of the sacculus and lagena of a teleost fish. Hear. Res. **5**: 245–263.

Popper, A.N., and Lu, Z. 2000. Structure–function relationships in fish otolith organs. Fish. Res. **46**: 15–25.

Popper, A.N., and Platt, C. 1993. Inner ear and lateral line. *In* Physiology of Fishes. *Edited by* D.H. Evans. CRC Press, London, UK. p. 99–136.

Scott, W.B., and Scott, M.G. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219. 731 p.

Secor, D.H., Dean, J.M., and Laban, E.H. 1992. Otolith removal and preparation for microstructural examination. *In* Otolith microstructure examination and analysis. Canadian Special Publication of Fisheries and Aquatic Sciences 117. *Edited by* D.K. Stevenson and S.E. Campana. p. 19–57.

Secor, D.H., Dean, J.M., and Campana, S.E. (*Editors*). 1995. Recent developments in fish otolith research. University of South Carolina Press, Columbia, SC. 735 p.

Smale, M.J., Watson, G., and Hecht, T. 1995. Otolith atlas of southern African marine fishes. Ichthylological monographs of the J.L.B. Smith Institute of Ichthyology. Vol. 1. p. xiv. 253 p.

Summerfelt, R.C., and Hall, G.E. (*Editors*). 1987. Age and growth of fish. Iowa State University Press, Ames, IA. 544 p.

Tollit, D.J., Steward, M.J., Thompson, P.M., Pierce, G.J., Santos, M.B., and Hughes, S. 1997. Species and size differences in the digestion of otoliths and beaks: implications for estimates of pinniped diet composition. Can. J. Fish. Aquat. Sci. **54**: 105–119.

Van Neer, W., Augustynen, S., and Linkowski, T. 1993. Daily growth increments on fish otoliths as seasonality indicators on archaeological sites: the tilapia from late palaeolithic Makhadma in Egypt. Inter. J. Osteoarch. **3**: 241–248.

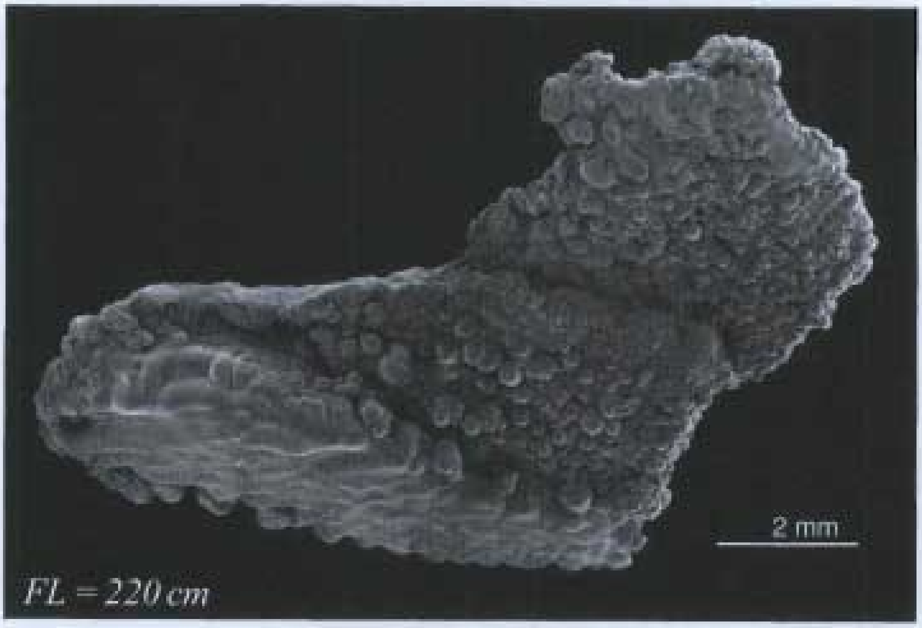
Volpedo, A.V., and Echeverria, D.D. 2000. Cataloga y claves de otolitos para las identificacion de peces del mar Argentino. Editorial Dunken, Buenos Aires. 88 p.

Williams, R., and McEldowney, A. 1990. A guide to the fish otoliths from waters off the Australian Antarctic Territory, Heard and Macquarie Islands. ANARE (Aust. Natl. Antarct. Res. Exped.) Res. Notes 75. Australian National Antarctic Research Expeditions, Kingston, Tasmania. 173 p.

Photographic plates

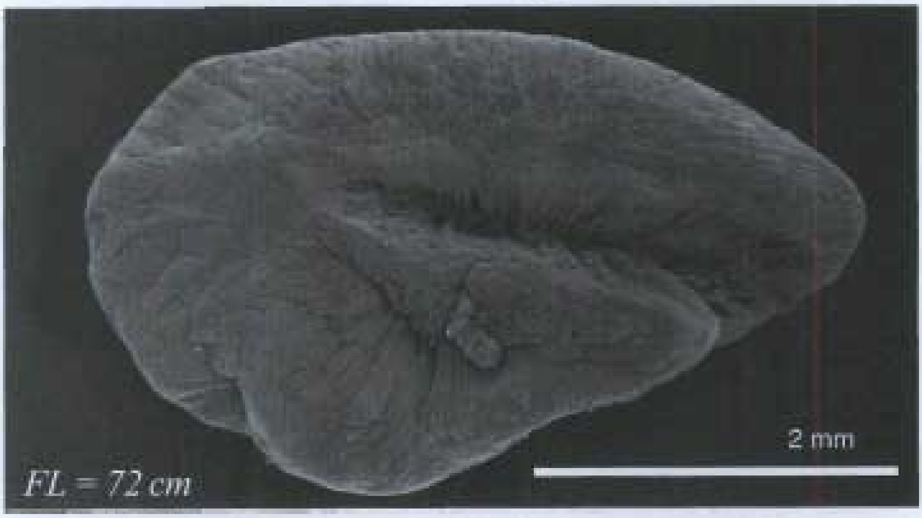
Acipenseriformes

Acipenseridae: *Acipenser oxyrhynchus*



Albuliformes

Halosauridae: *Halosauropsis macrochir*



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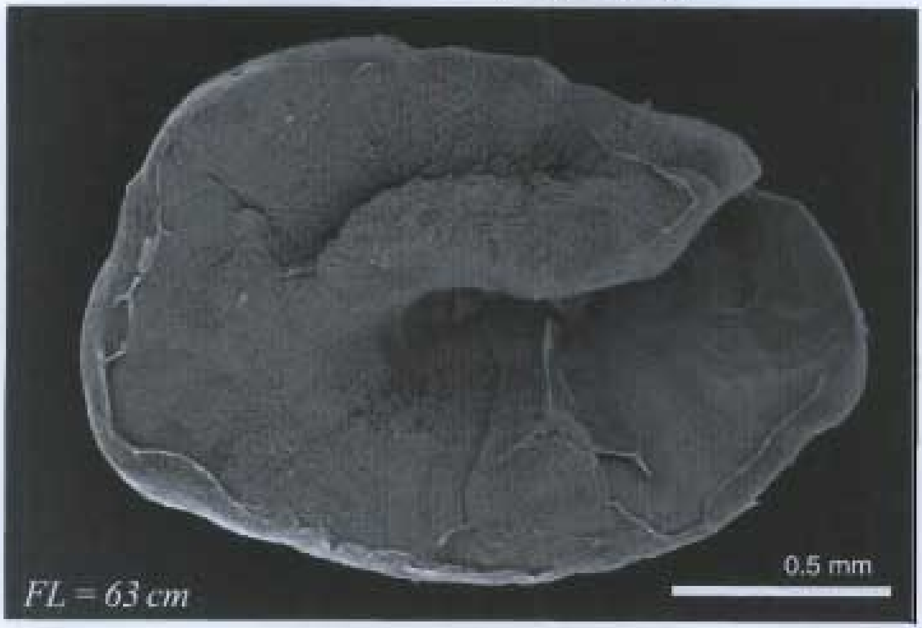

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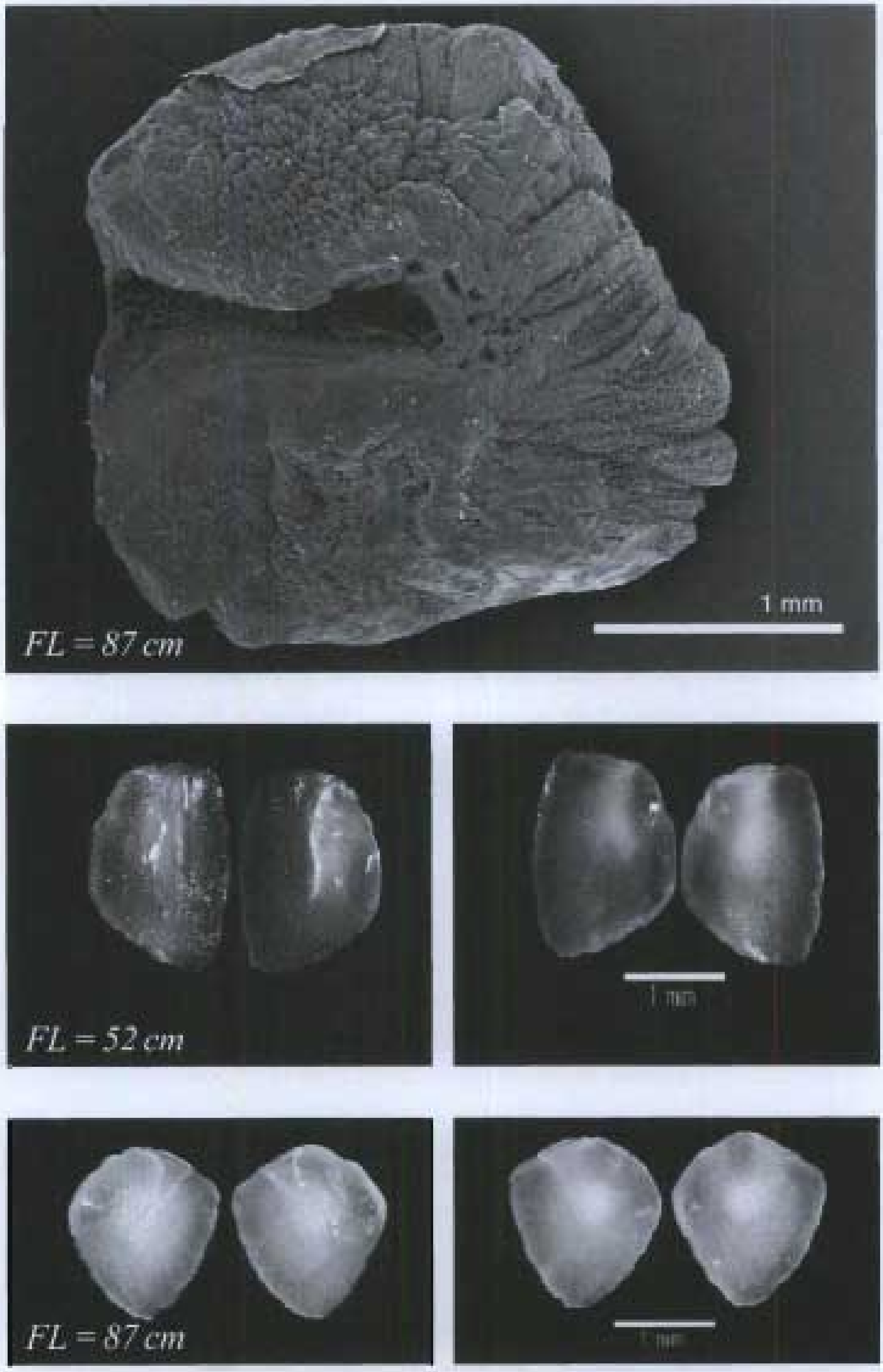
Notacanthidae: *Notacanthus chemnitzi*



Albuliformes

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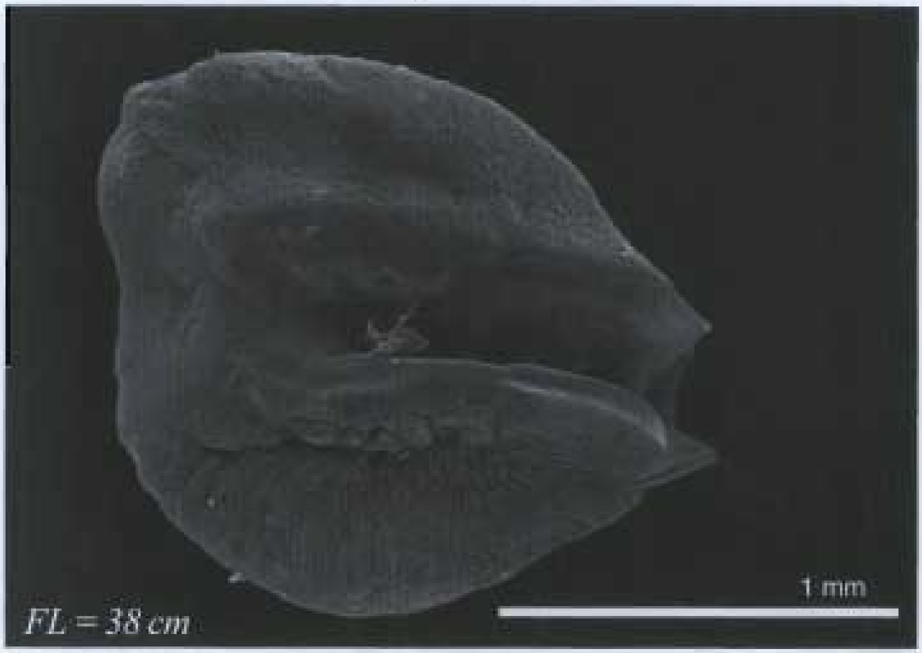
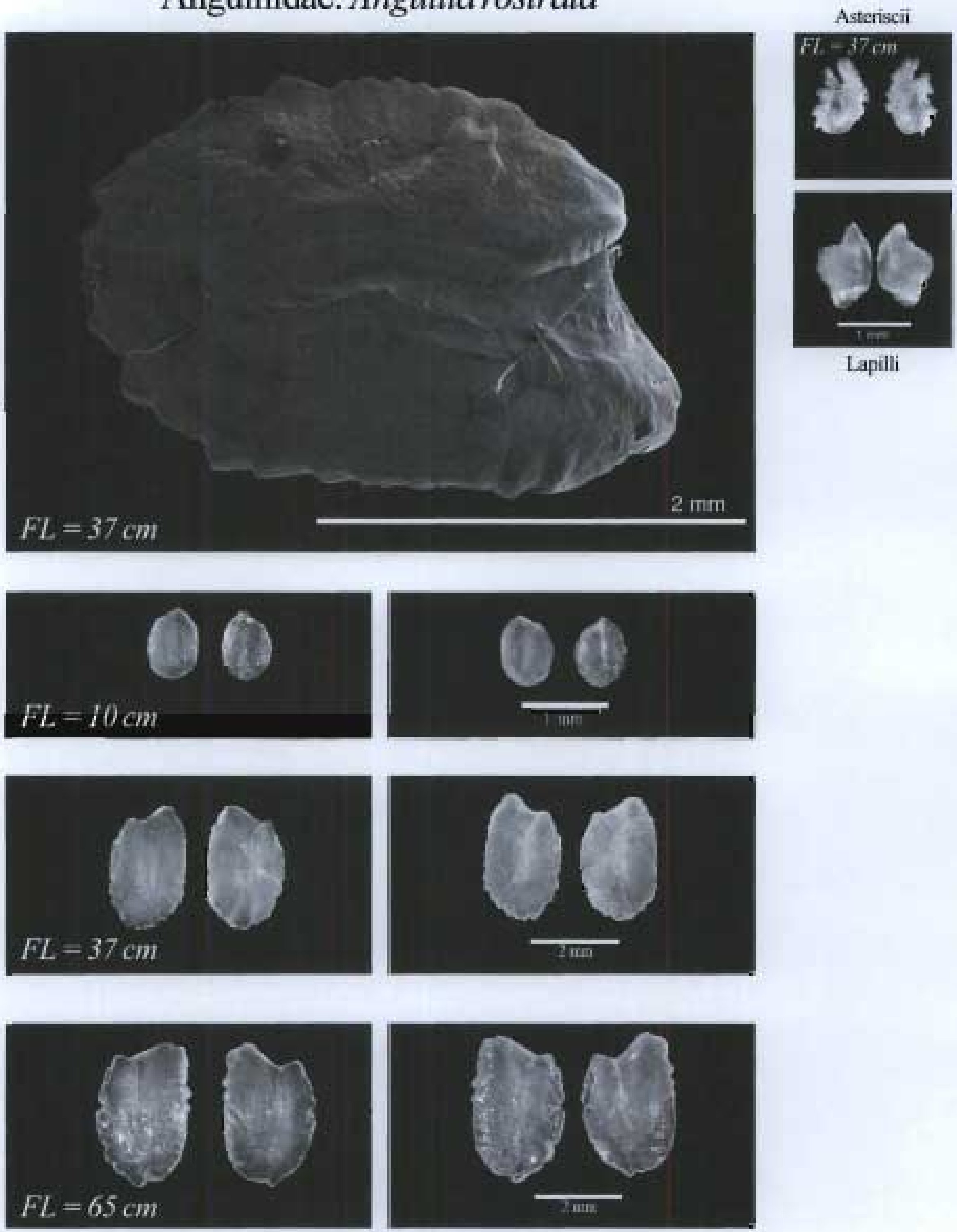


Anguilliformes

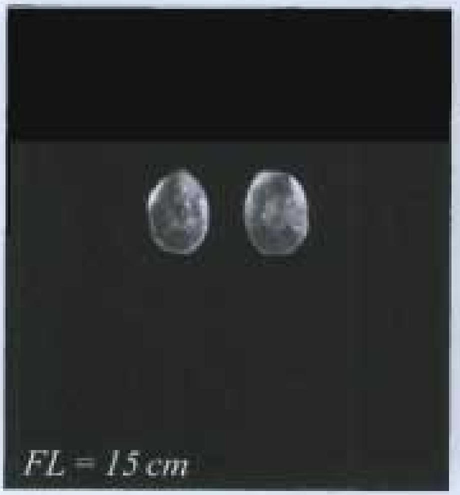
Anguillidae: *Anguilla rostrata*

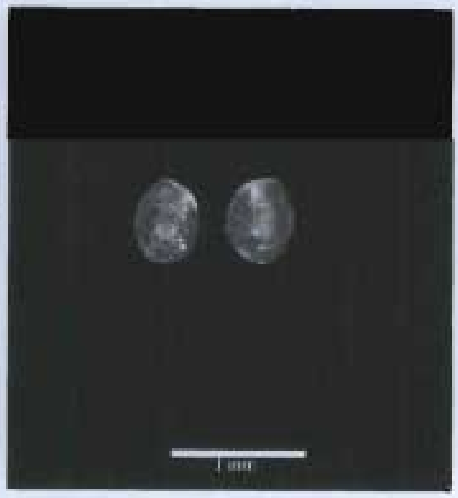


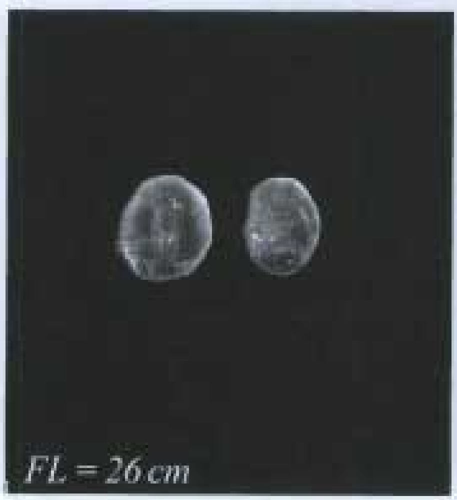
Anguilliformes

Derichthyidae: *Derichthys serpentinus*

Asteriscii
& Lapilli

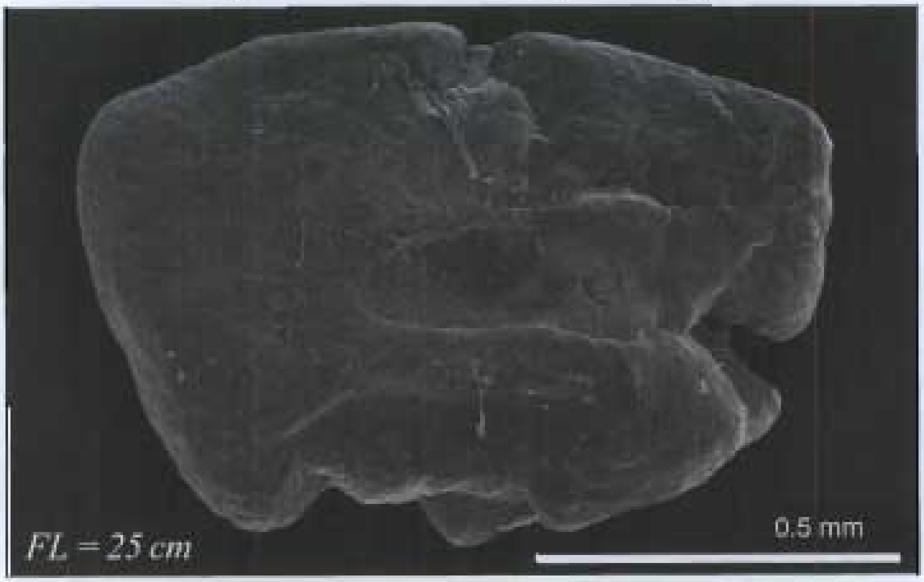


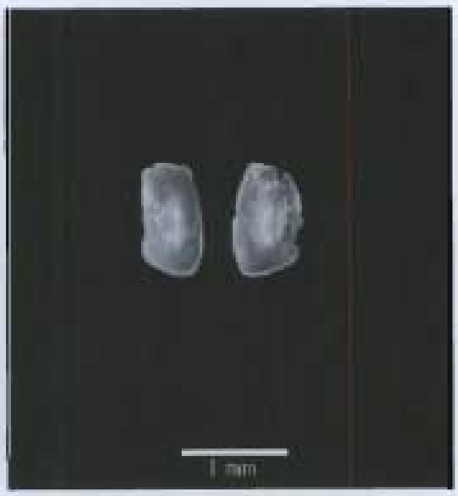




Anguilliformes

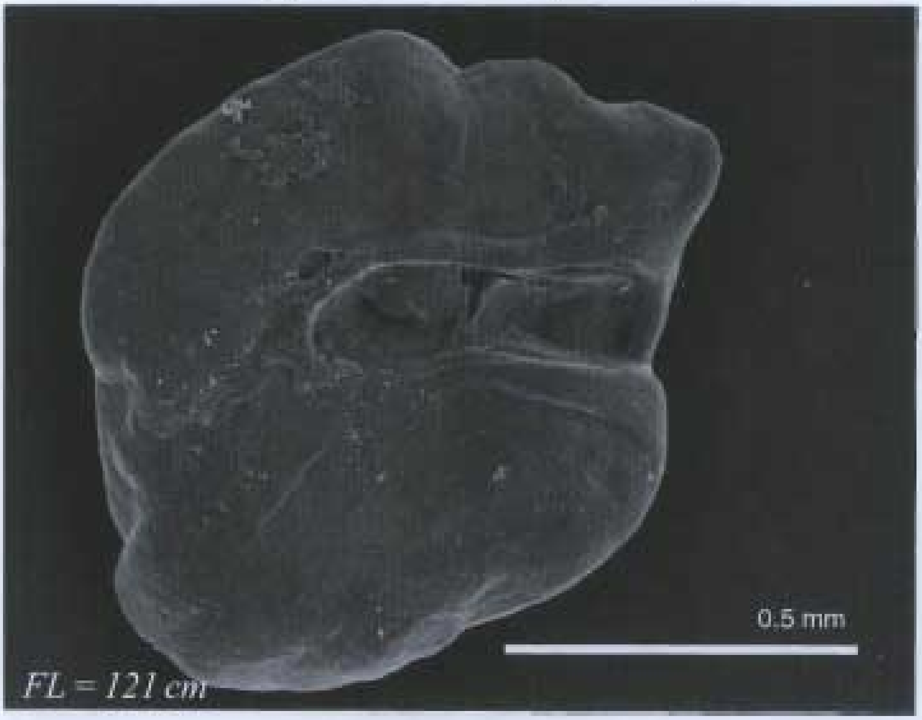
Derichthyidae: *Nessorhamphus ingolfianus*

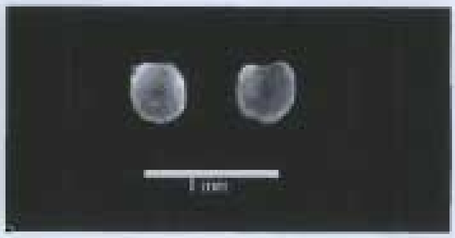




Anguilliformes

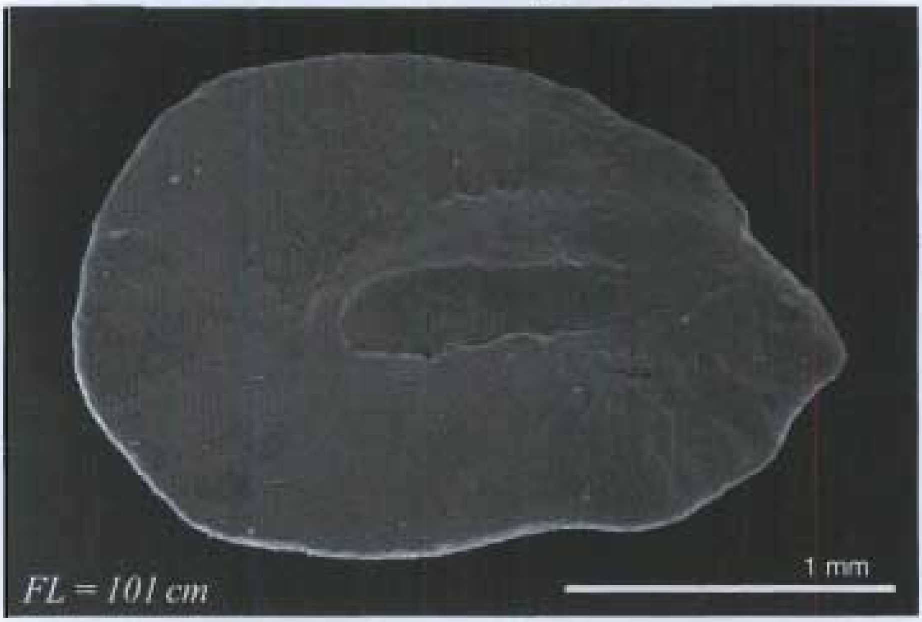
Nemichthyidae: *Nemichthys scolopaceus*





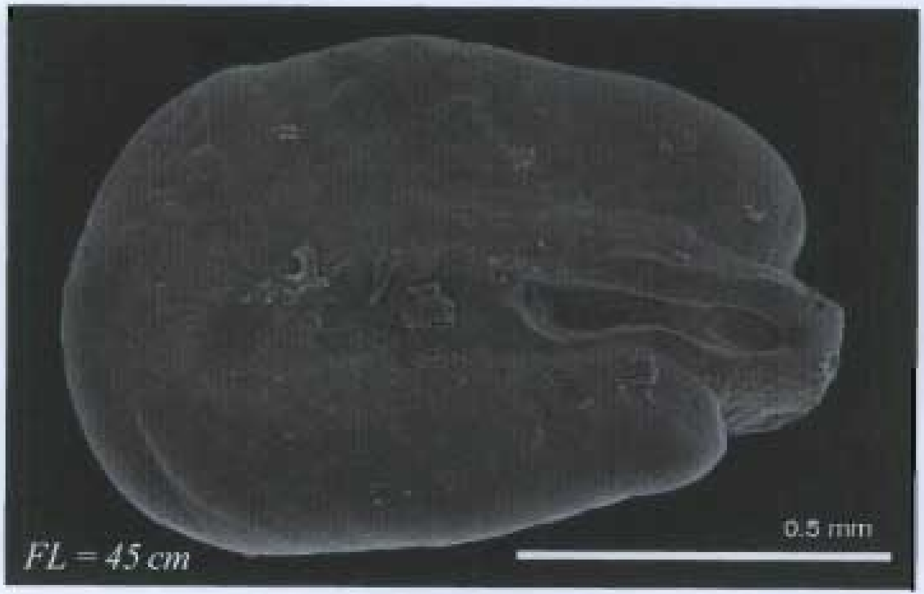
Anguilliformes

Nettastomatidae: *Venefica procera*



Anguilliformes

Serrivomeridae: *Serrivomer beani*

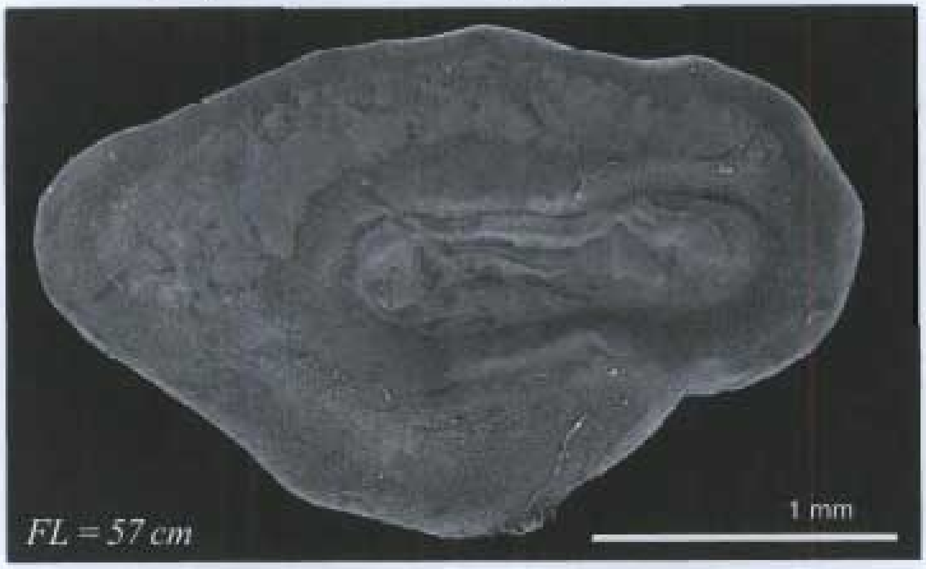


Asteriscii

Lapilli

Anguilliformes

Synaphobranchidae: *Ilyophis brunneus*



Anguilliformes

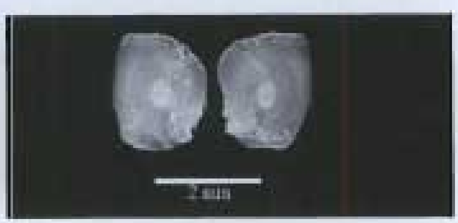
Synaphobranchidae: *Simenchelys parasiticus*

Anguilliformes

Synaphobranchidae: *Synaphobranchus kaupi*

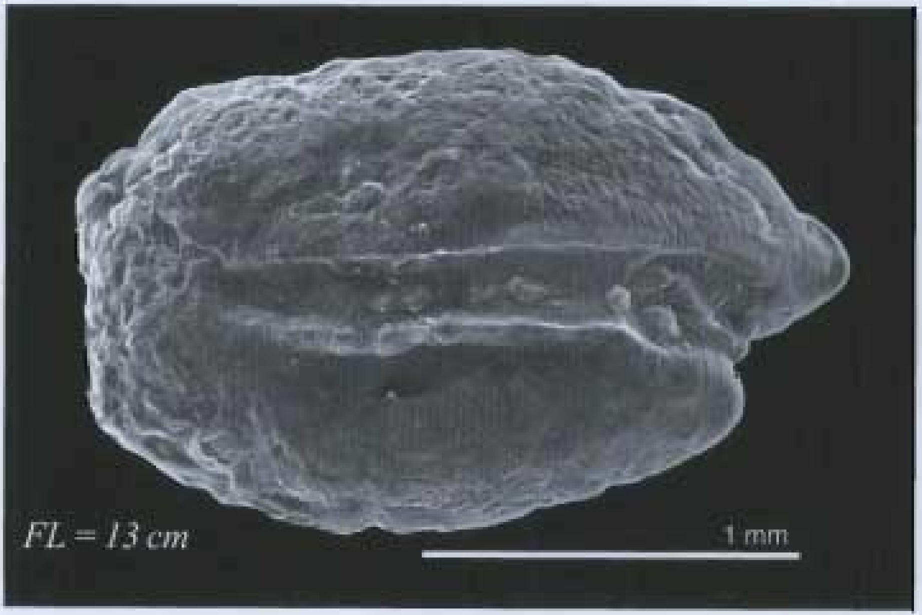
Asteriscii

Lapilli



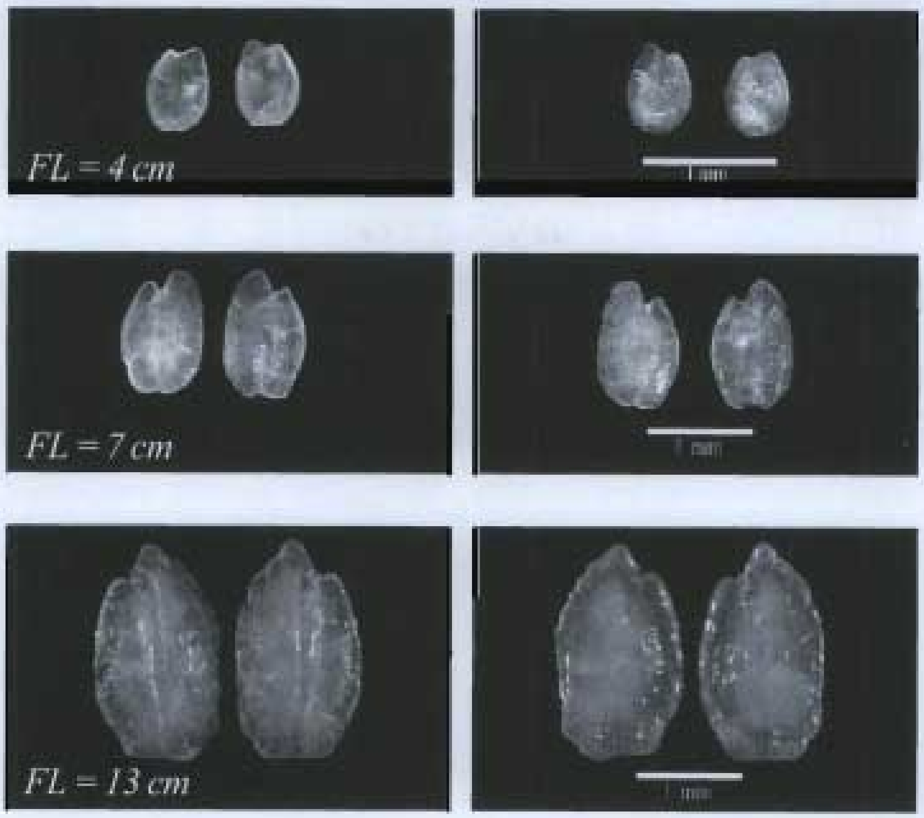
Atheriniformes

Atherinidae: *Menidia menidia*



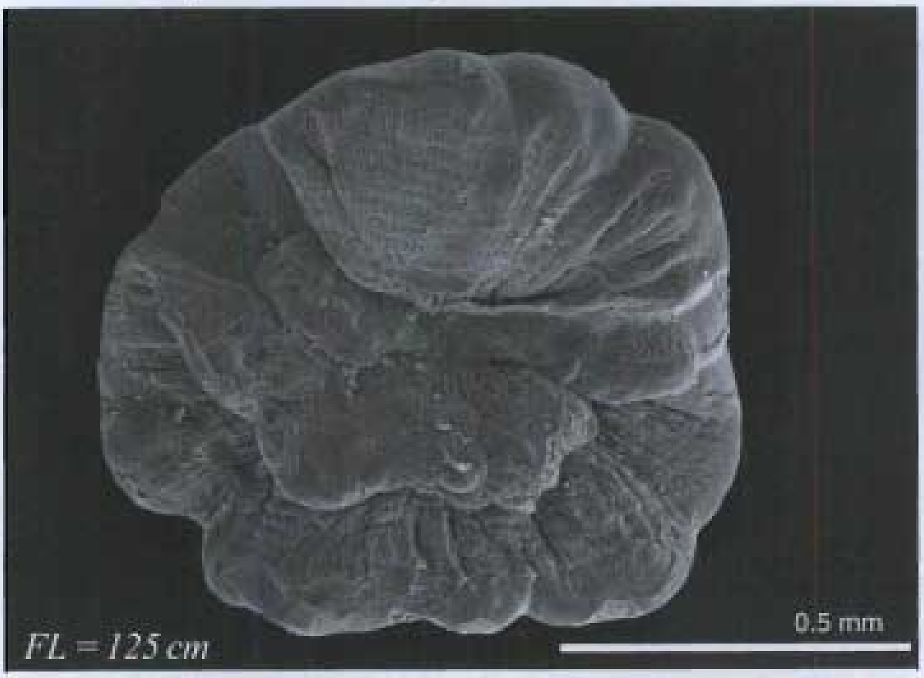
Asteriscii

Lapilli



Aulopiformes

Alepisauridae: *Alepisaurus brevirostris*

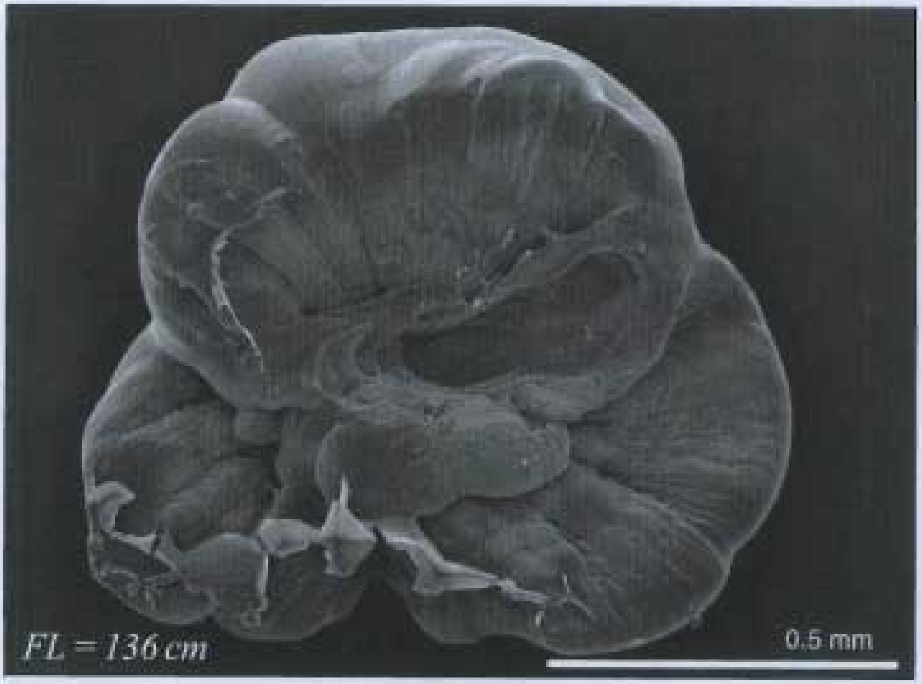


Asteriscii

Lapilli

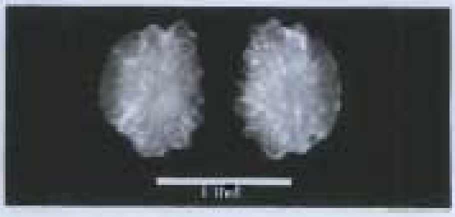
Aulopiformes

Alepisauridae: *Alepisaurus ferox*



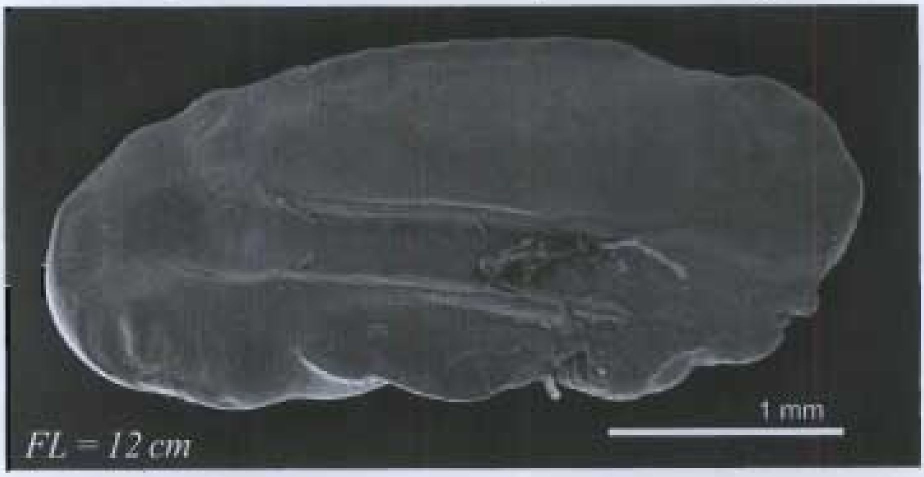
Asteriscii

Lapilli



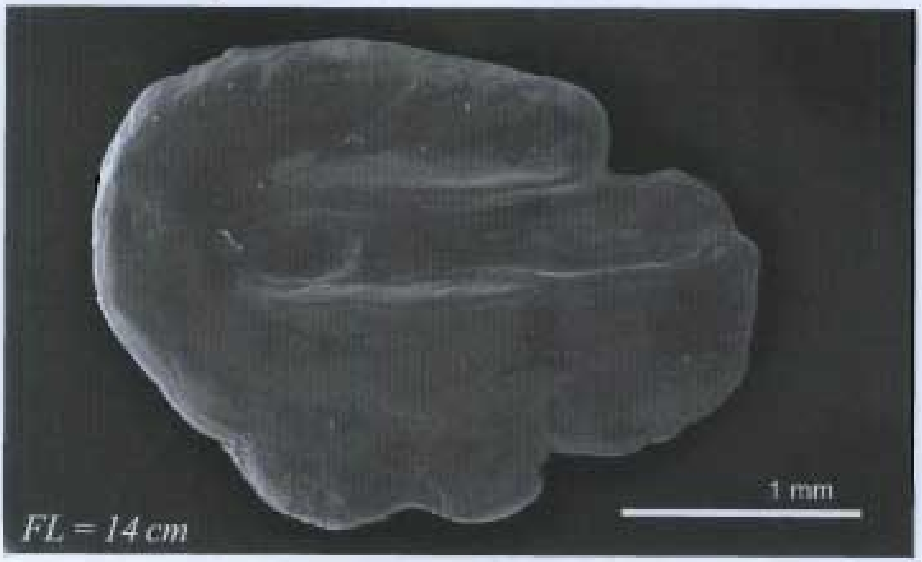
Aulopiformes

Chlorophthalmidae: *Chlorophthalmus agassizi*



Aulopiformes

Chlorophthalmidae: *Parasudis truculenta*

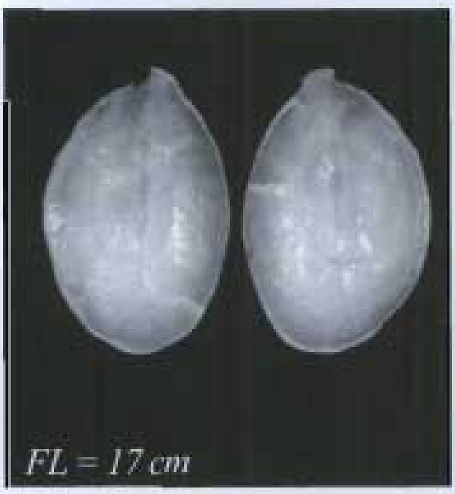


Aulopiformes

Ipnopidae: *Bathypterois quadrifilis*

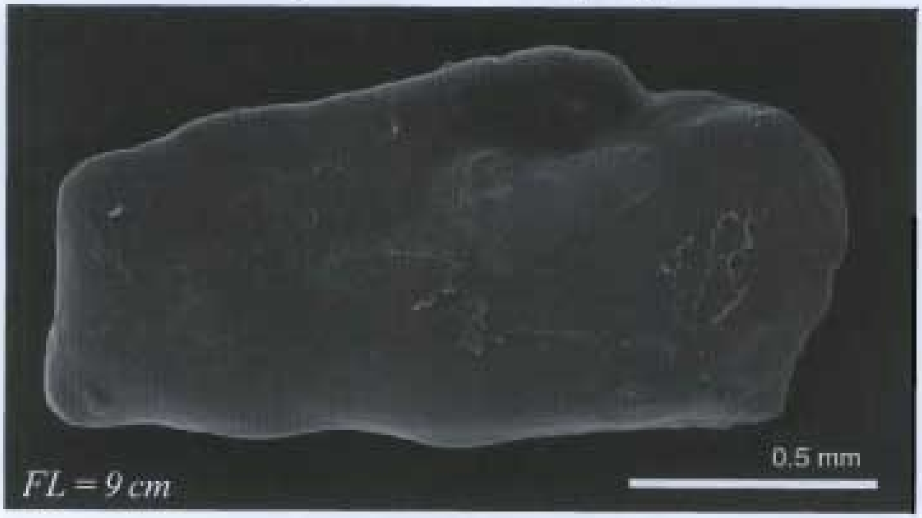
Asteriscii

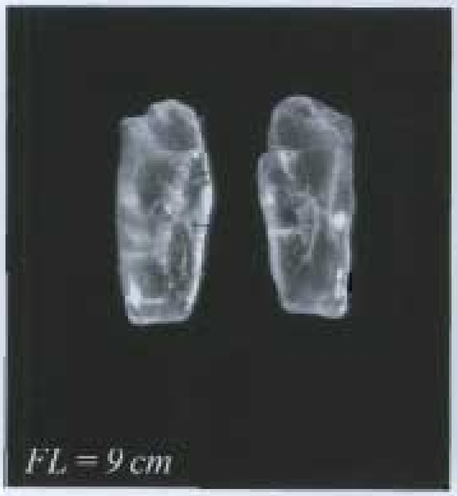
Lapilli



Aulopiformes

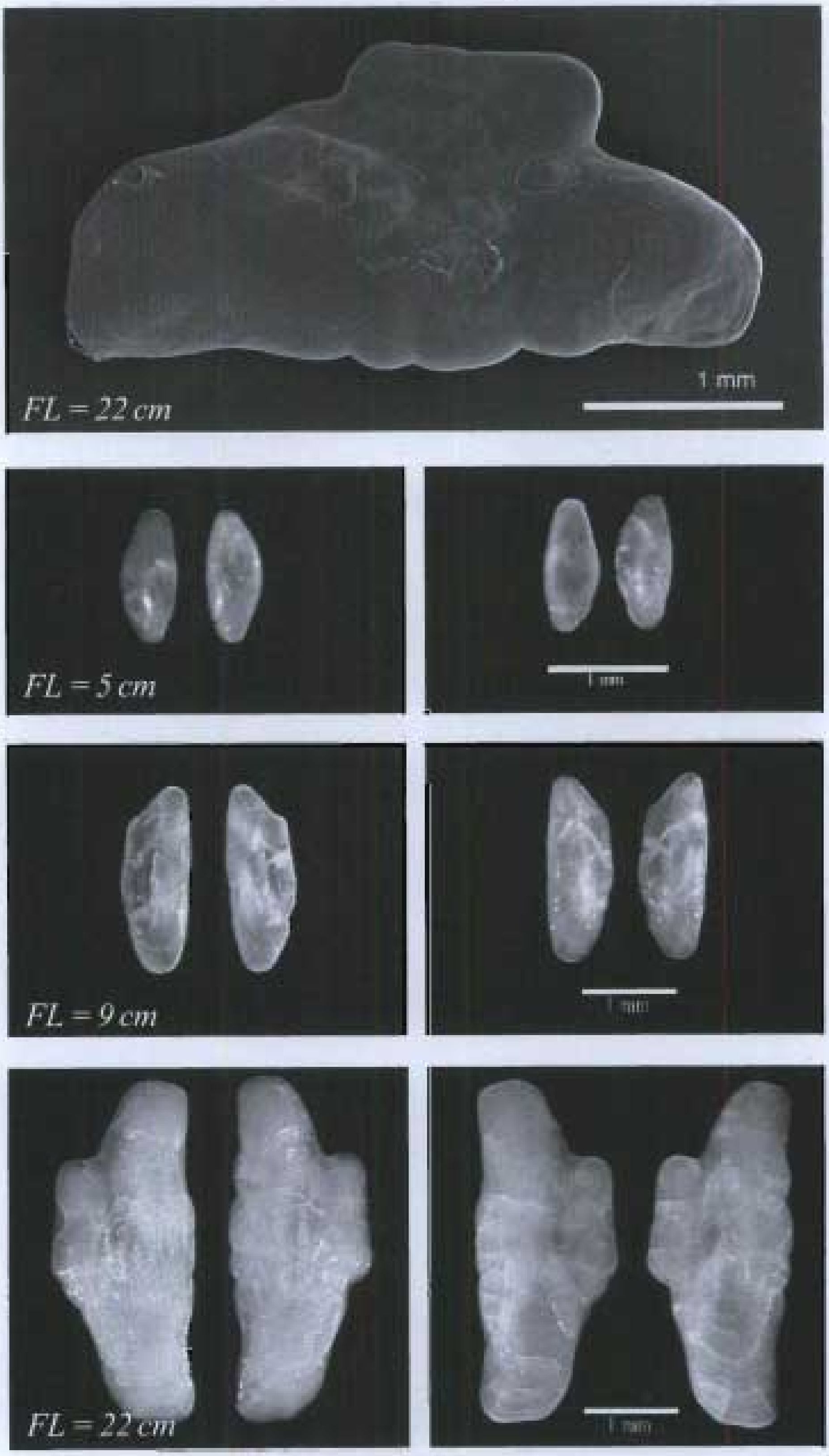
Paralepididae: *Lestidiops affinis*





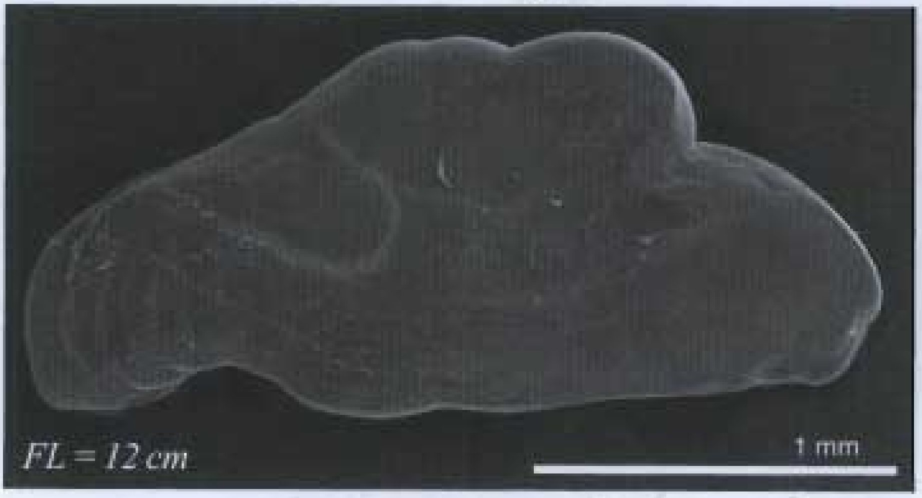
Aulopiformes

Paralepididae: *Notolepis rissoi*



Aulopiformes

Paralepididae: *Paralepis atlantica*

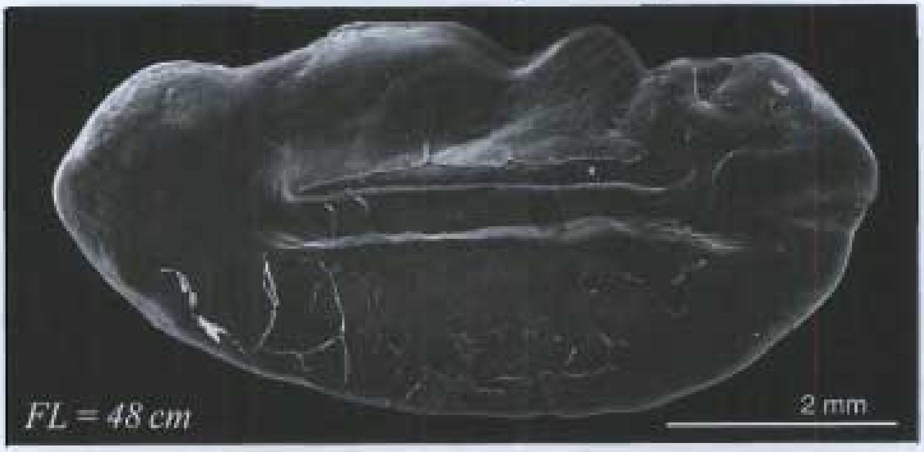


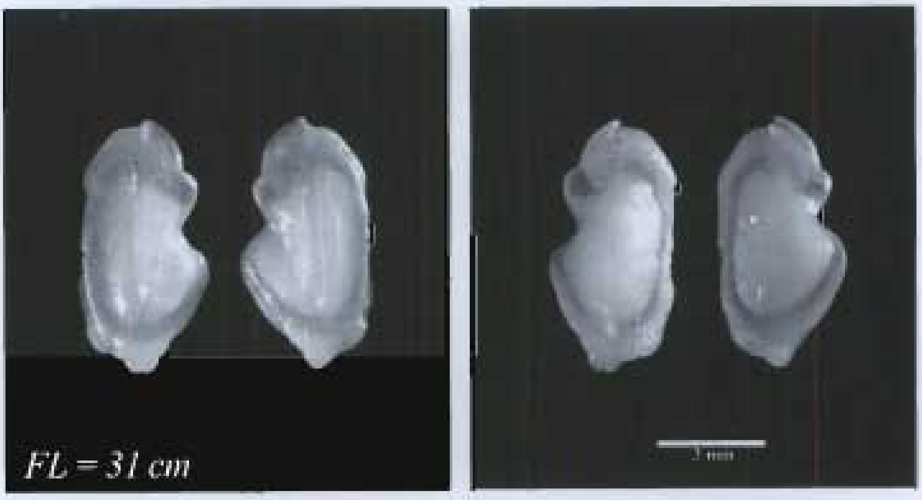
Asteriscii

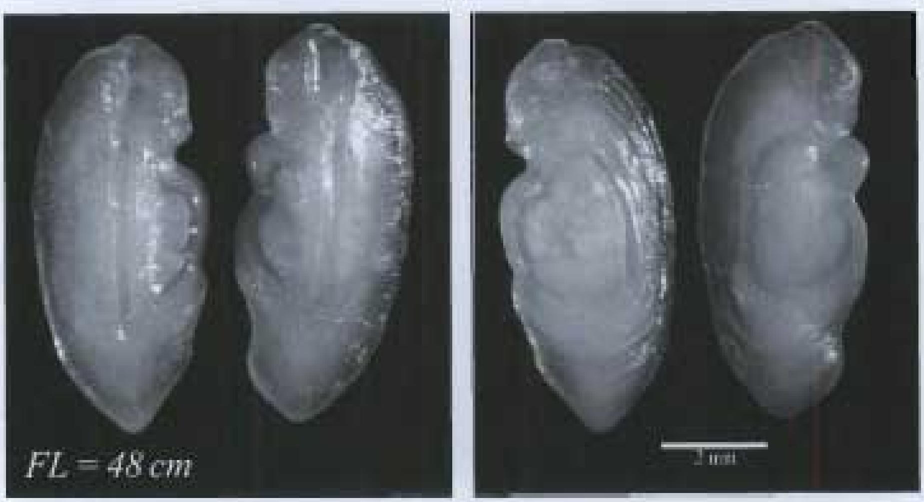
Lapilli

Aulopiformes

Synodontidae: *Bathysaurus ferox*

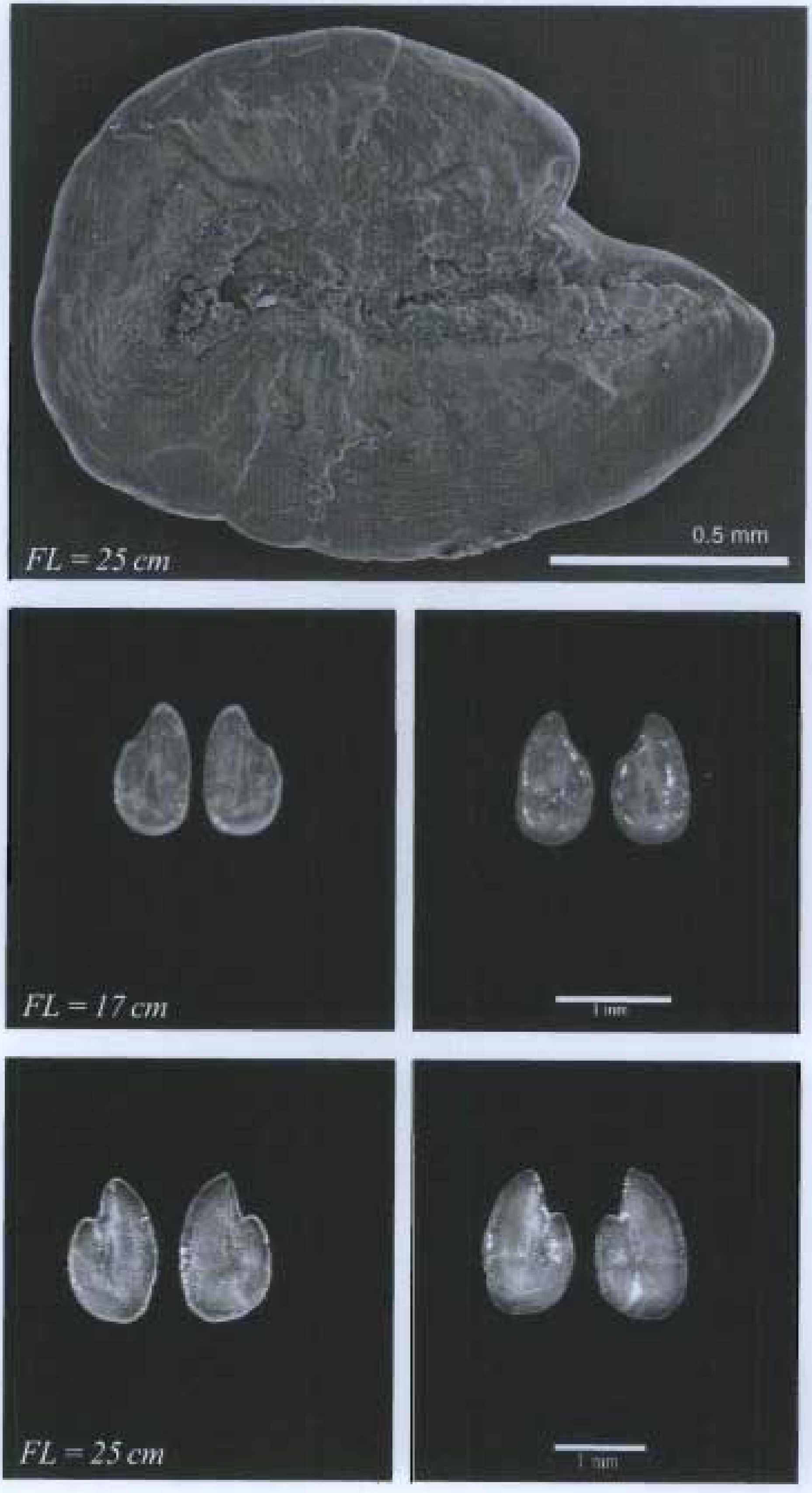






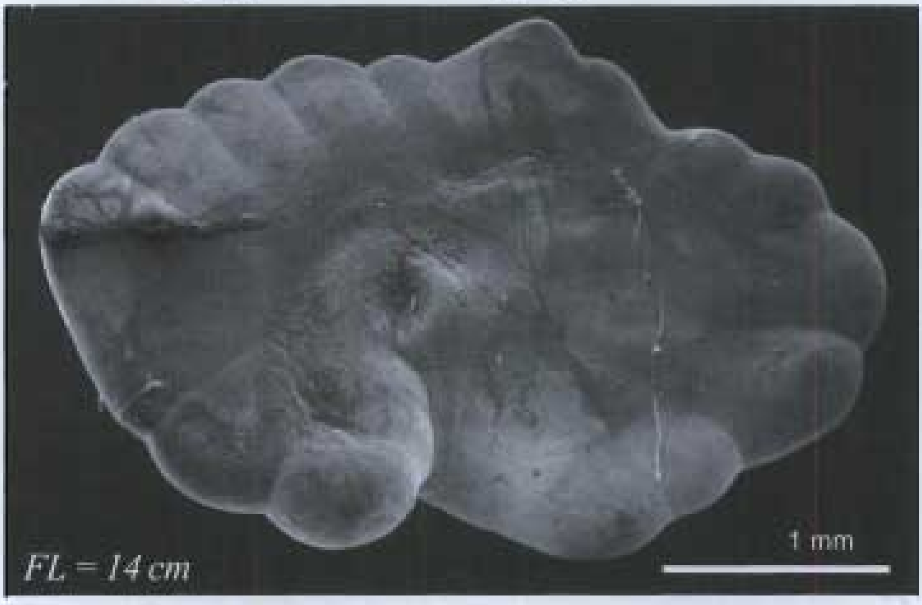
Beloniformes

Scomberesocidae: *Scomberesox saurus*



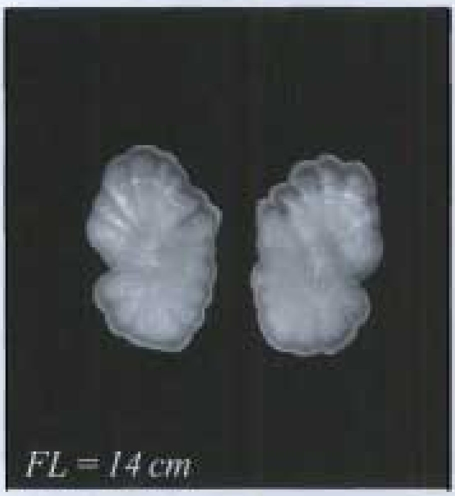
Beryciformes

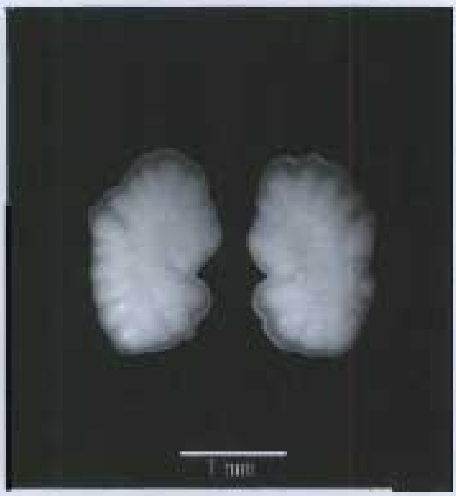
Anoplogasteridae: *Anoplogaster cornuta*



Asteriscii

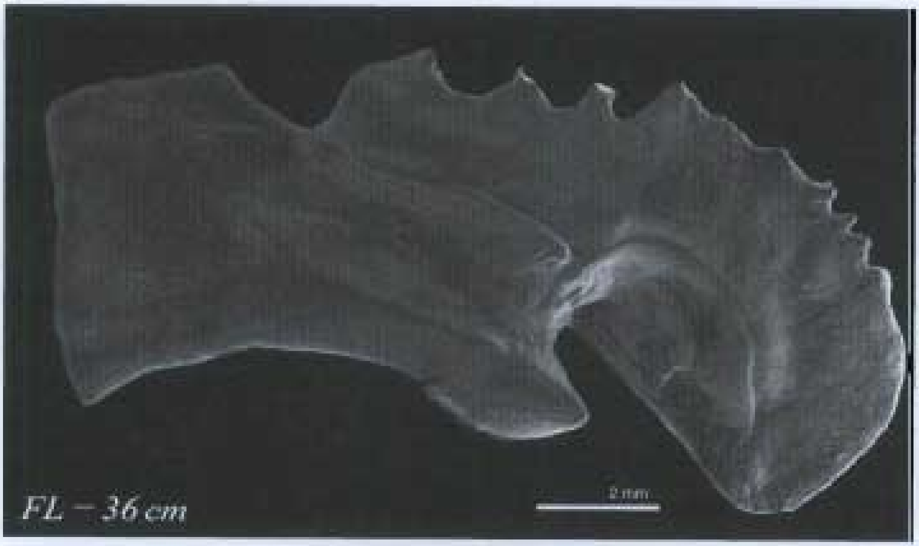
Lapilli

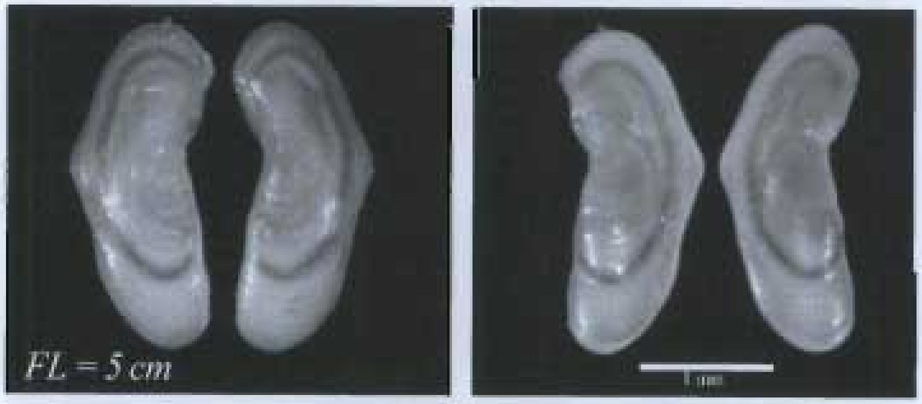


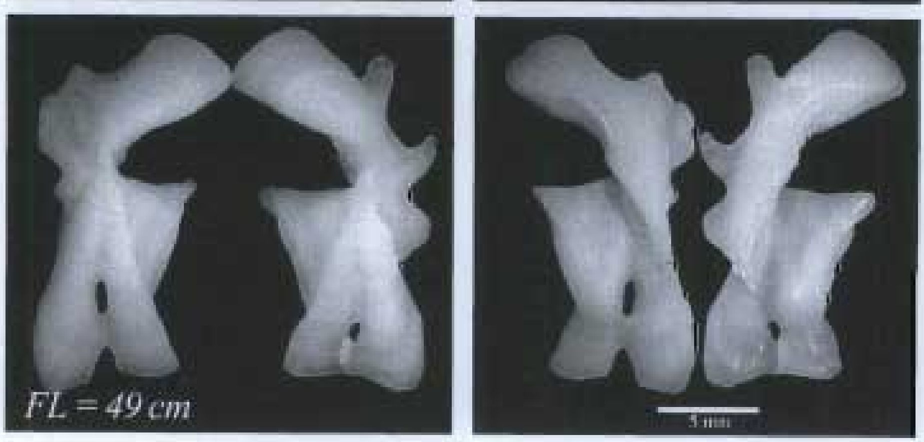


Beryciformes

Trachichthyidae: *Hoplostethus atlanticus*

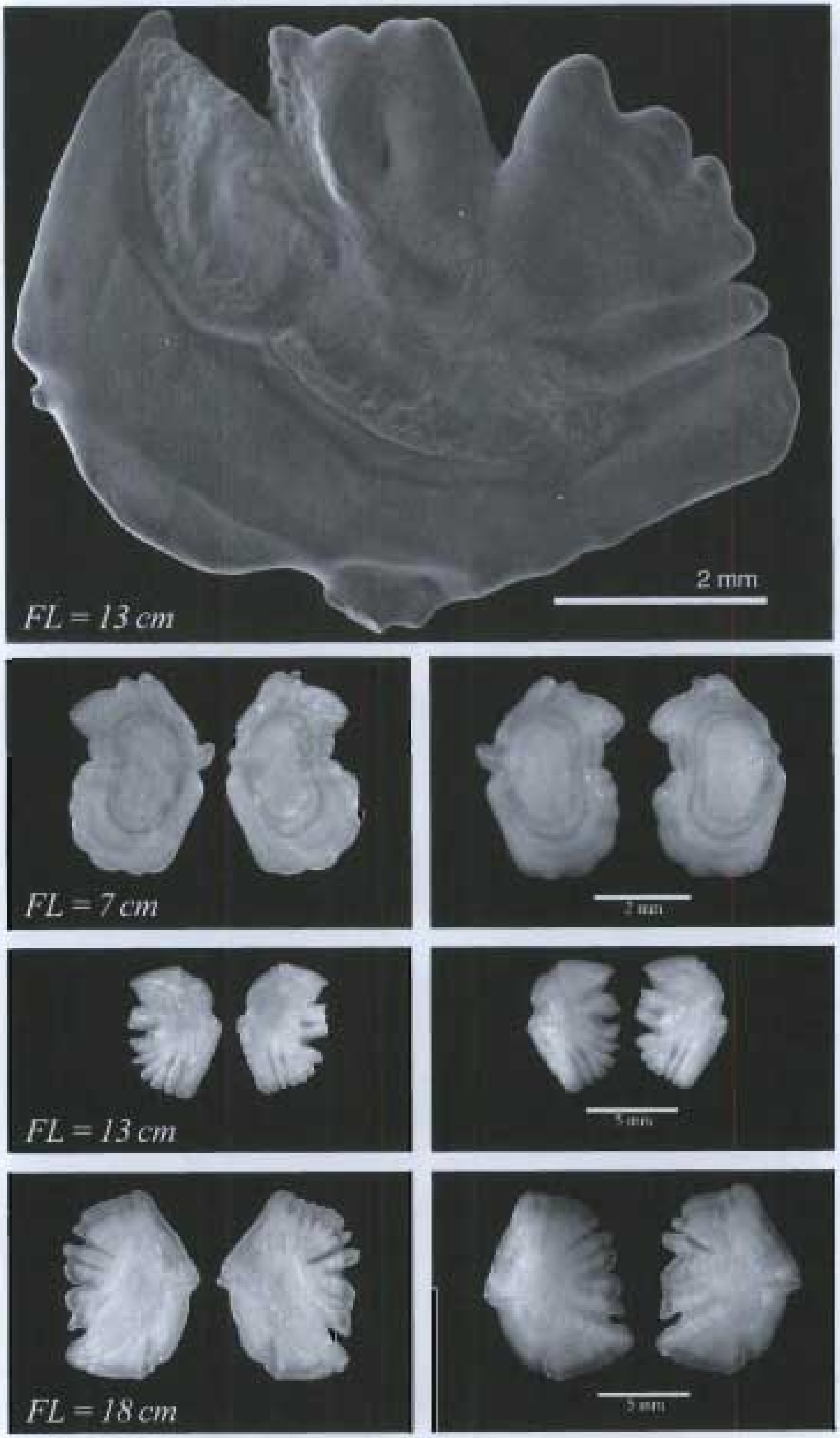






Beryciformes

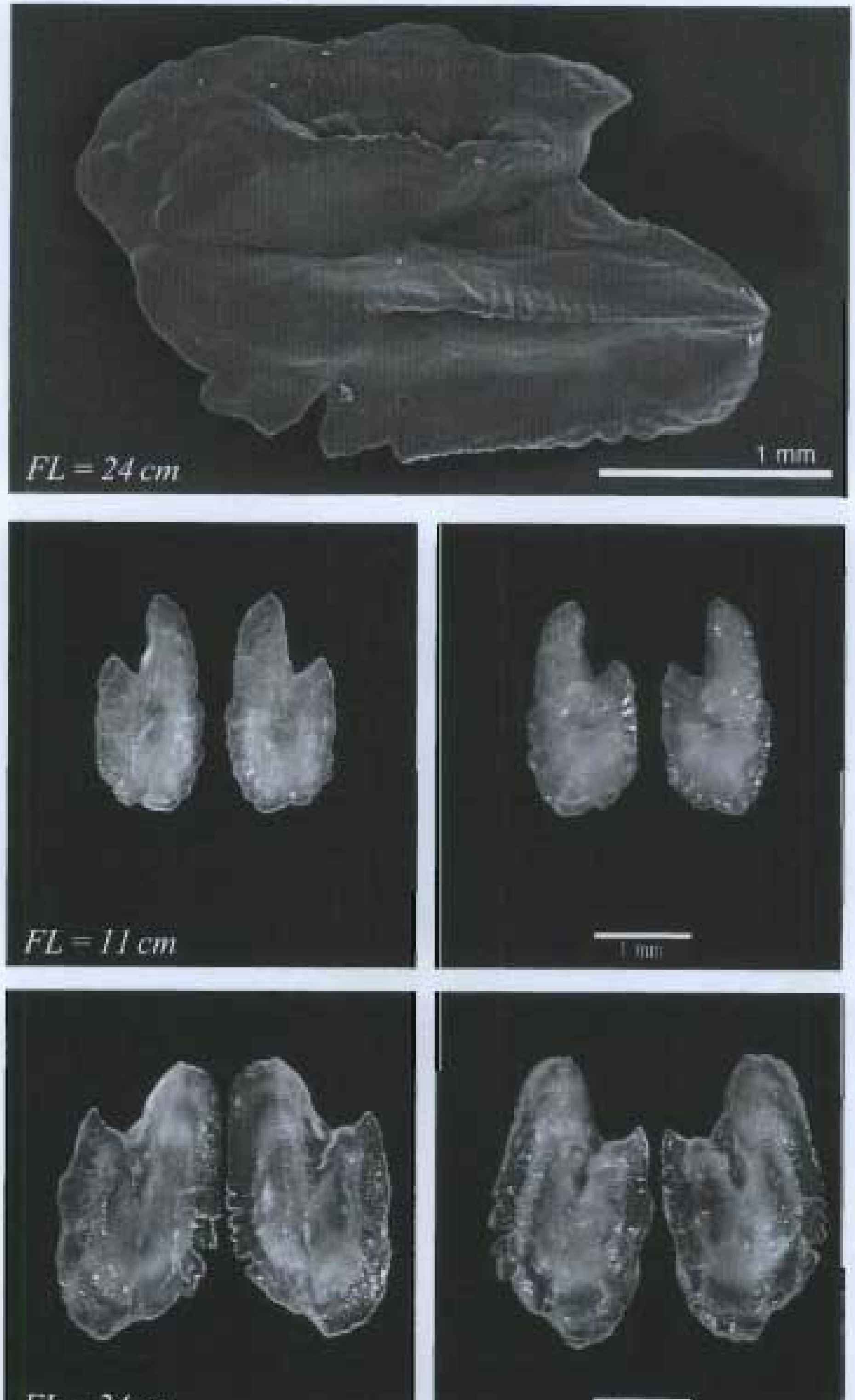
Trachichthyidae: *Hoplostethus mediterraneus*



Lapilli
& Asterisci

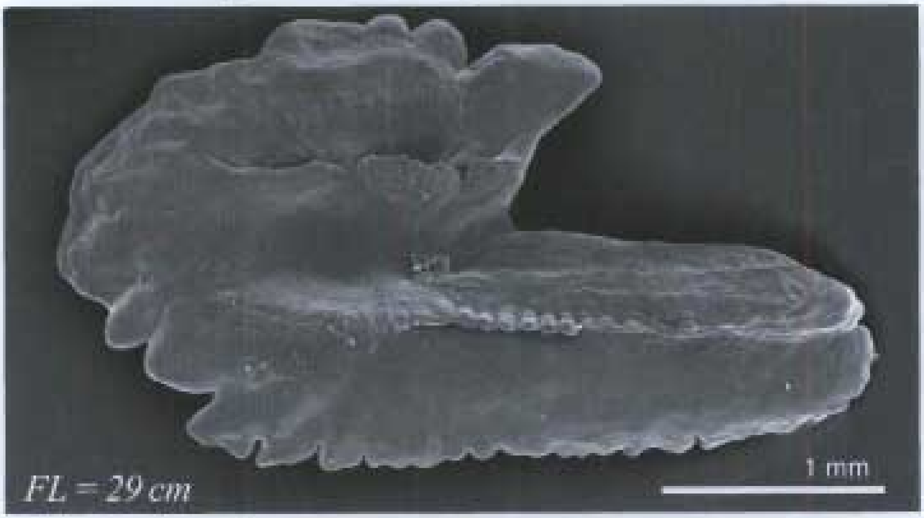
Clupeiformes

Clupeidae: *Alosa aestivalis*



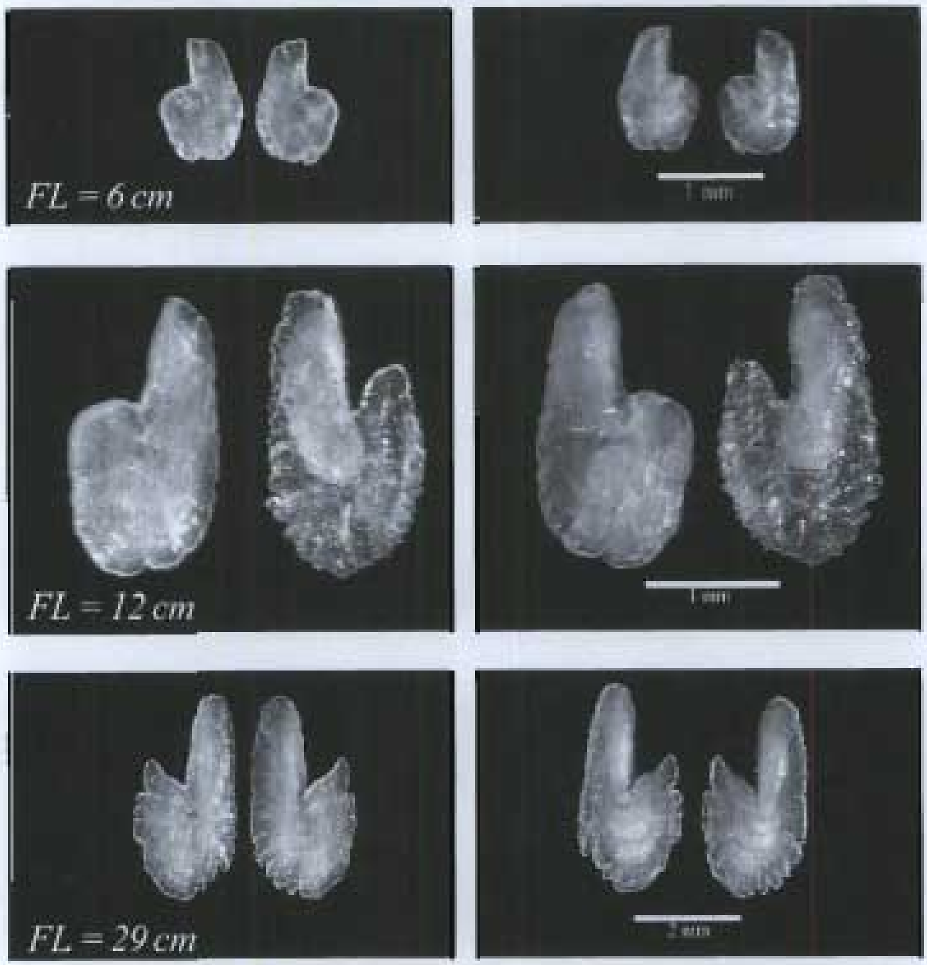
Clupeiformes

Clupeidae: *Alosa pseudoharengus*



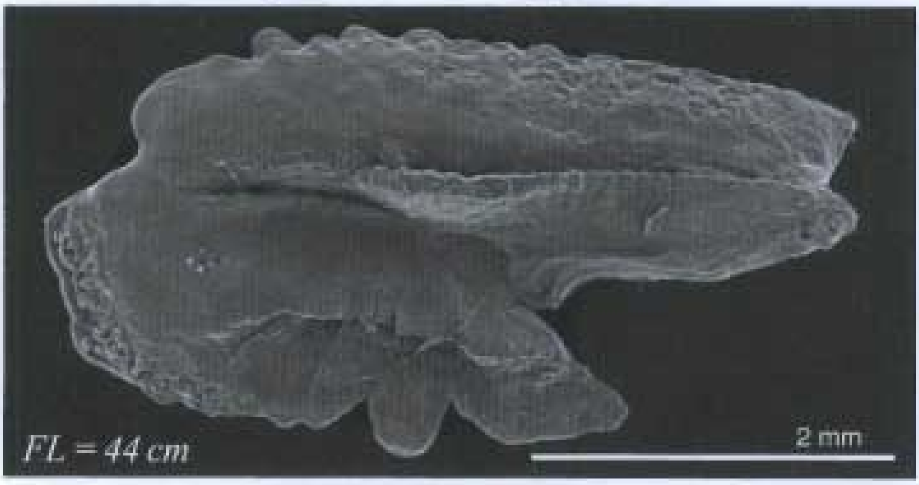
Asterisci

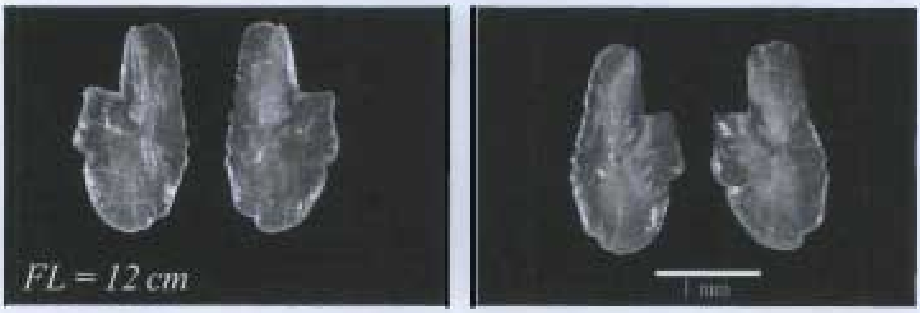
Lapilli

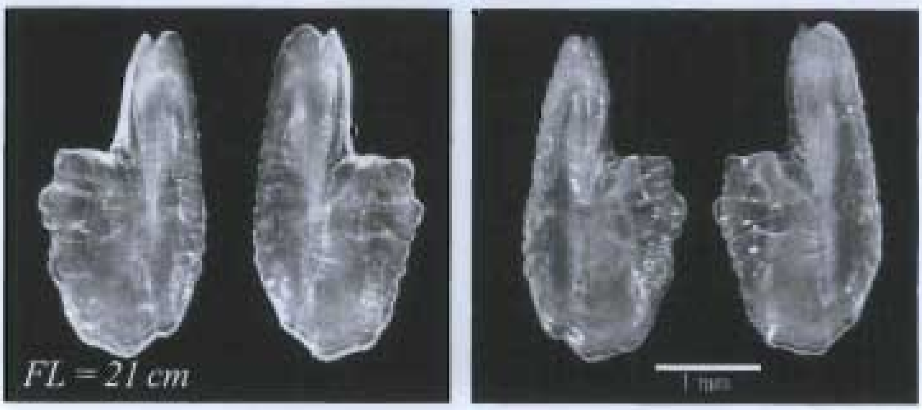


Clupeiformes

Clupeidae: *Alosa sapidissima*

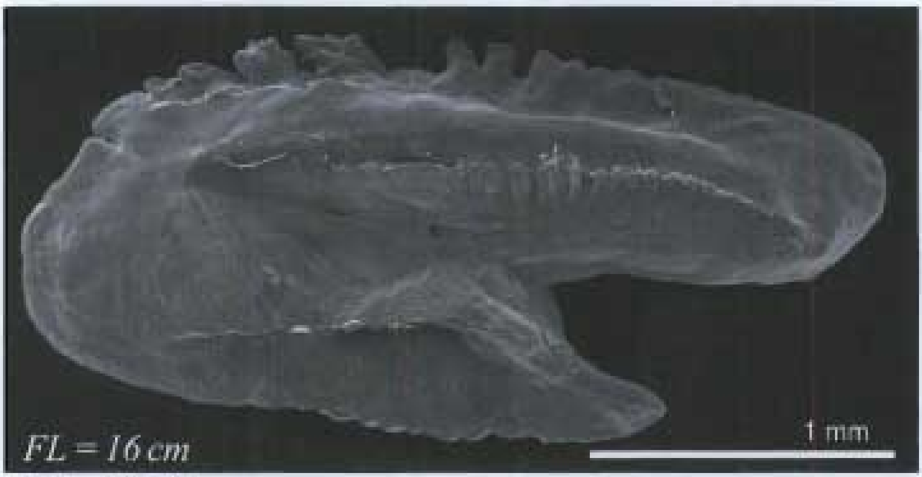






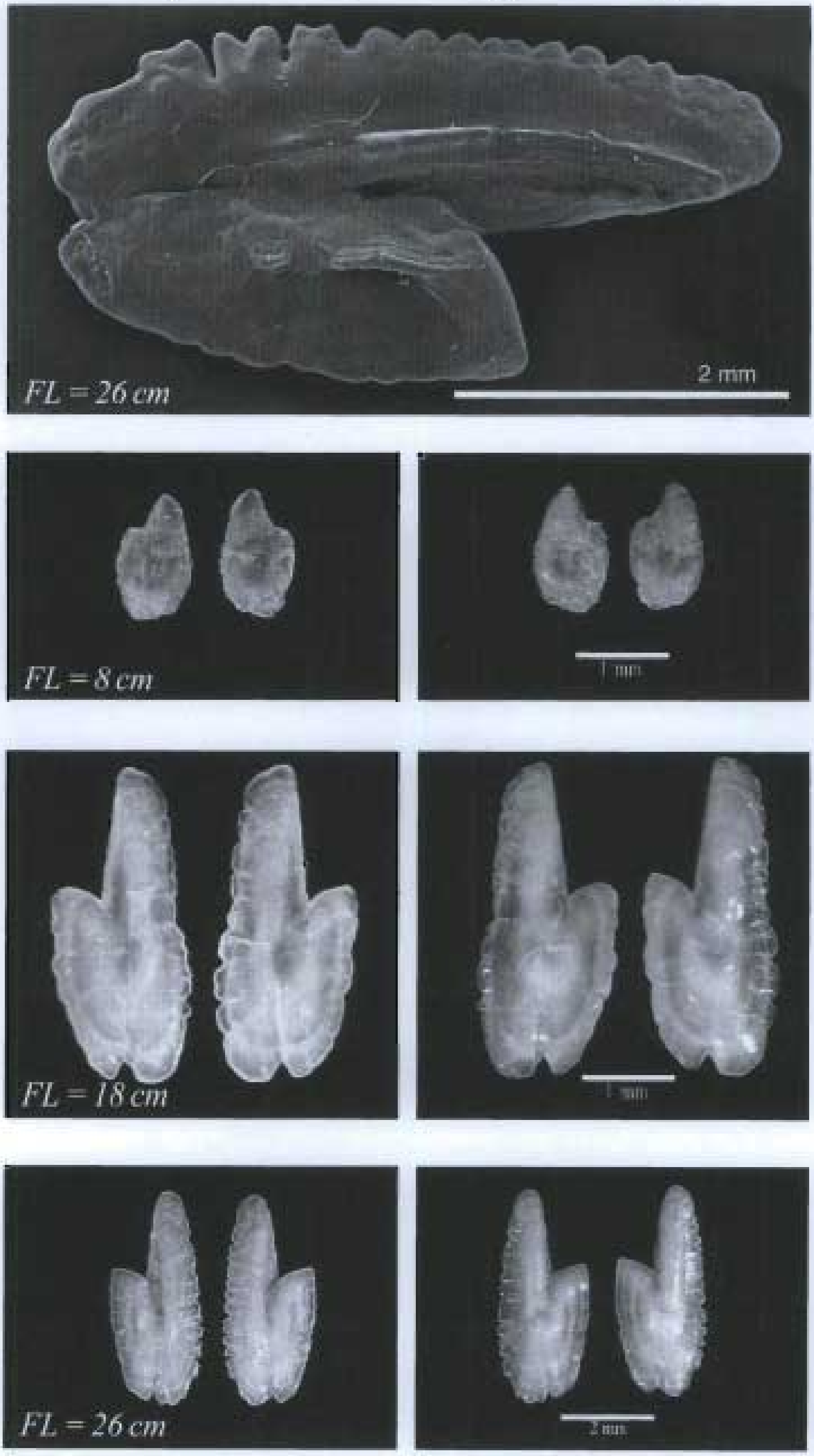
Clupeiformes

Clupeidae: *Brevoortia tyrannus*



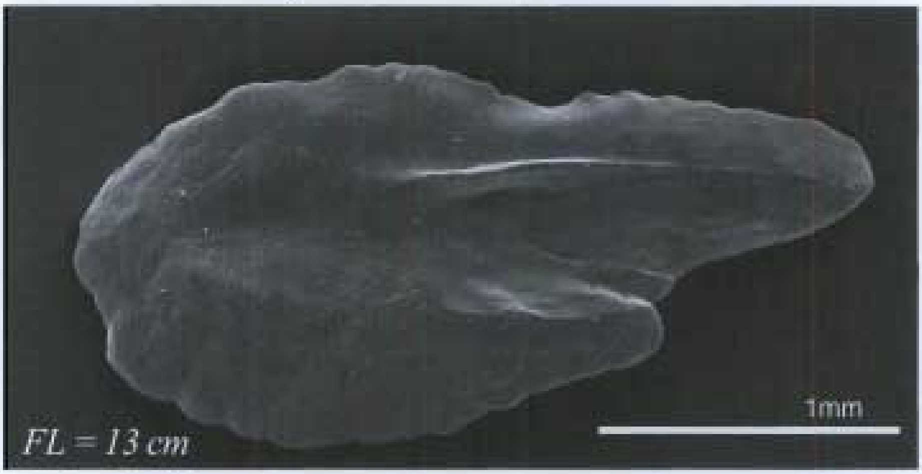
Clupeiformes

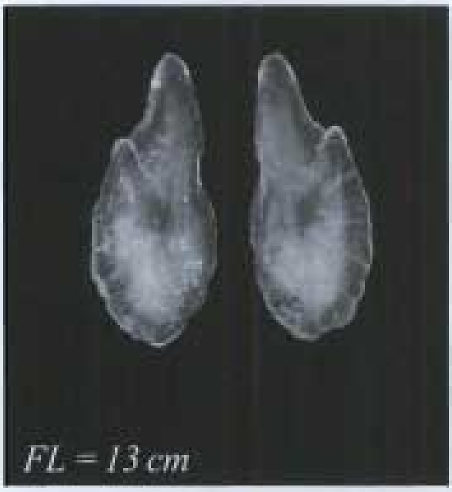
Clupeidae: *Clupea harengus harengus*

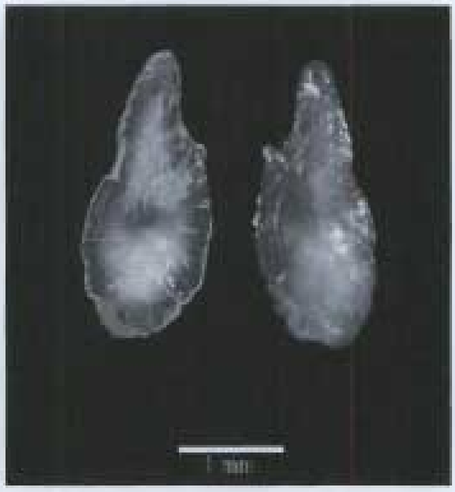


Clupeiformes

Clupeidae: *Etrumeus teres*

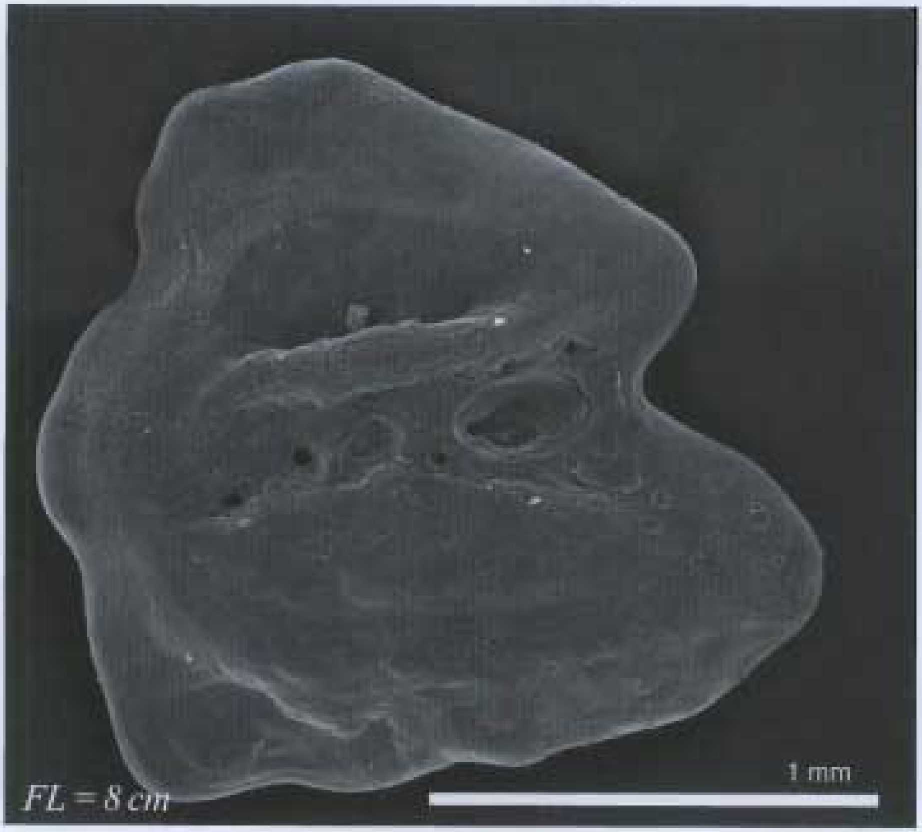






Cyprinodontiformes

Fundulidae: *Fundulus diaphanus*

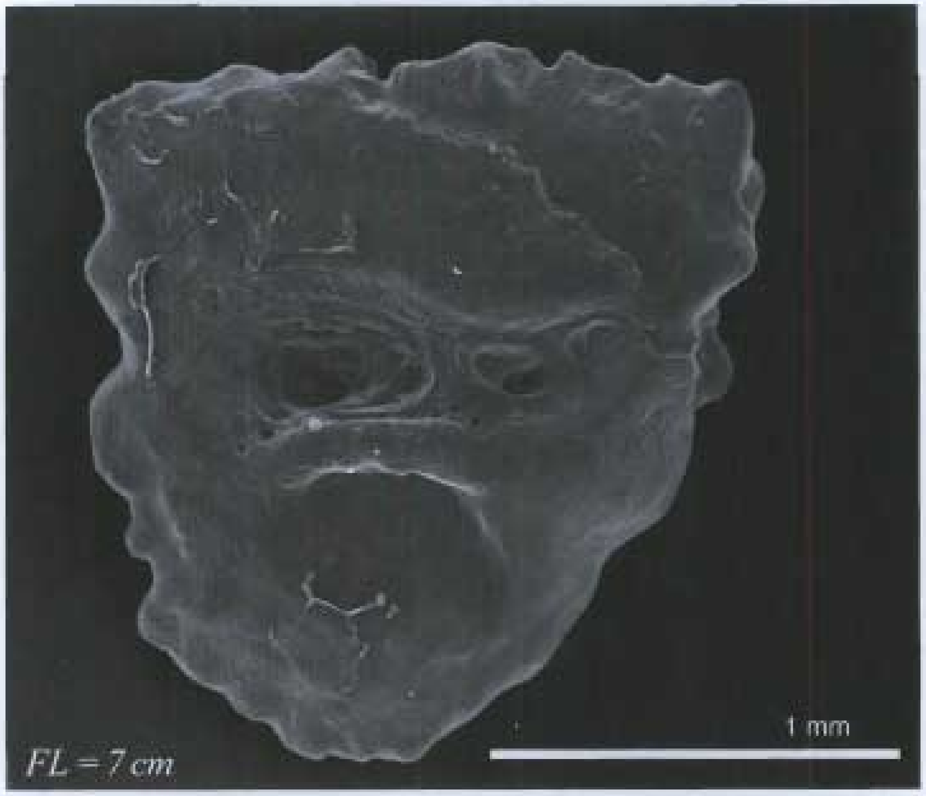


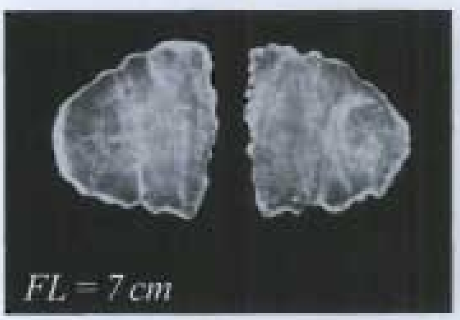
Asteriscii

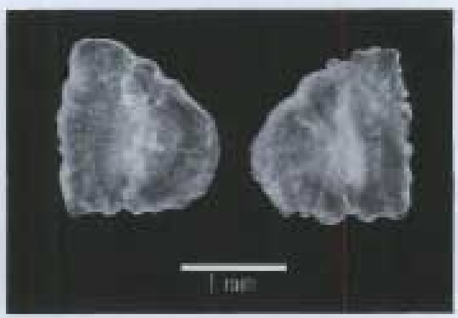
Lapilli

Cyprinodontiformes

Fundulidae: *Fundulus heteroclitus*

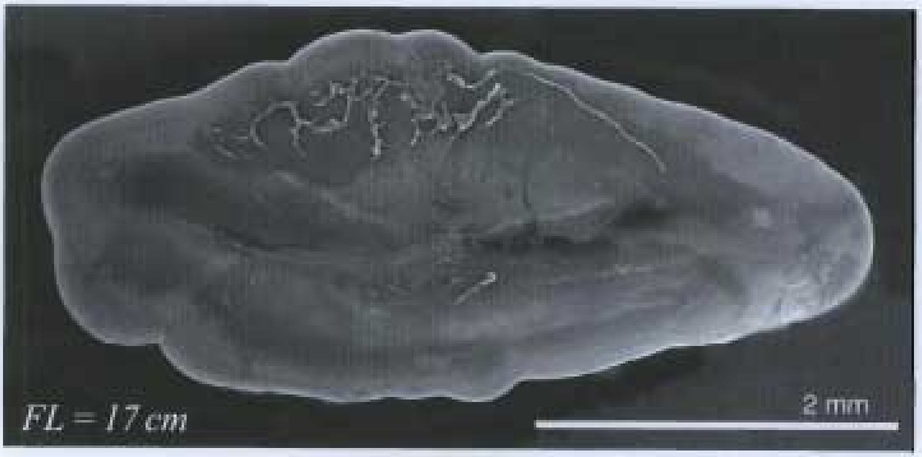






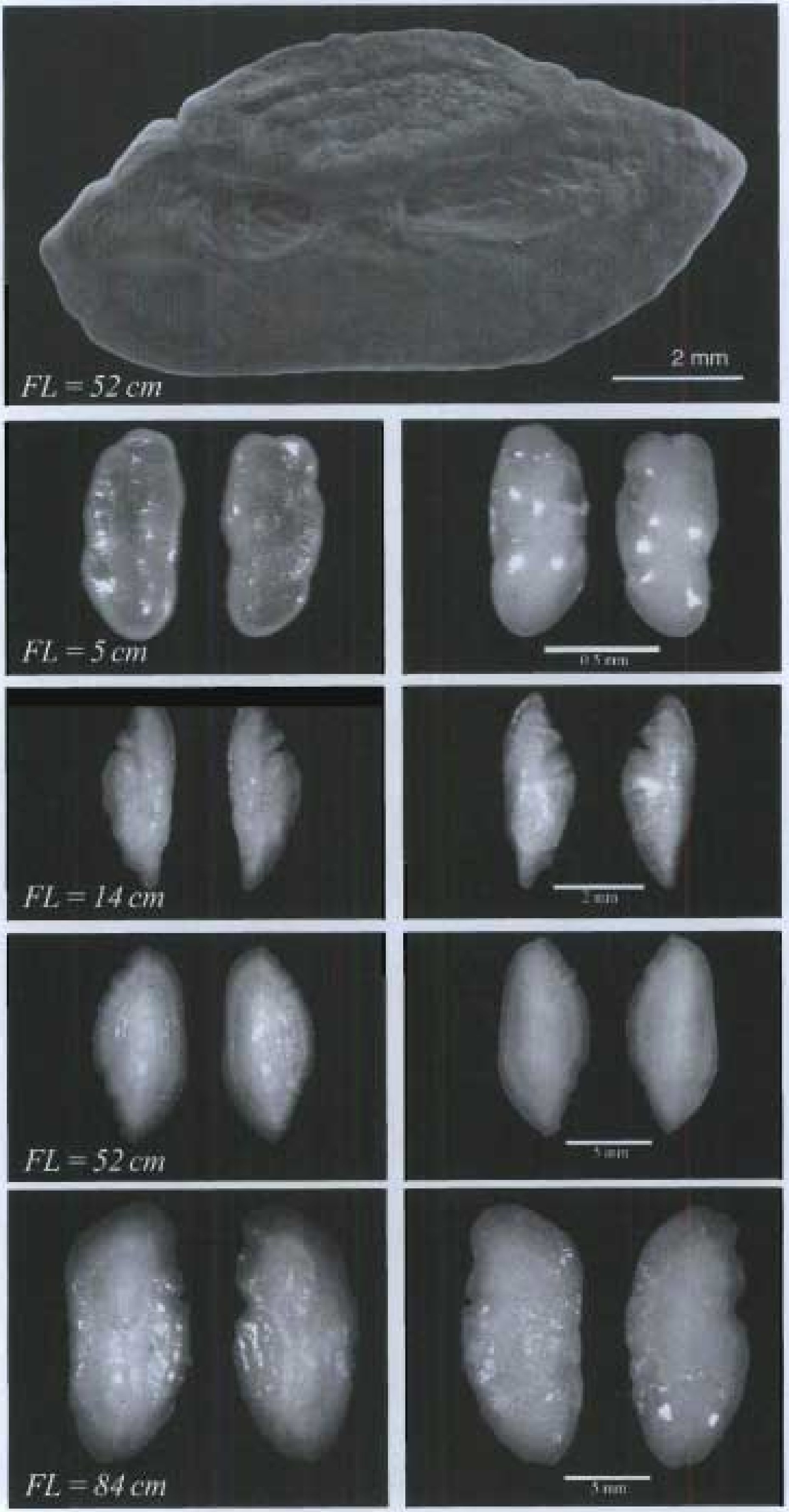
Gadiformes

Gadidae: *Boreogadus saida*



Gadiformes

Gadidae: *Brosme brosme*

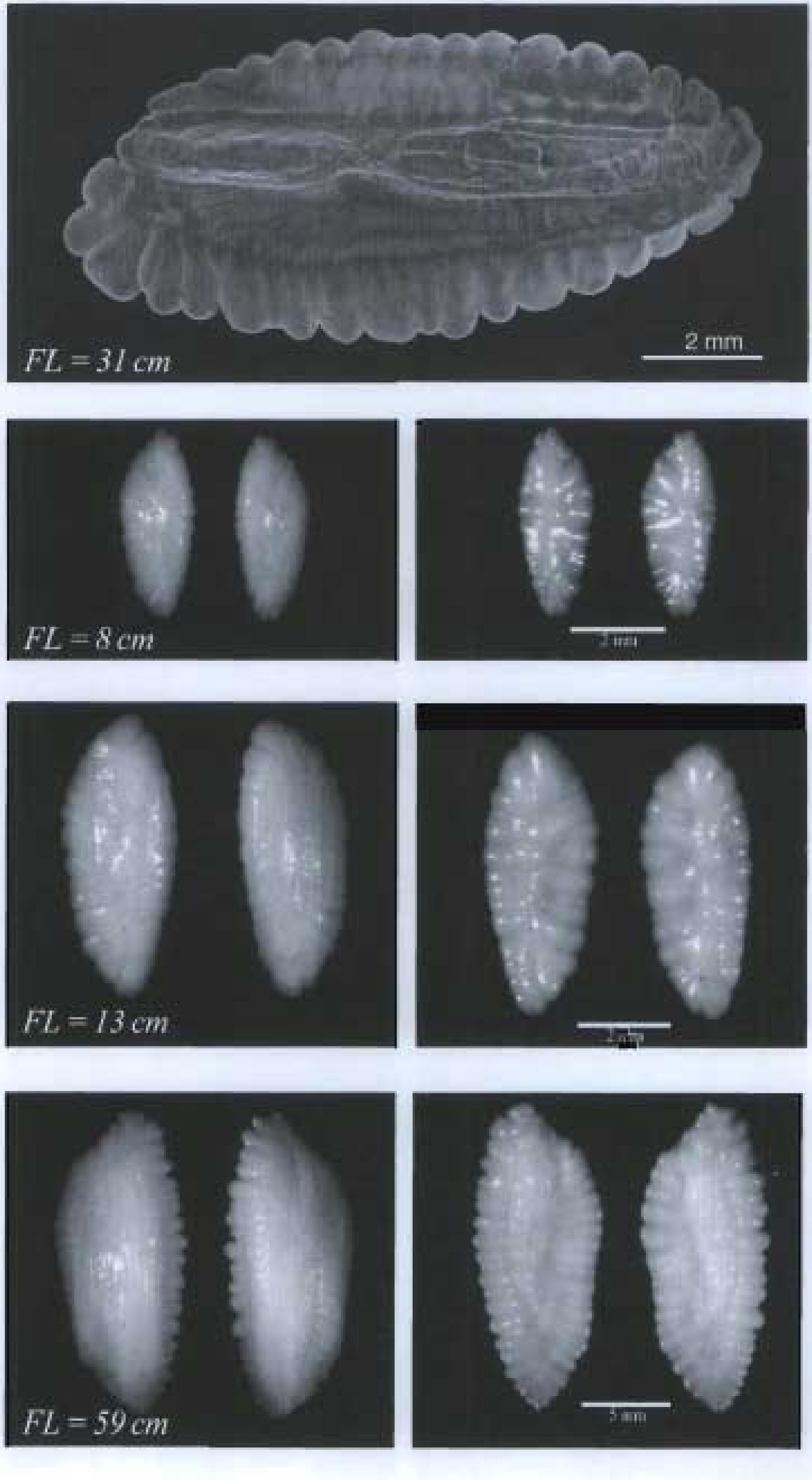


Gadiformes

Gadidae: *Gadus morhua*

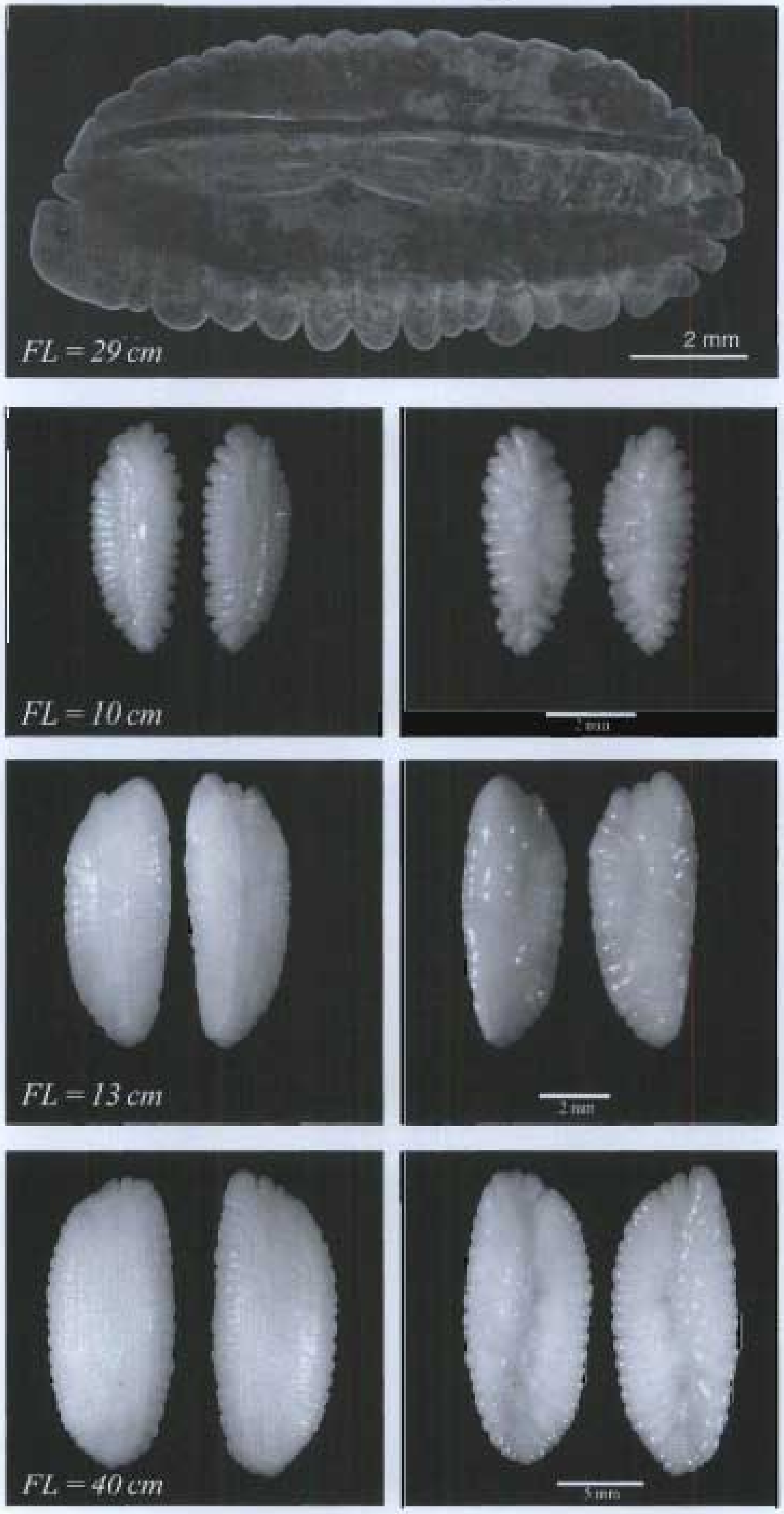
Asteriscii

Lapilli



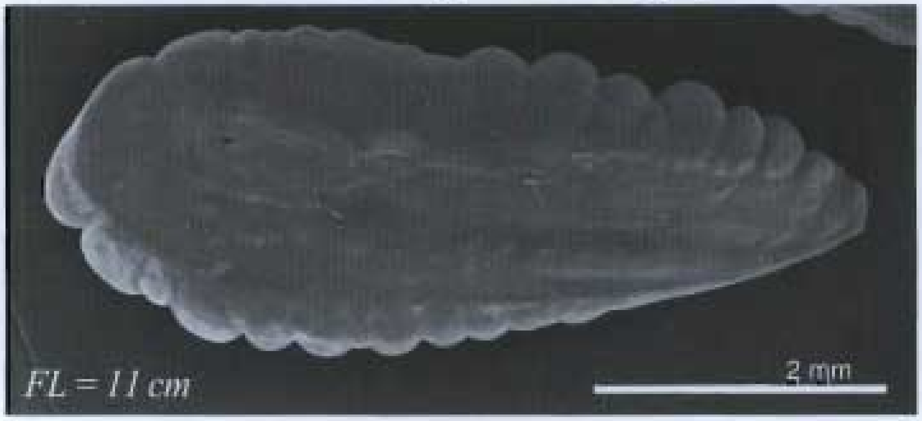
Gadiformes

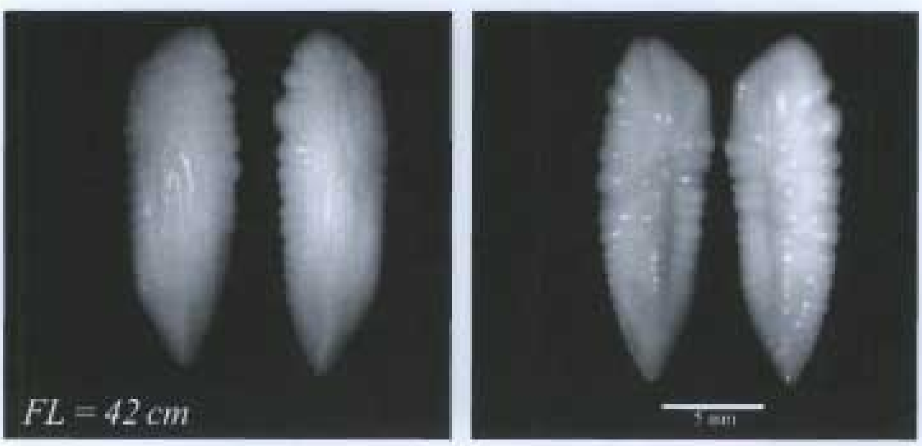
Gadidae: *Gadus ogac*



Gadiformes

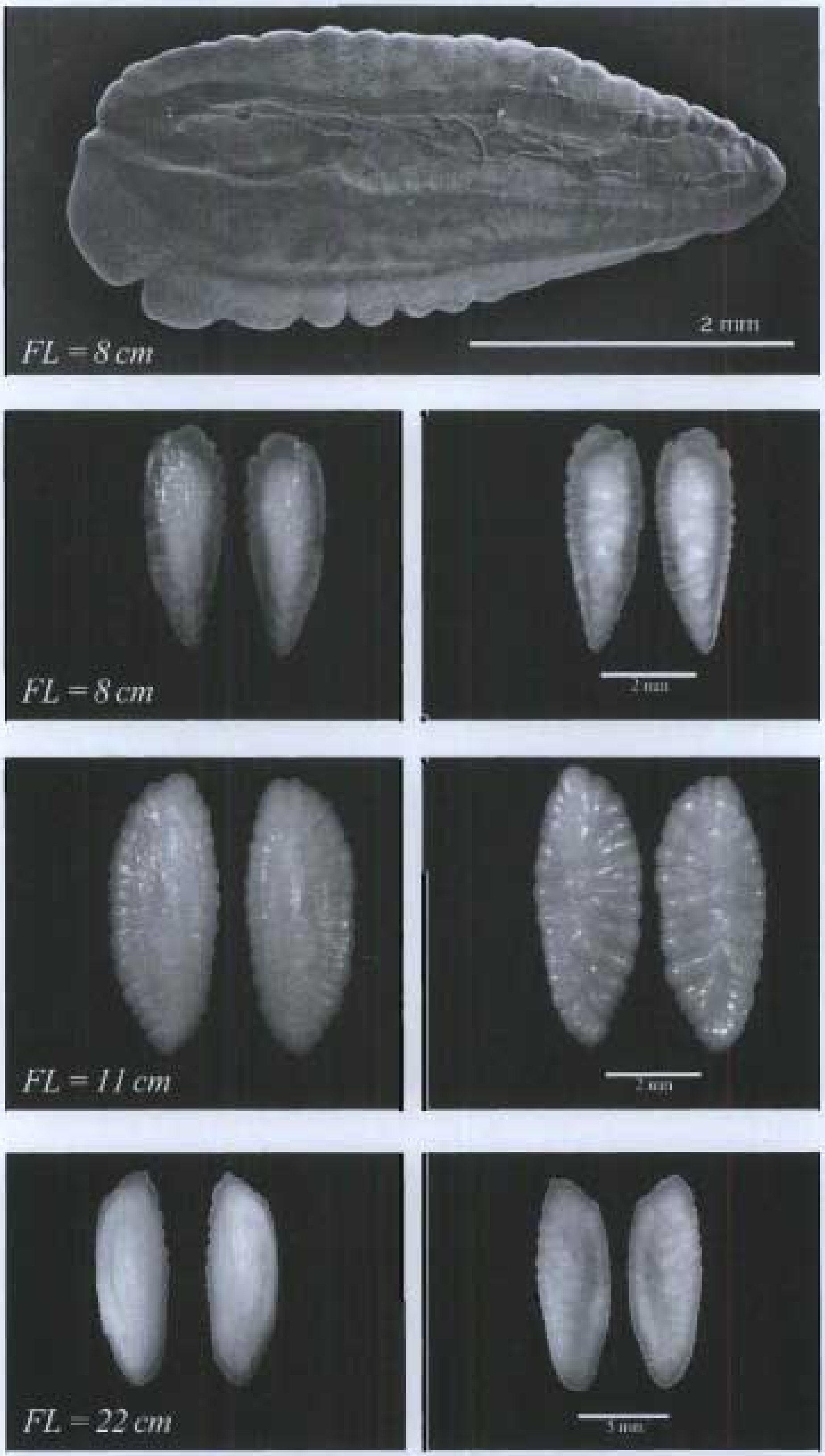
Gadidae: *Melanogrammus aeglefinus*



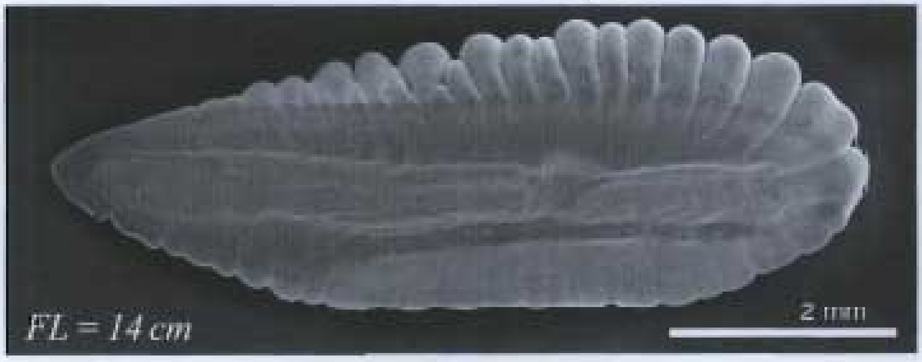


Gadiformes

Gadidae: *Microgadus tomcod*

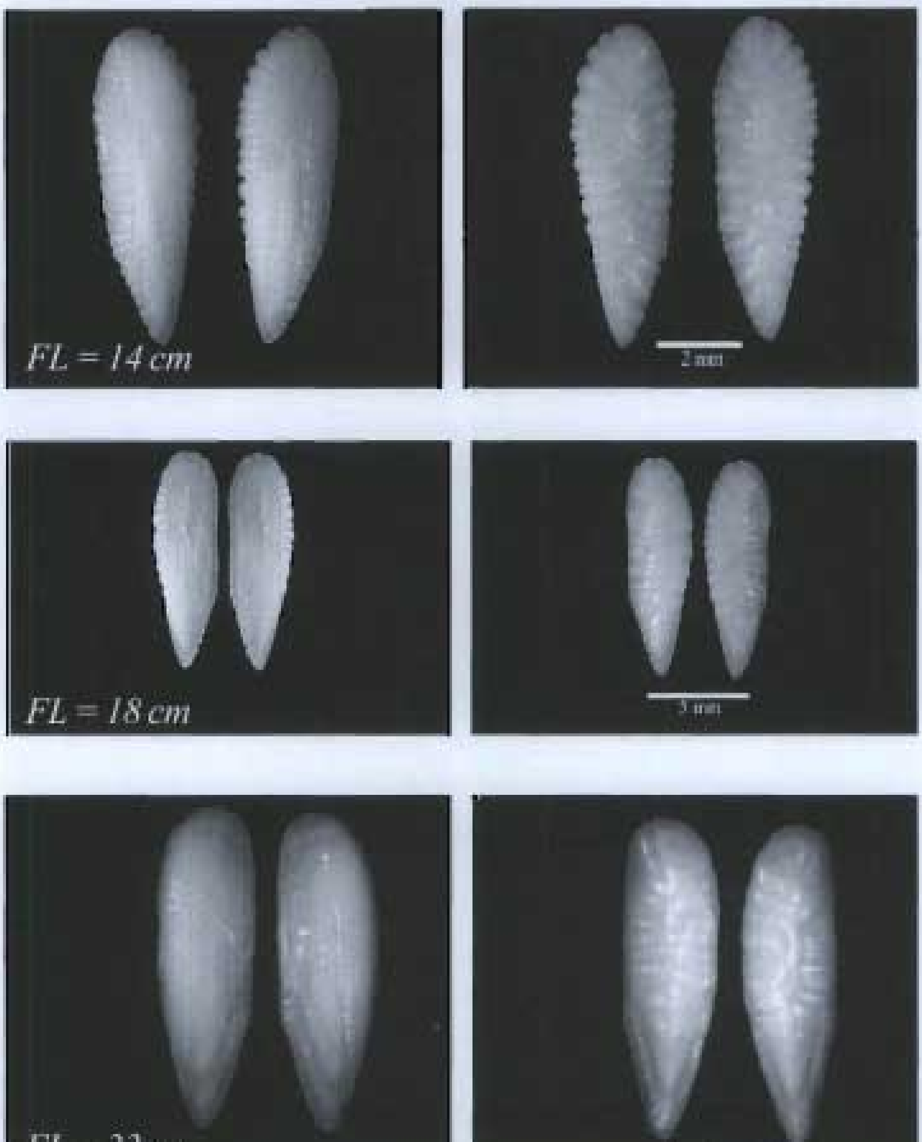


Gadidae: *Micromesistius poutassou*



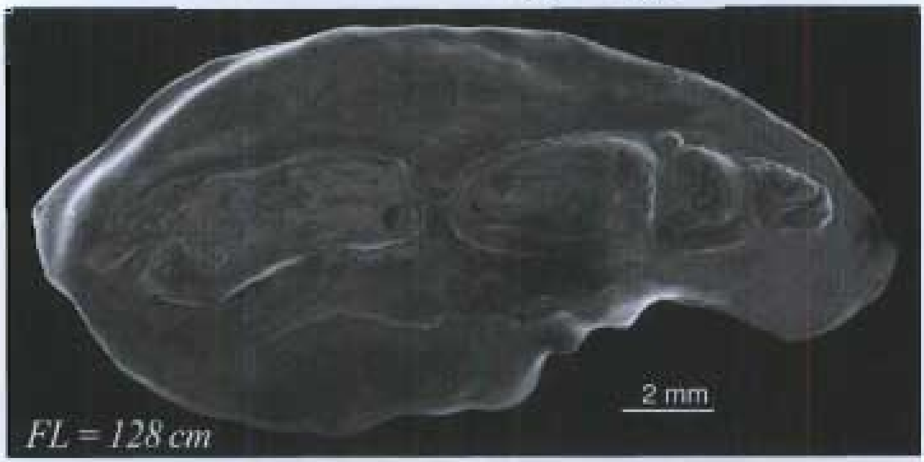
Asteriscii

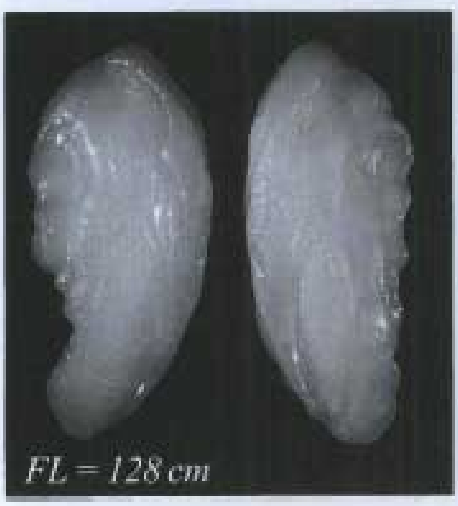
Lapilli



Gadiformes

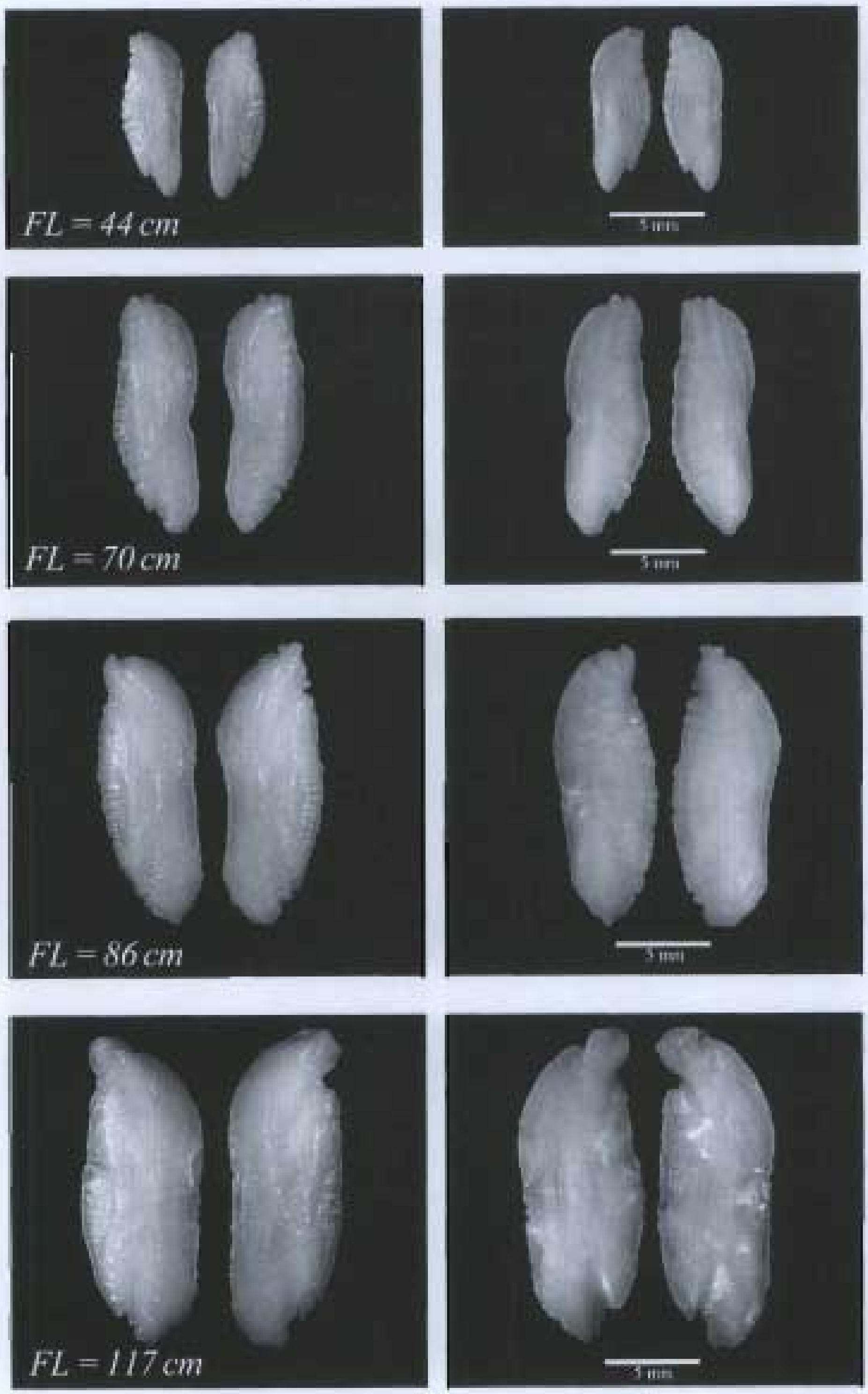
Gadidae: *Molva dypterygia*





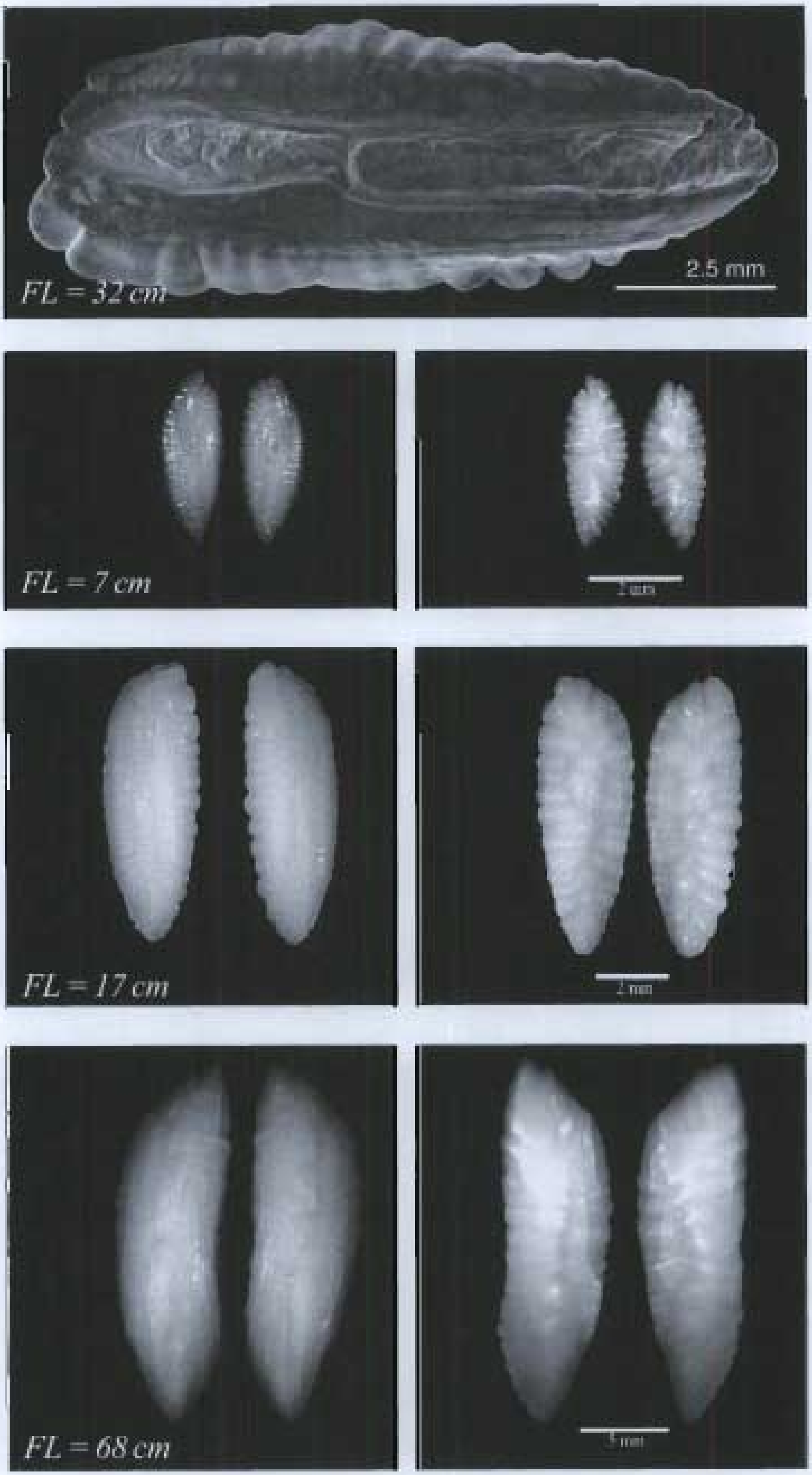
Gadiformes

Gadidae: *Molva molva*



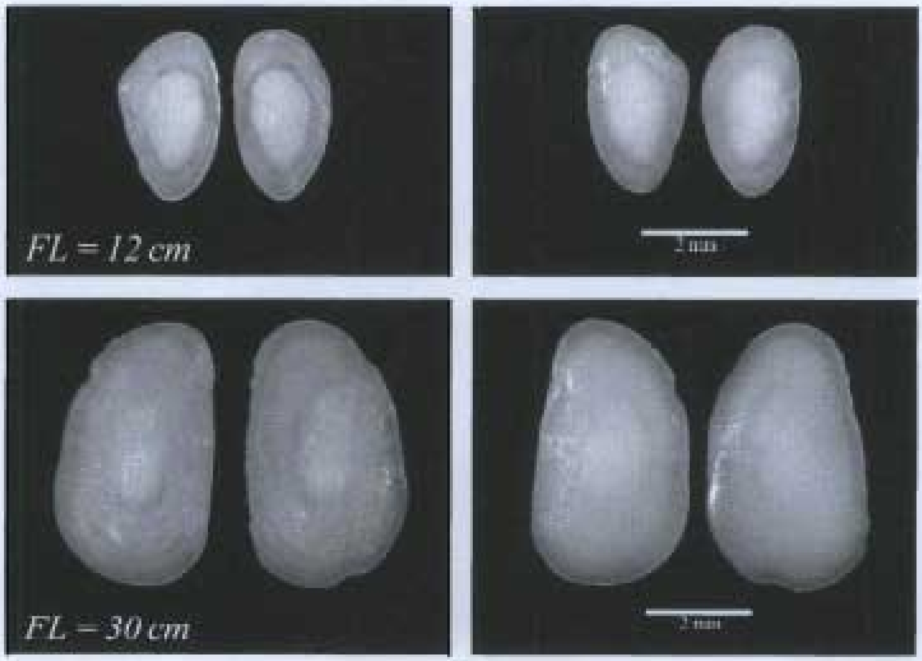
Gadiformes

Gadidae: *Pollachius virens*



Gadiformes

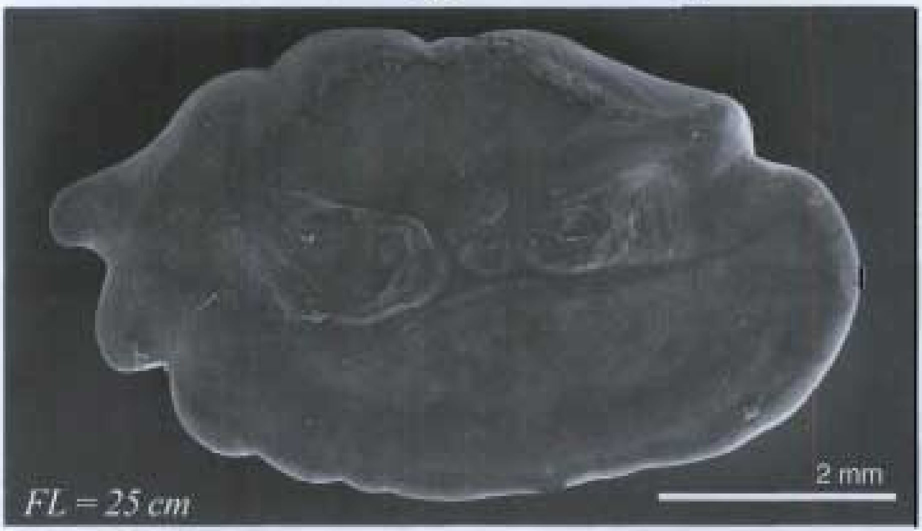
Macrouridae: *Chalinura brevibarbis*



Macrouridae: *Coryphaenoides guentheri*

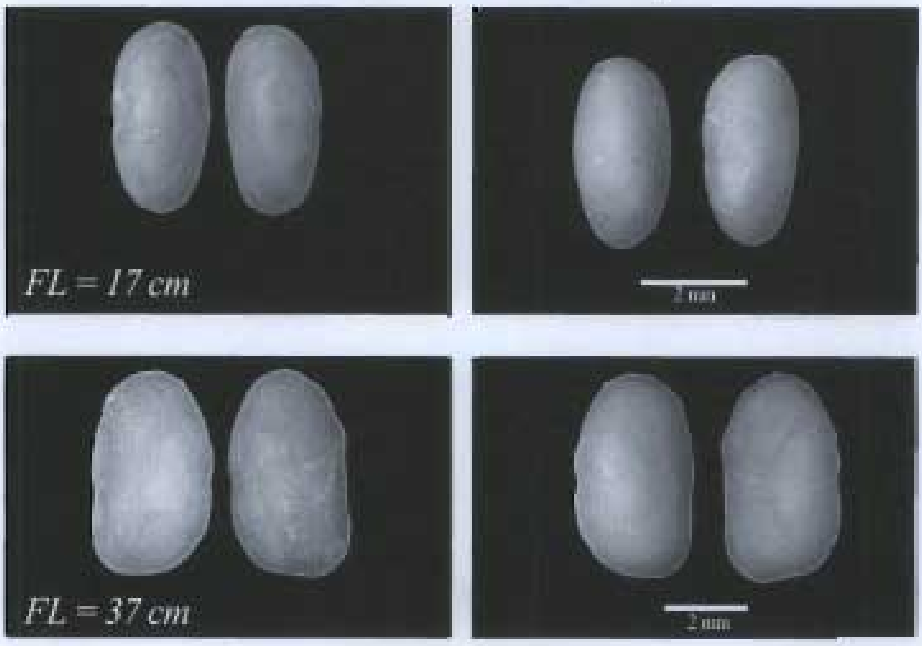
Gadiformes

Macrouridae: *Coryphaenoides rupestris*



Gadiformes

Macrouridae: *Lionurus carapinus*

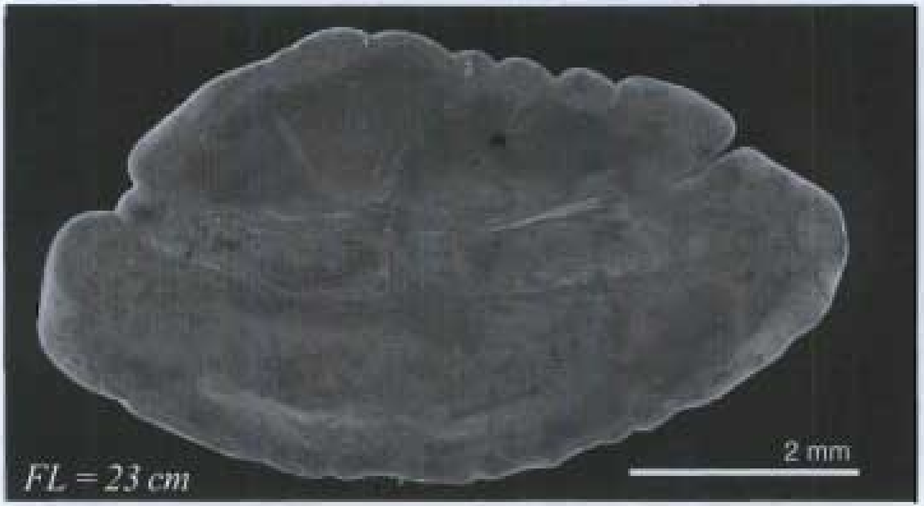


Gadiformes

Macrouridae: *Macrourus berglax*

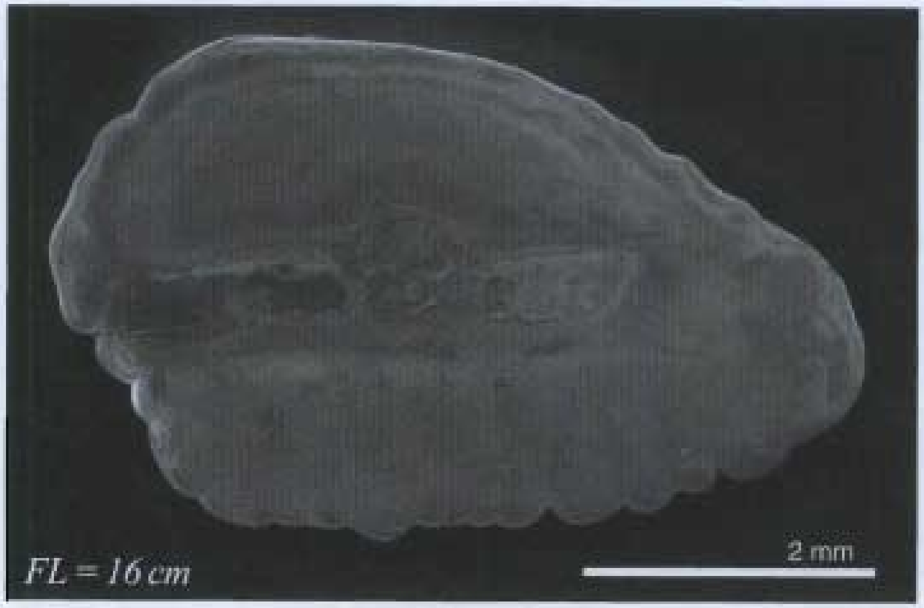
Asterisci

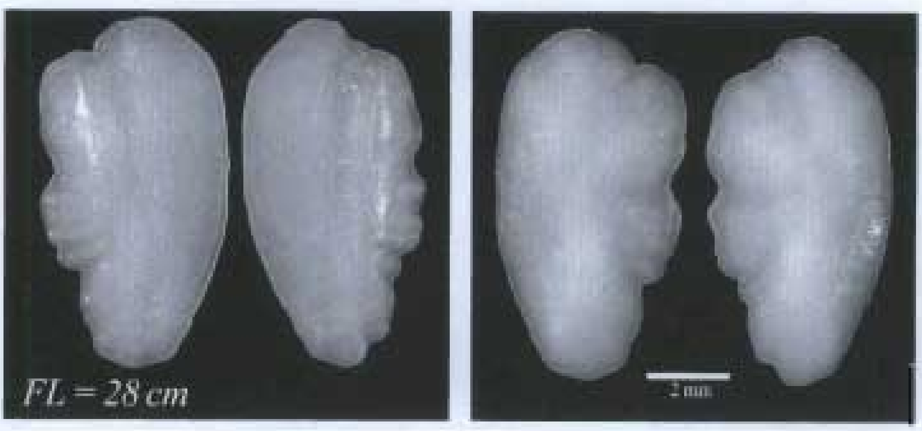
Lapilli



Gadiformes

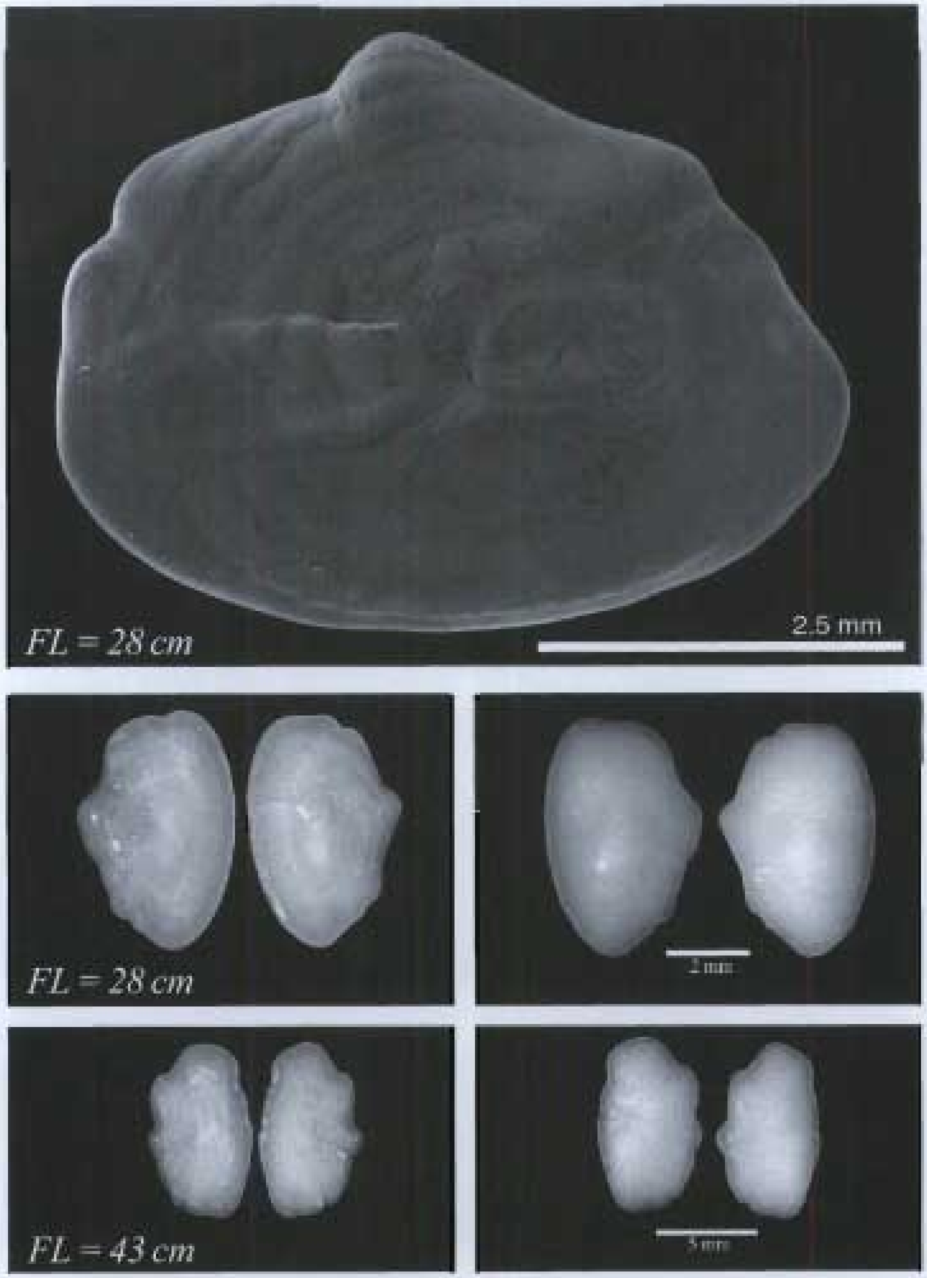
Macrouridae: *Nezumia bairdi*





Gadiformes

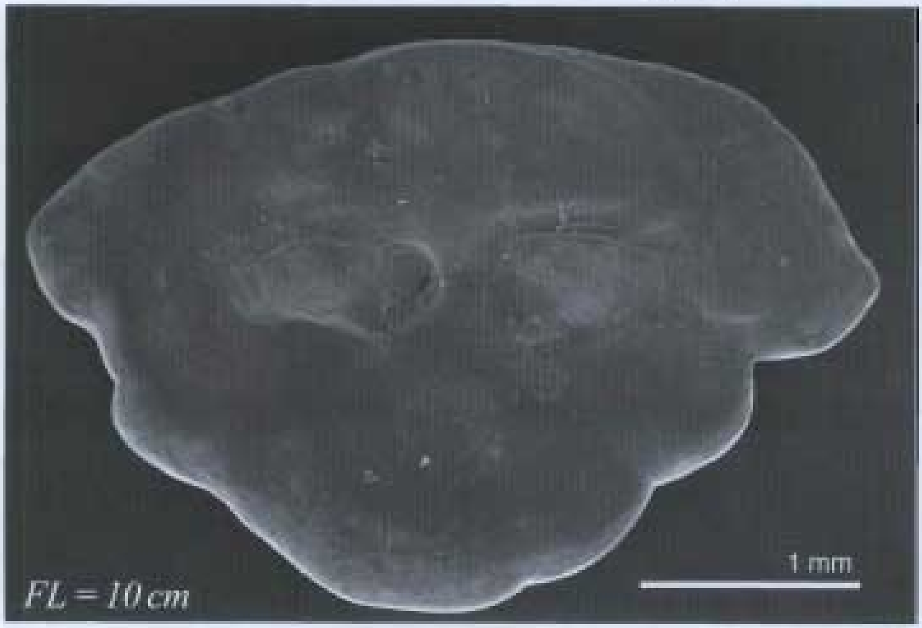
Macrouridae: *Nezumia sclerorhynchus*



Macrouridae: *Trachyrhynchus murrayi*

Gadiformes

Melanonidae: *Melanonus zugmayeri*

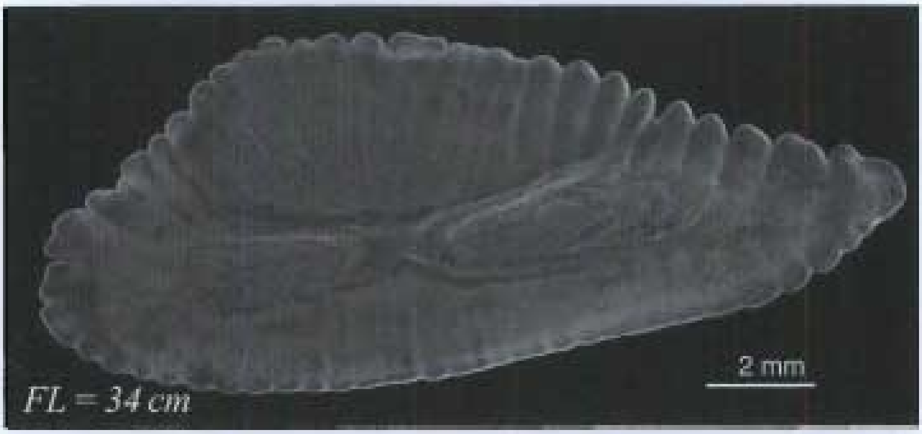


Asteriscii

Lapilli

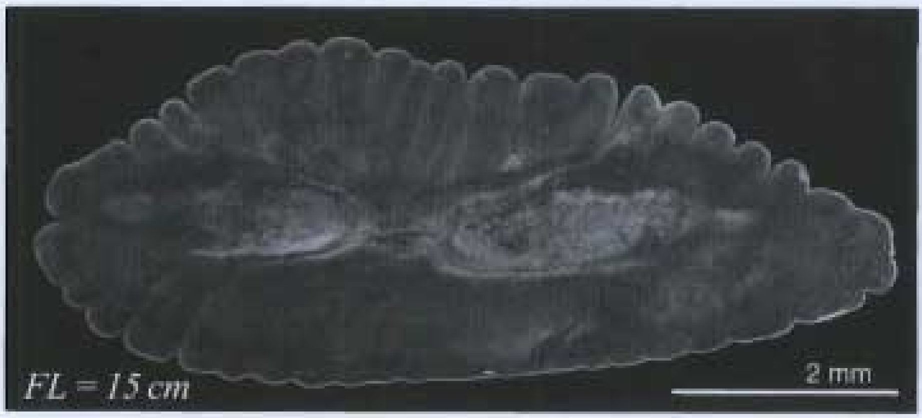
Gadiformes

Merlucciidae: *Merluccius albidus*

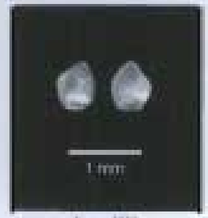


Gadiformes

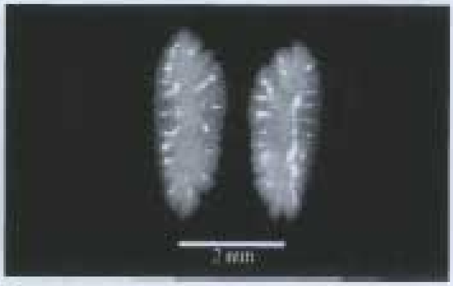
Merlucciidae: *Merluccius bilinearis*



Asterisci



Lapilli

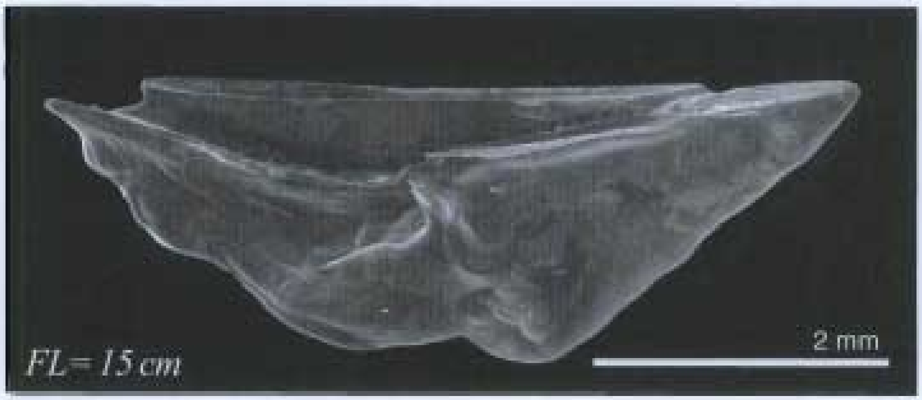


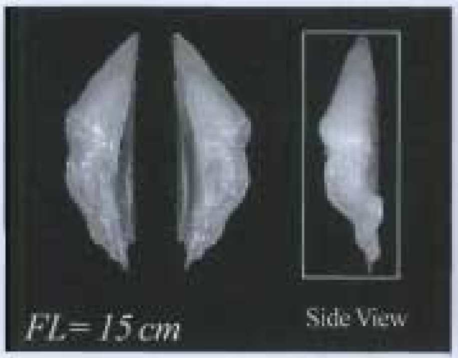
Gadiformes

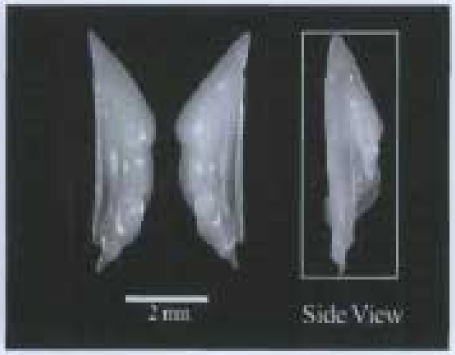
Moridae: *Antimora rostrata*

Gadiformes

Moridae: *Brosmiculus imberbis*





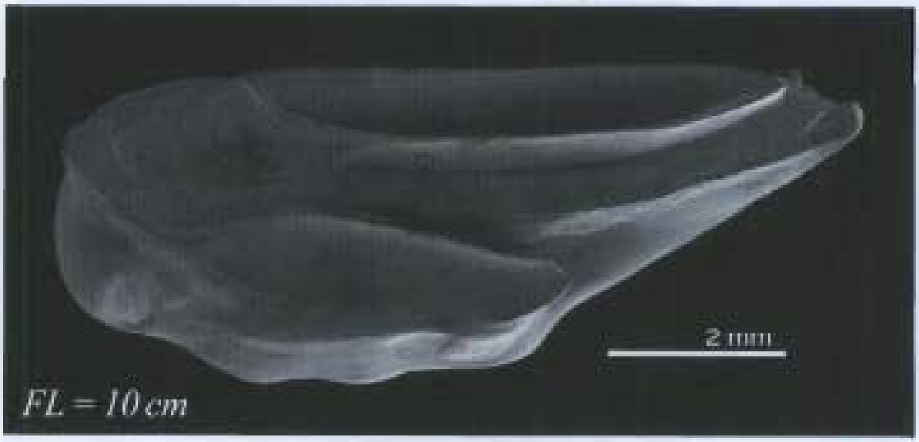


Gadiformes

Moridae: *Halargyreus johnsoni*

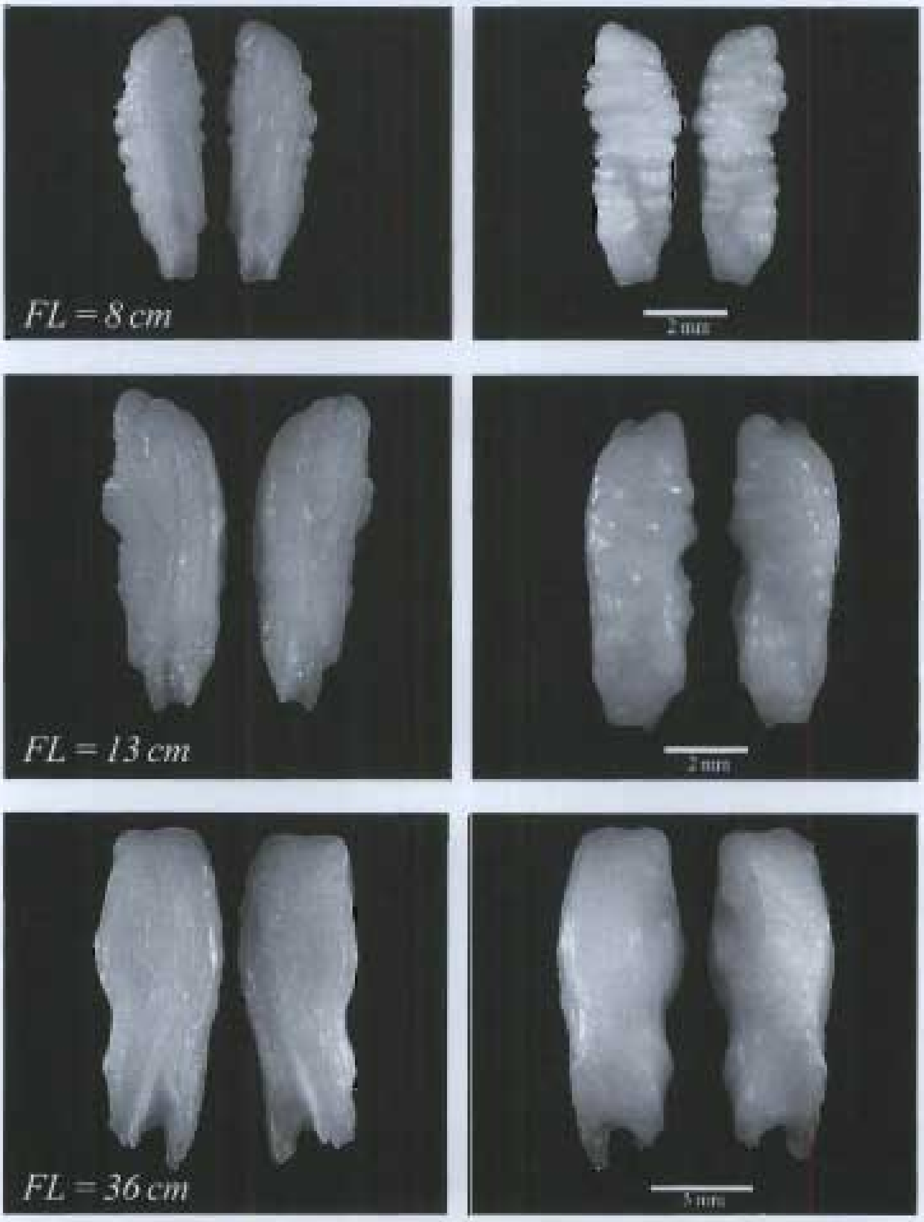
Gadiformes

Moridae: *Laemonema barbatula*

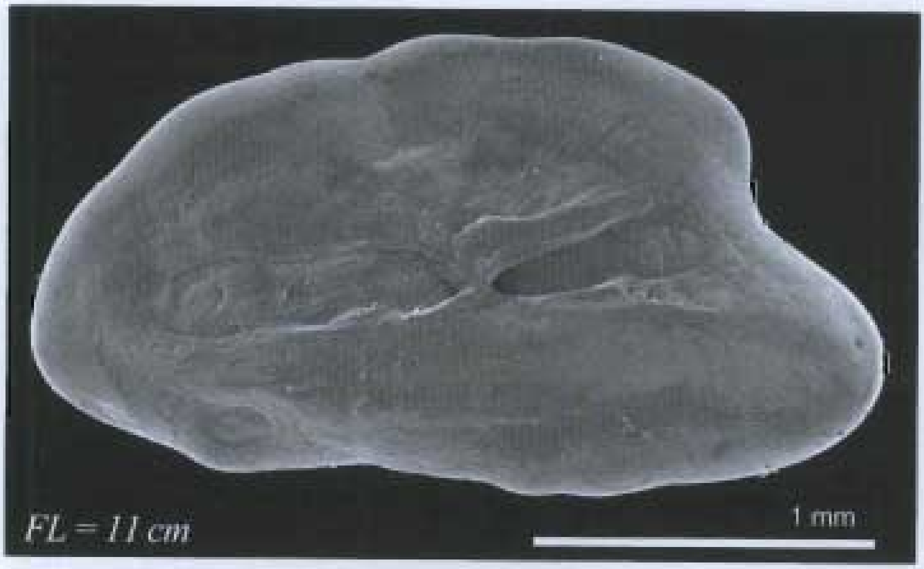


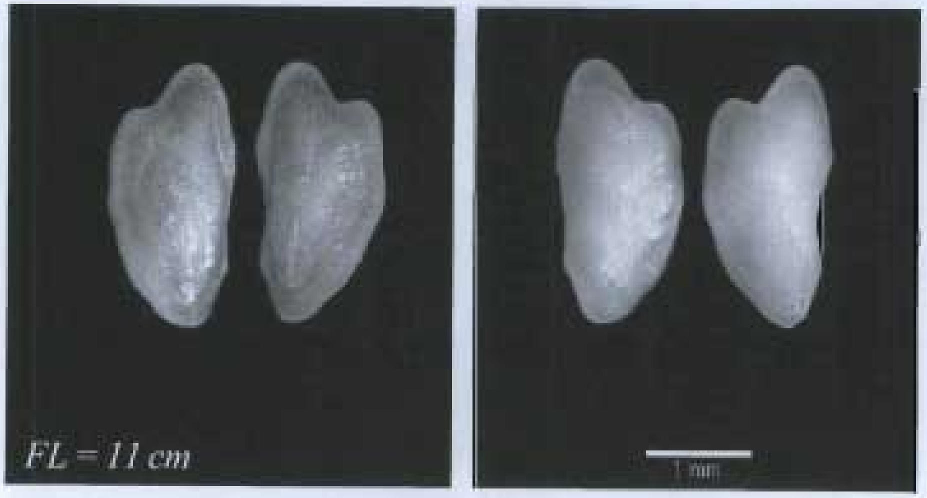
Gadiformes

Moridae: *Lepidion eques*



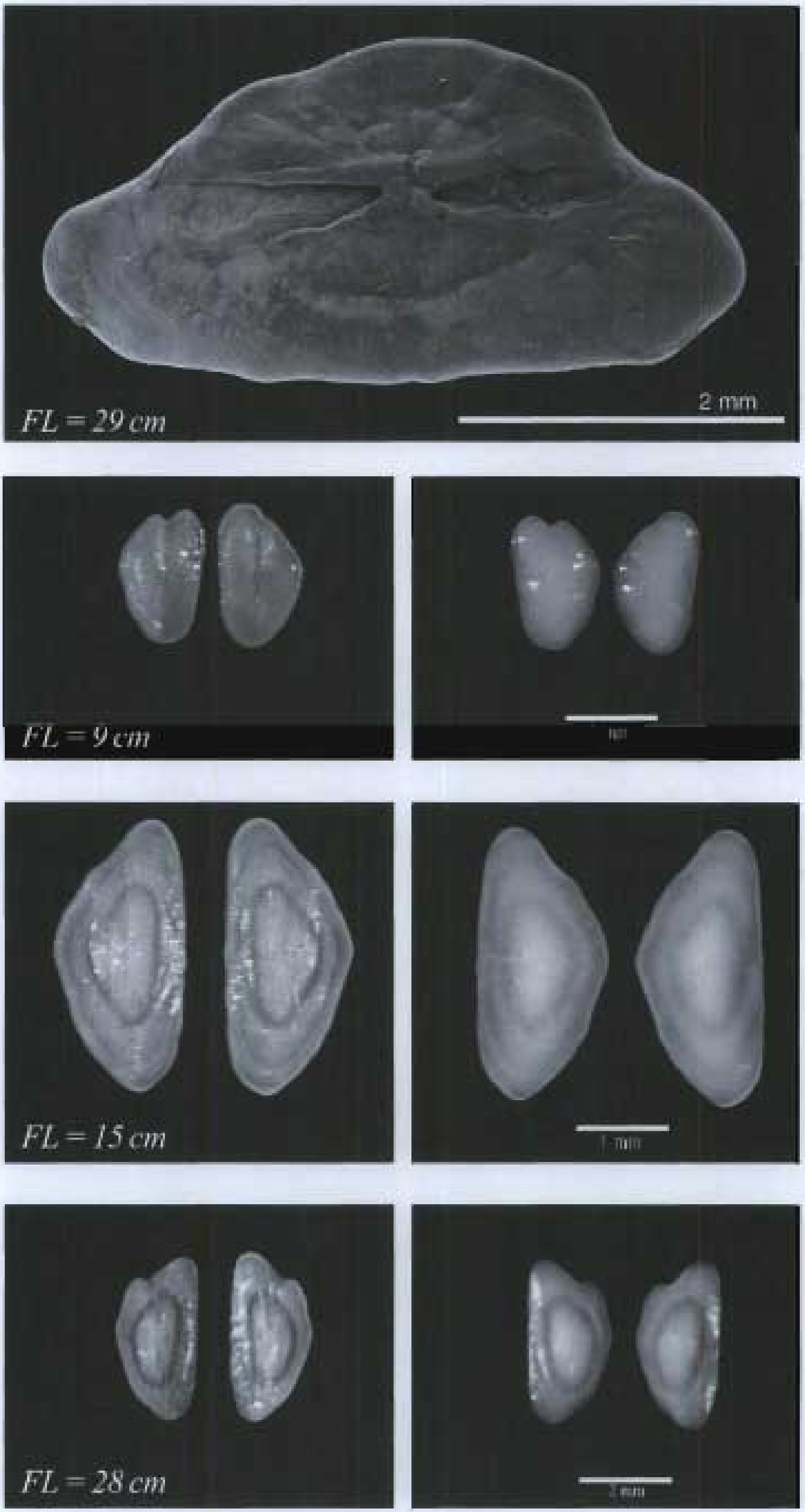
Phycidae: *Enchelyopus cimbrius*



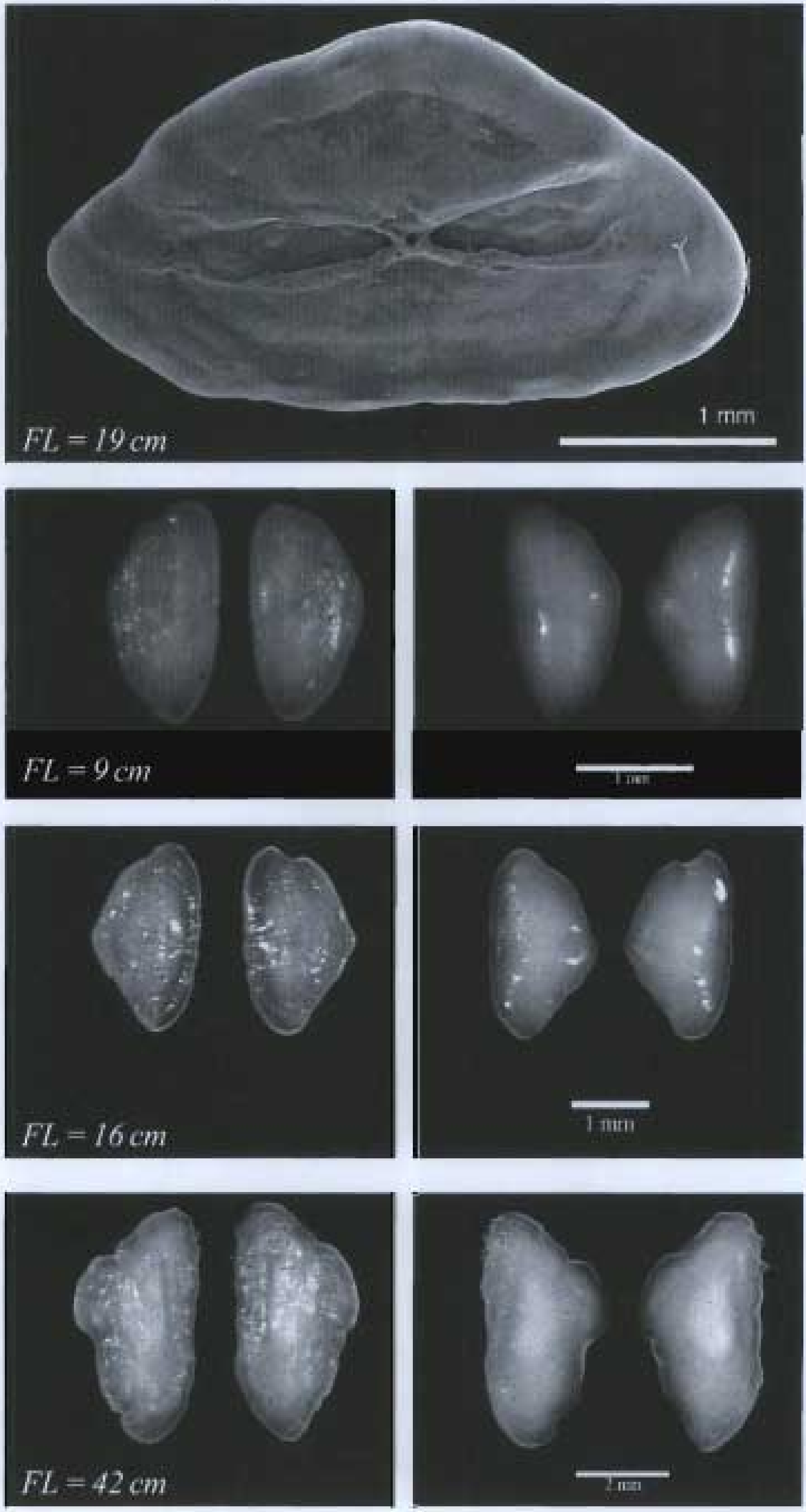


Gadiformes

Phycidae: *Gaidropsarus argentatus*

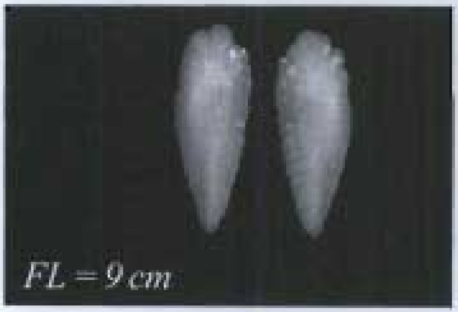


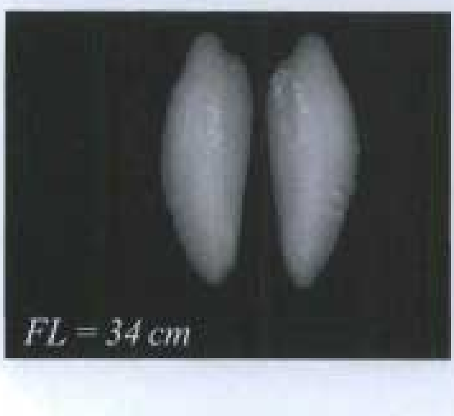
Phycidae: *Gaidropsarus ensis*



Gadiformes

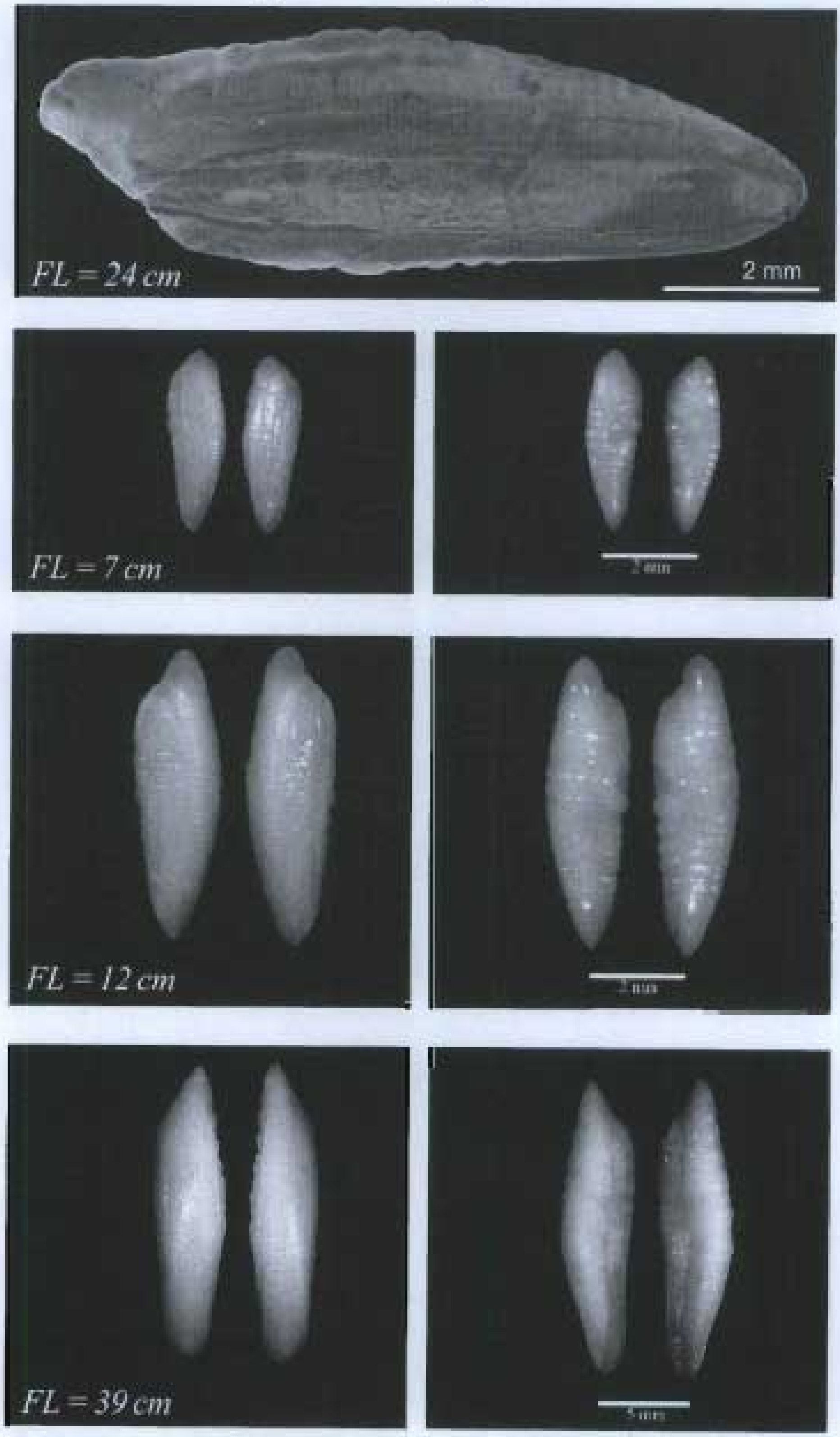
Phycidae: *Urophycis chesteri*





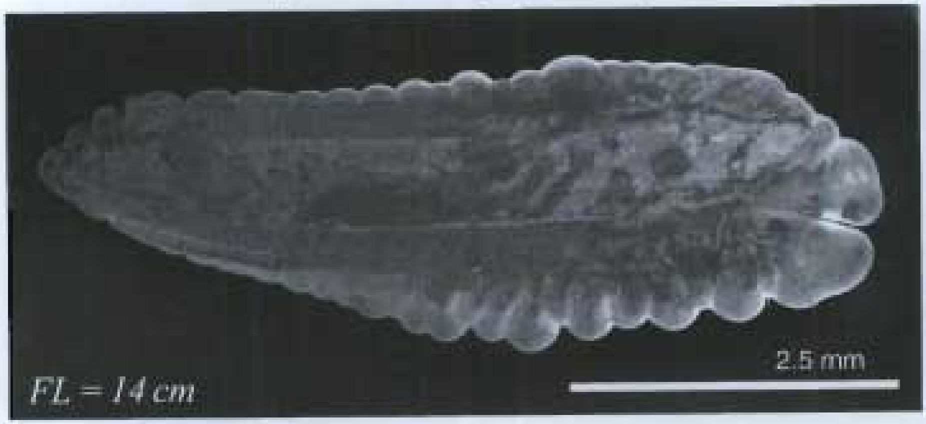
Gadiformes

Phycidae: *Urophycis chuss*



Gadiformes

Phycidae: *Urophycis regia*

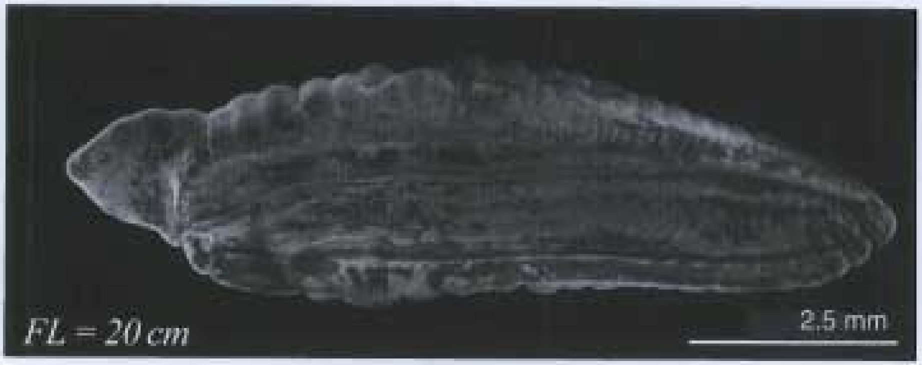


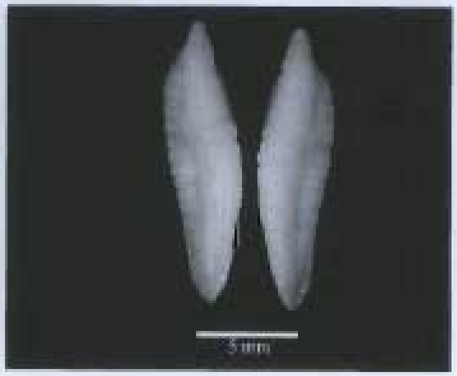
Asteriscii

Lapilli

Gadiformes

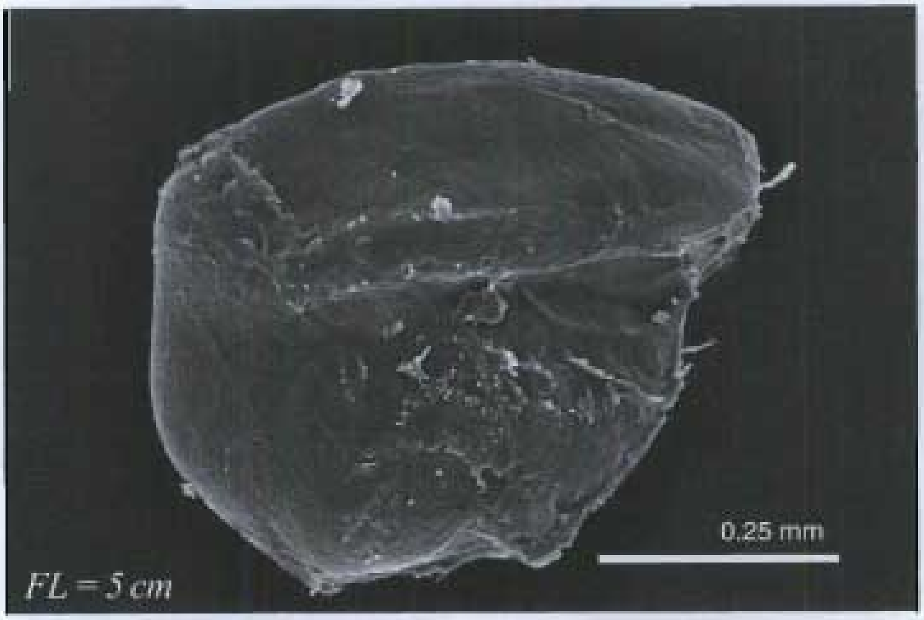
Phycidae: *Urophycis tenuis*





Gasterosteiformes

Gasterosteidae: *Apeltes quadracus*

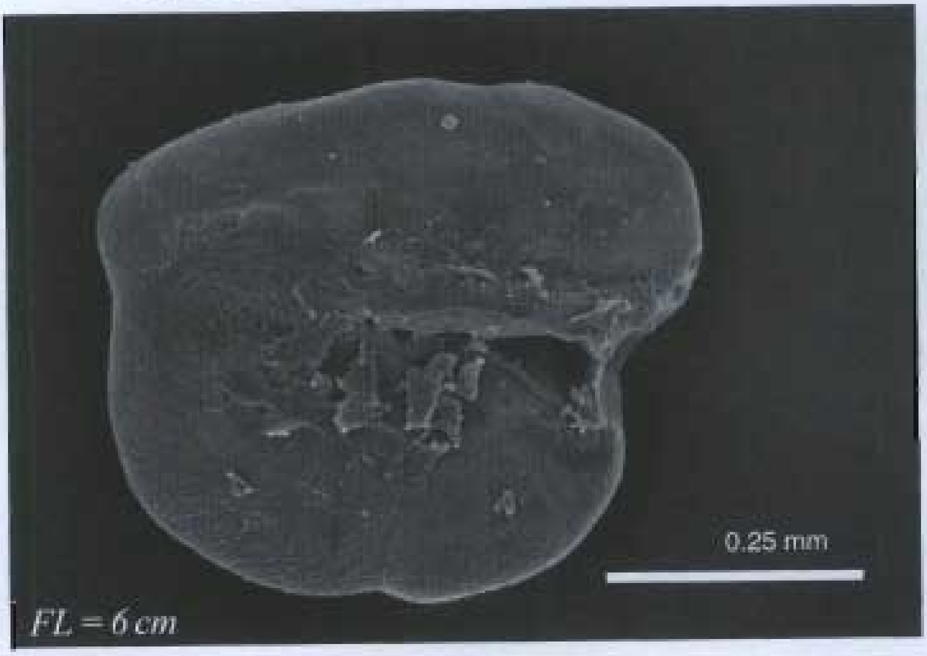


Asteriscii

Lapilli

Gasterosteiformes

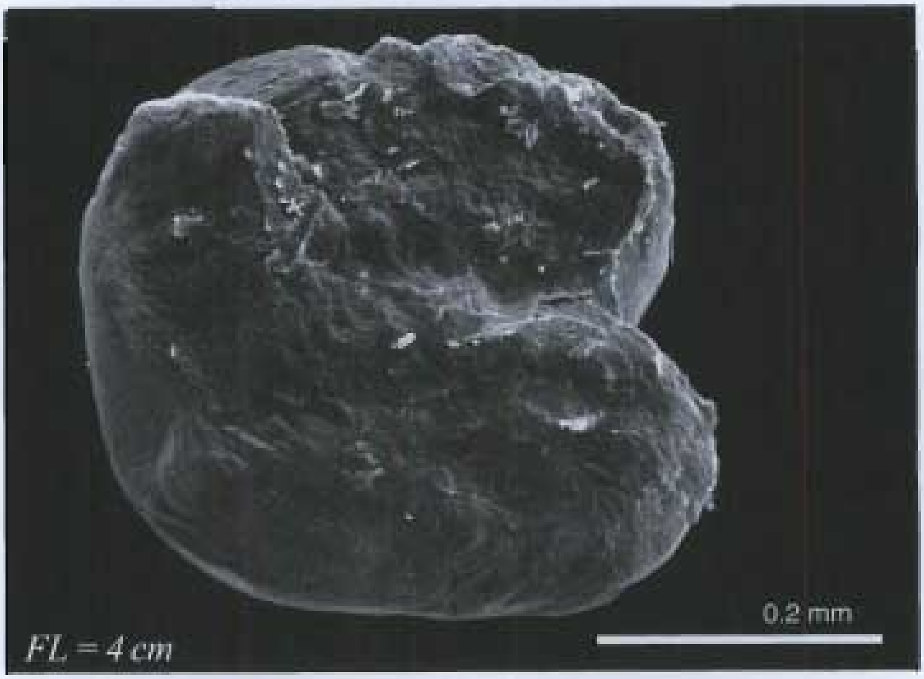
Gasterosteidae: *Gasterosteus aculeatus*



Asteriscii
& Lapilli

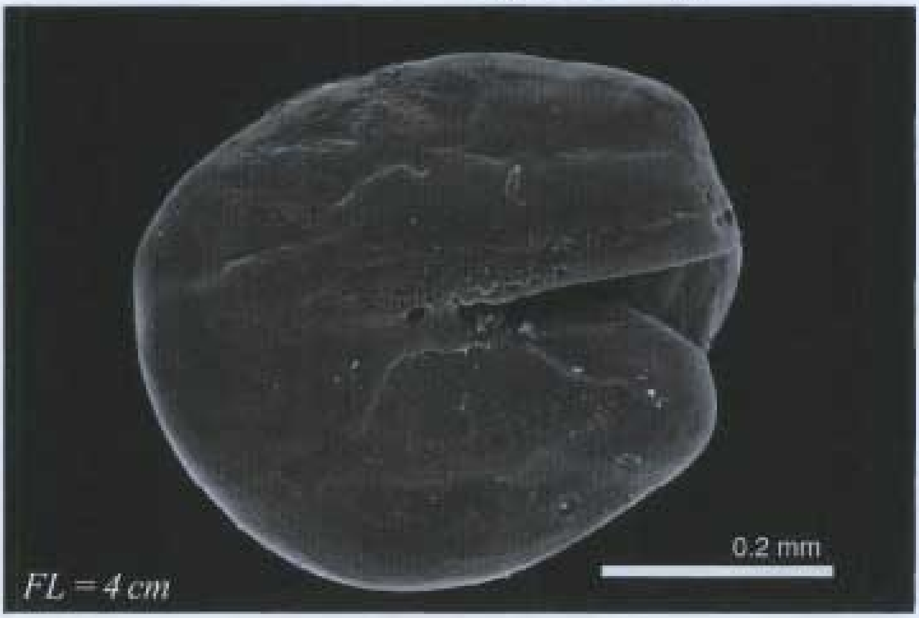
Gasterosteiformes

Gasterosteidae: *Gasterosteus wheatlandi*



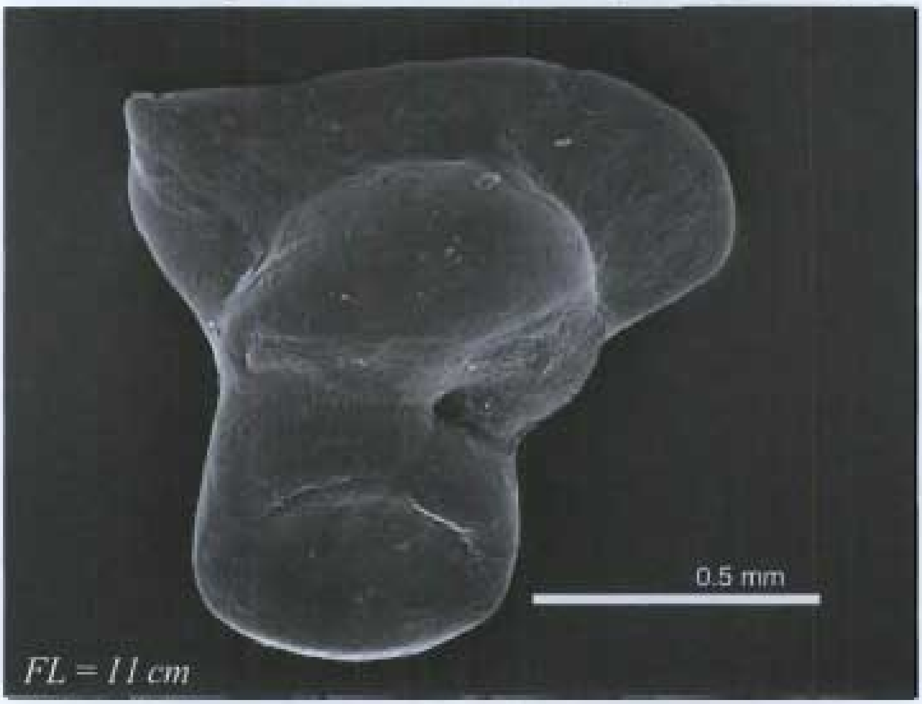
Gasterosteiformes

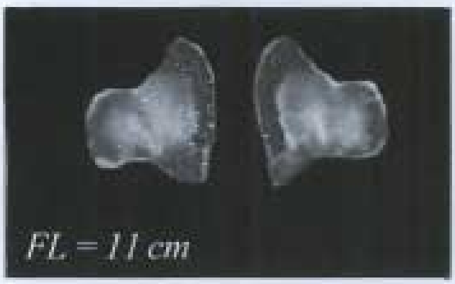
Gasterosteidae: *Pungitius pungitius*

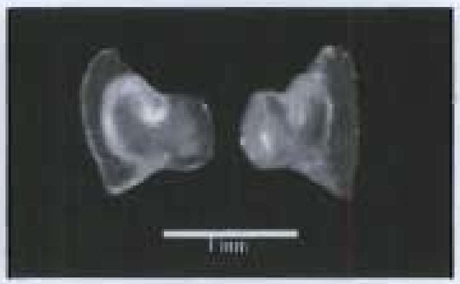


Gasterosteiformes

Macrorhamphosidae: *Macrorhamphosus scolopax*

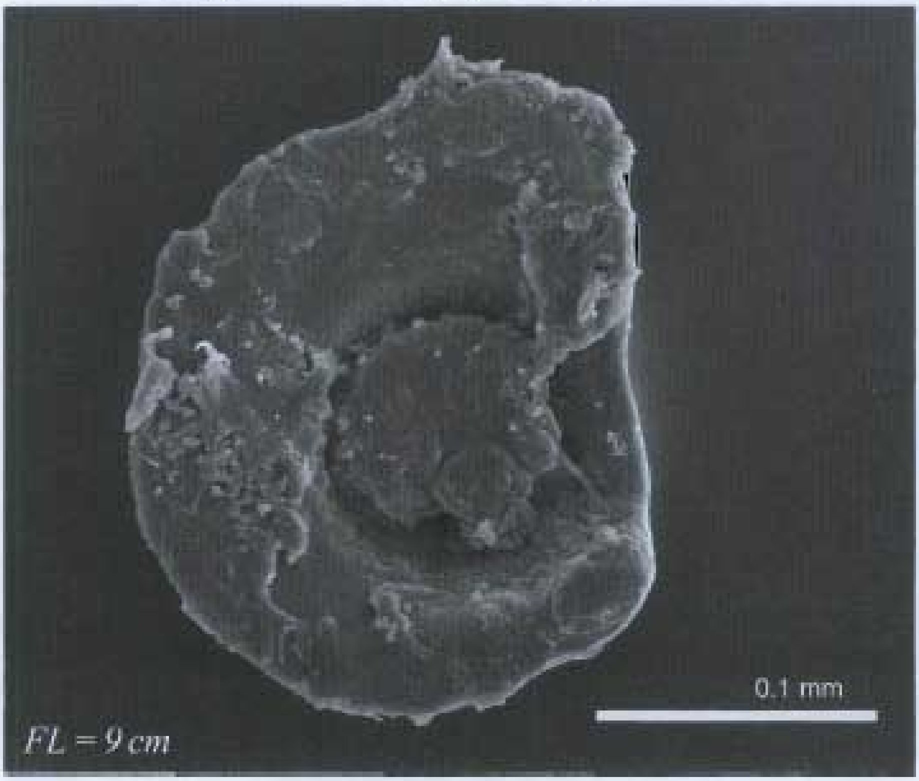






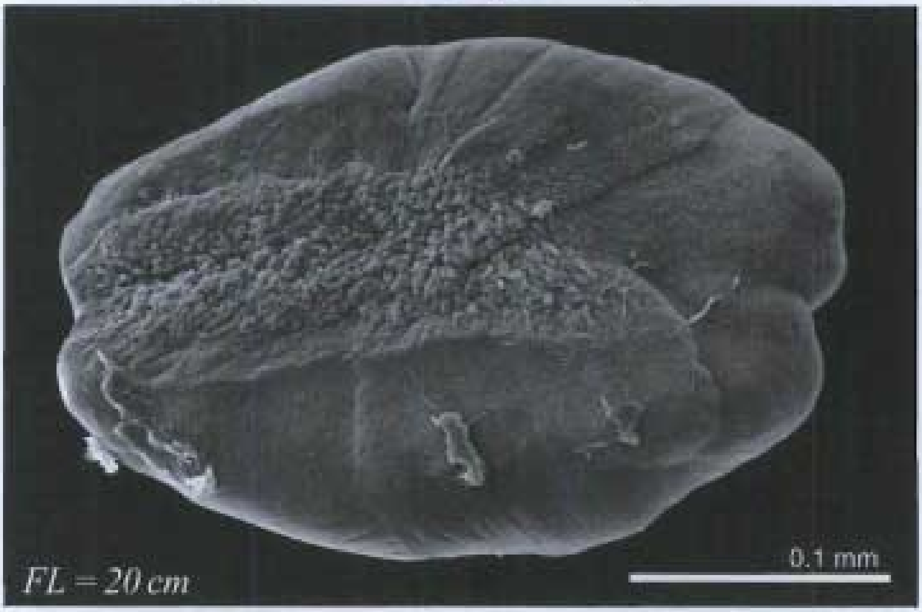
Gasterosteiformes

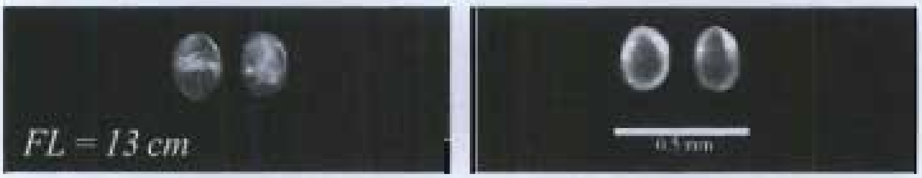
Syngnathidae: *Hippocampus erectus*

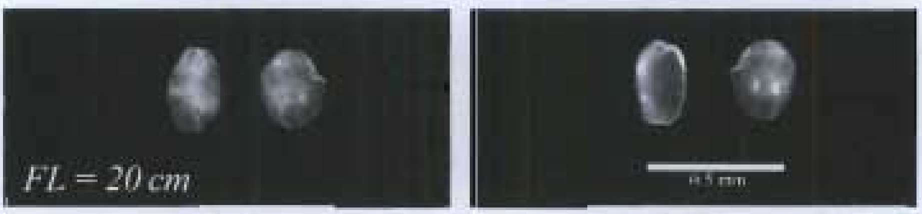


Gasterosteiformes

Syngnathidae: *Syngnathus fuscus*

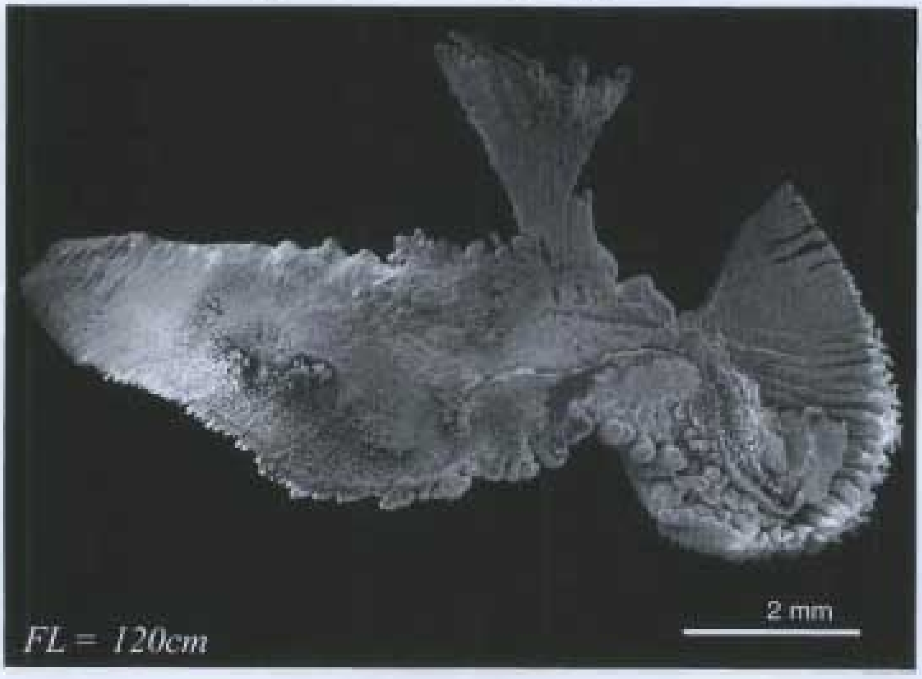






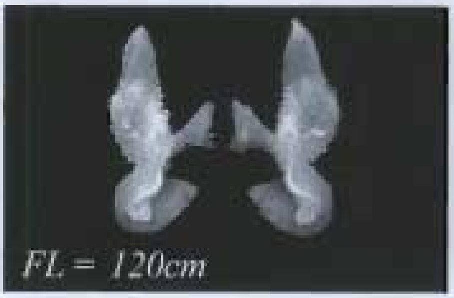
Lampridiformes

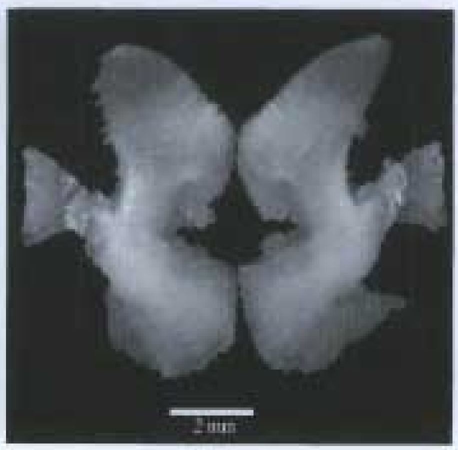
Lamprididae: *Lampris guttatus*



Asteriscii

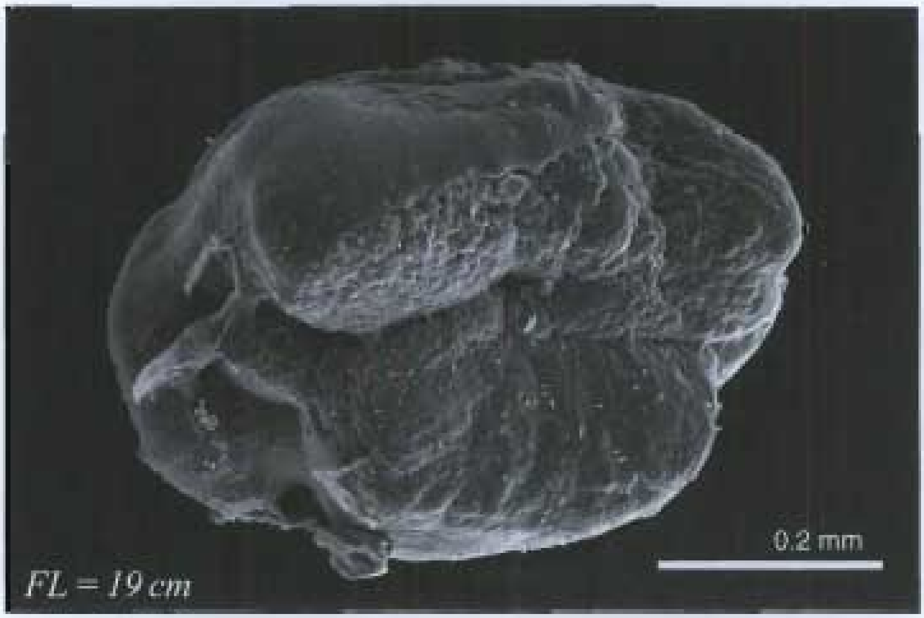
Lapilli

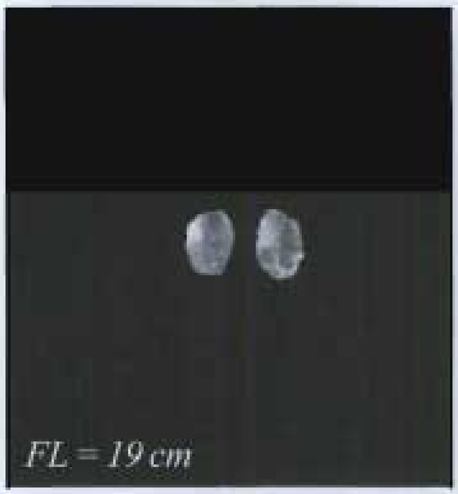




Lophiiformes

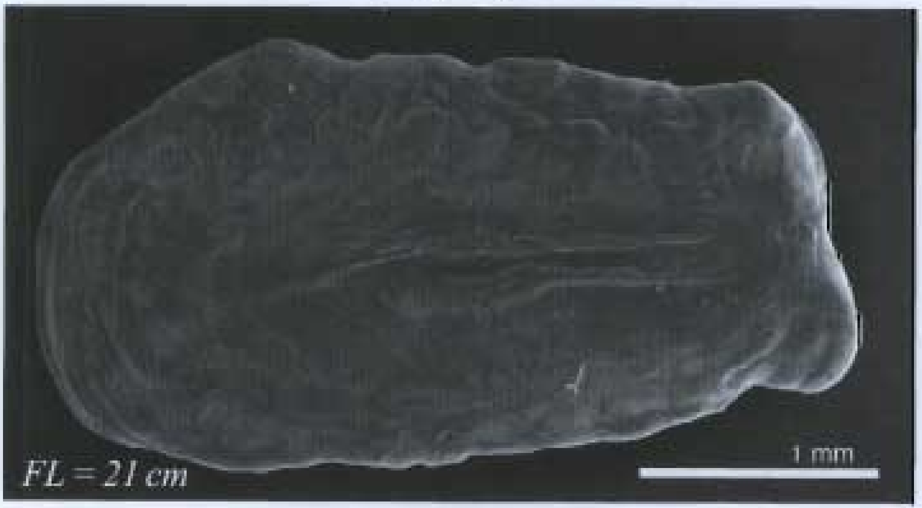
Ceratiidae: *Ceratias holboelli*





Lophiiformes

Ceratiidae: *Cryptopsaras couesi*

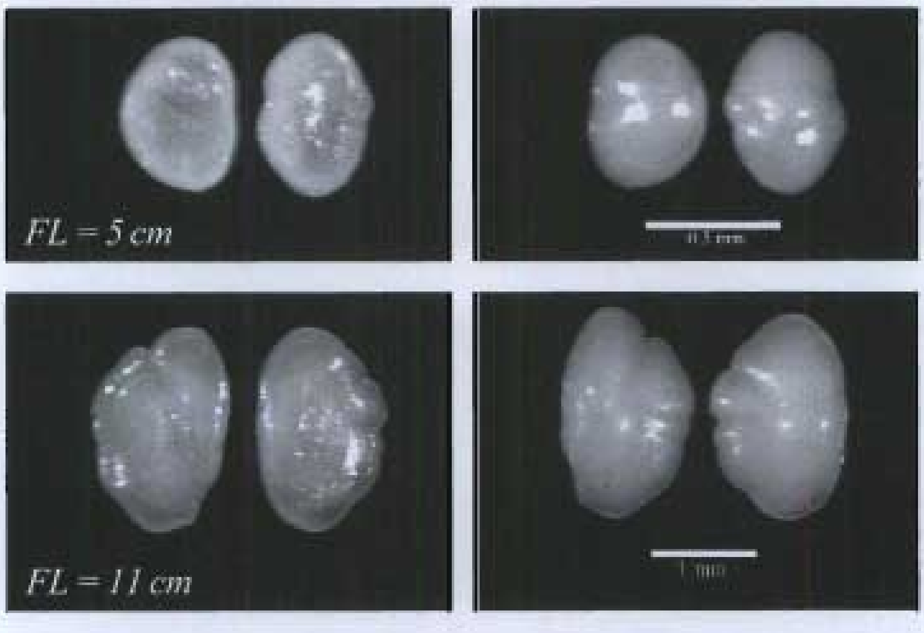


Lophiiformes

Lophiidae: *Lophius americanus*

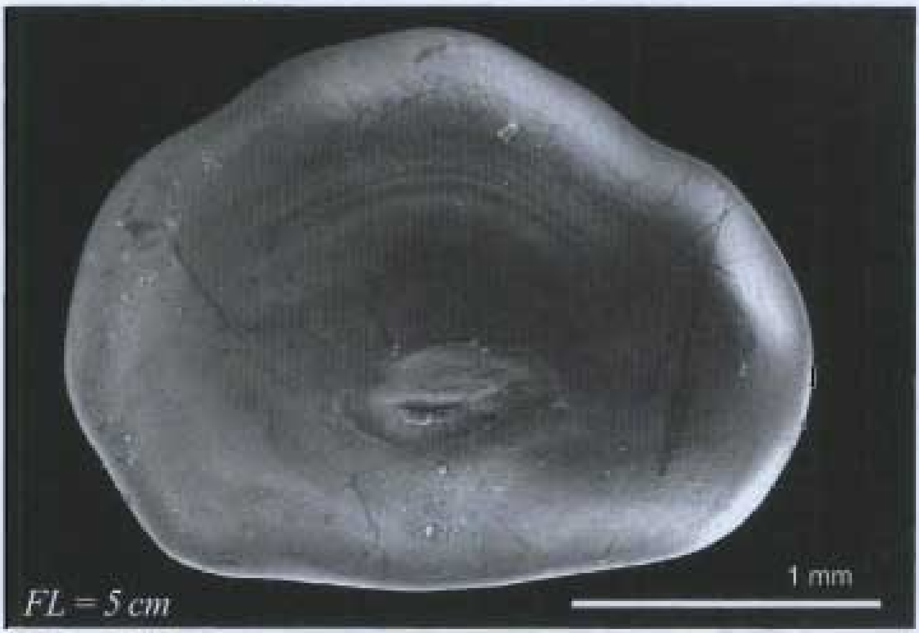
Asteriscii

Lapilli



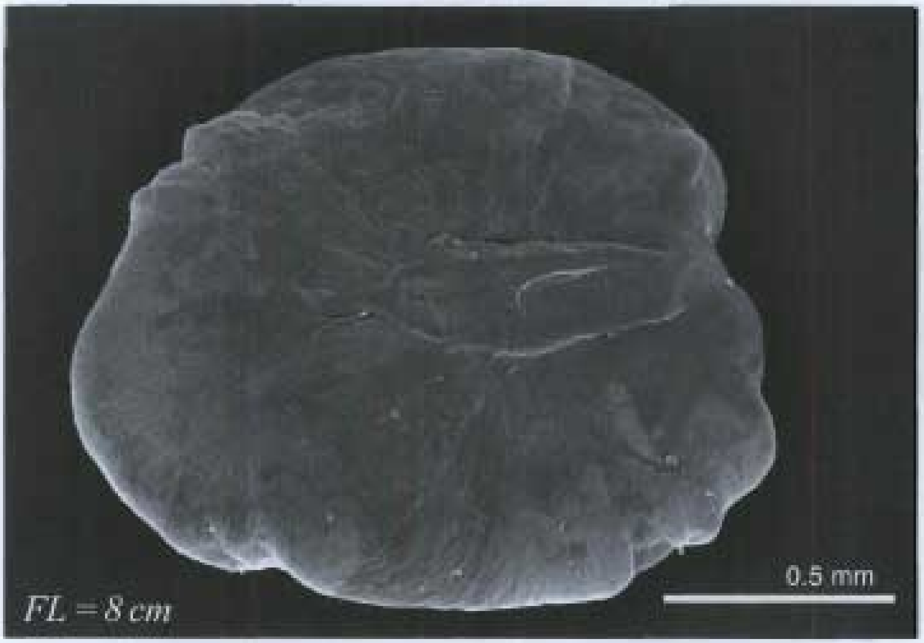
Lophiiformes

Ogcocephalidae: *Dibranchus atlanticus*



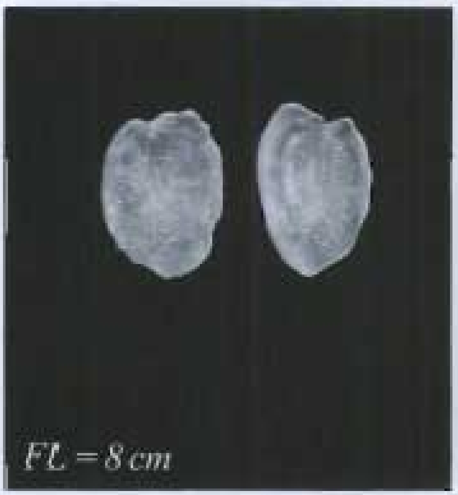
Lophiiformes

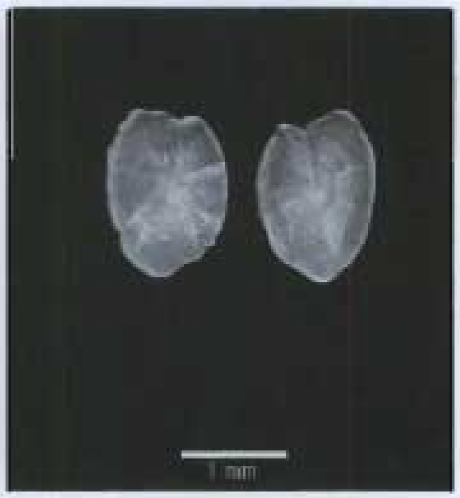
Oneirodidae: *Oneirodes sp.*



Asteriscii

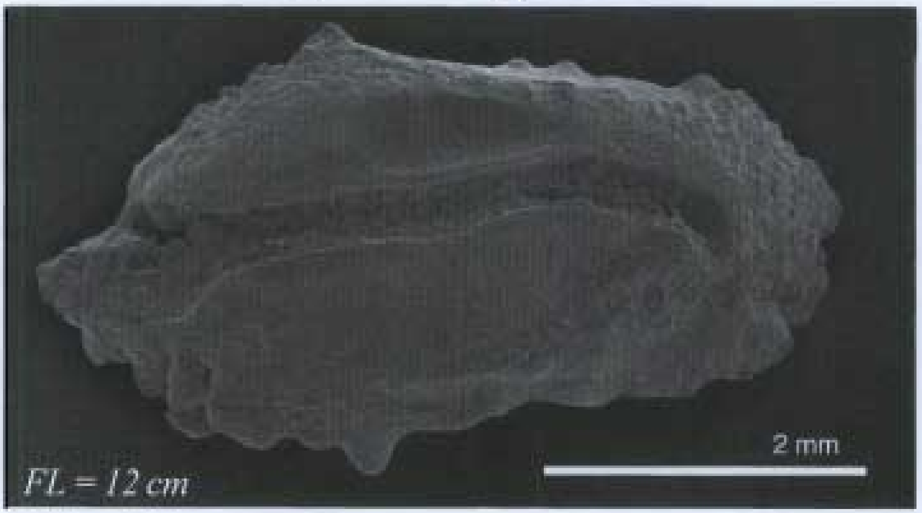
Lapilli





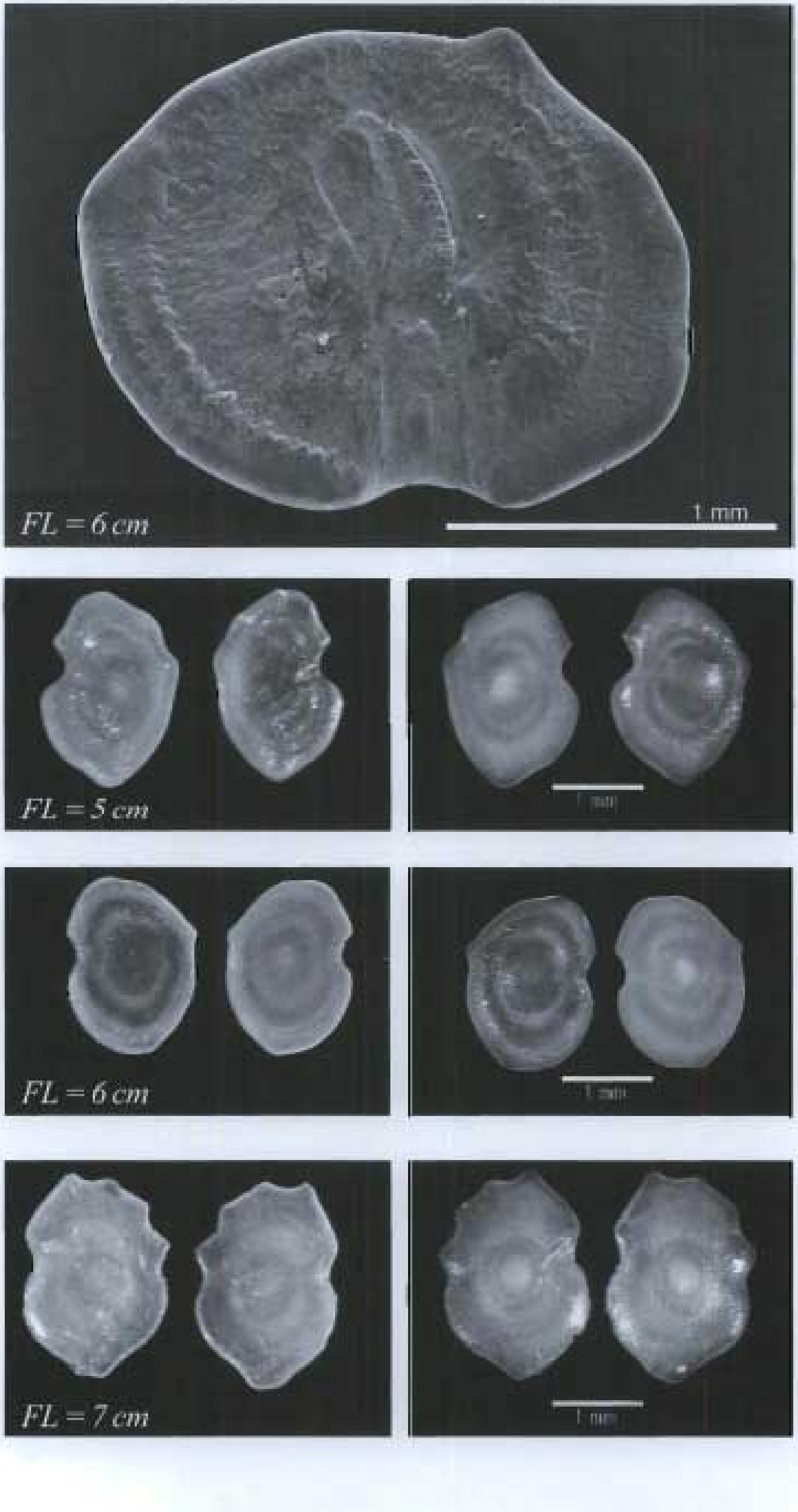
Mugiliformes

Mugilidae: *Mugil curema*



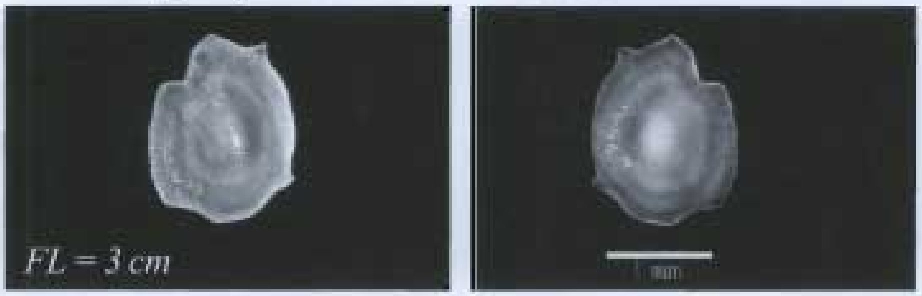
Myctophiformes

Myctophidae: *Benthosema glaciale*

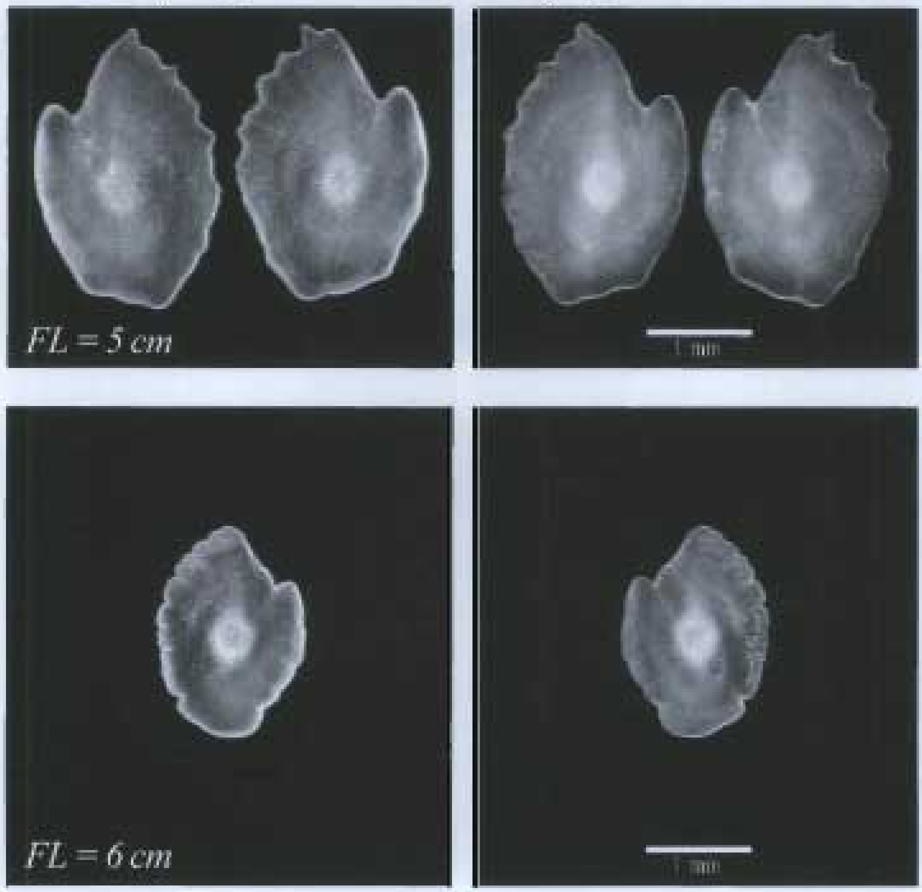


Myctophiformes

Myctophidae: *Benthosema suborbitale*

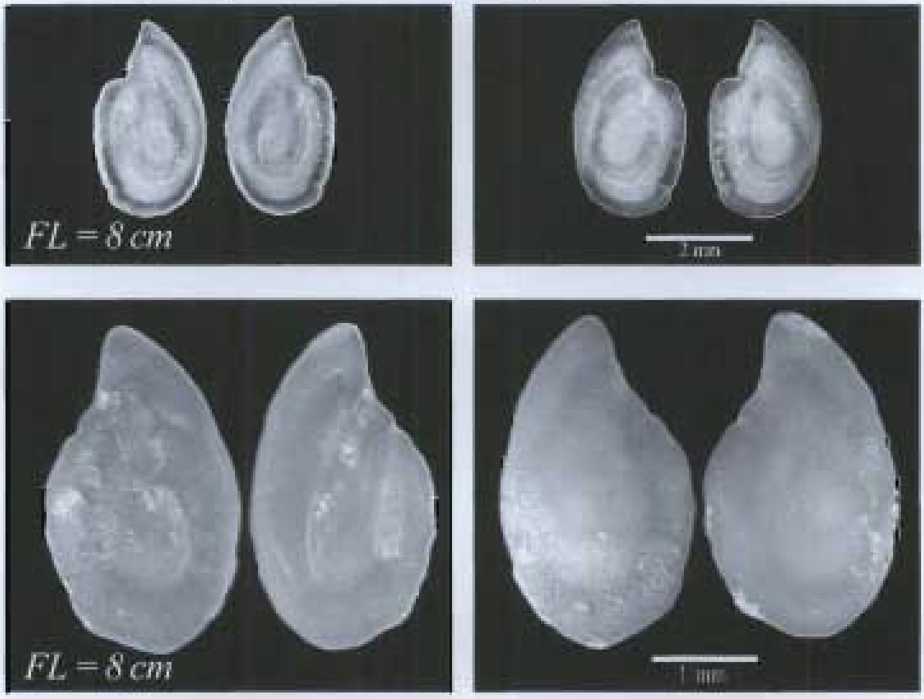


Myctophidae: *Bolinichthys photothorax*

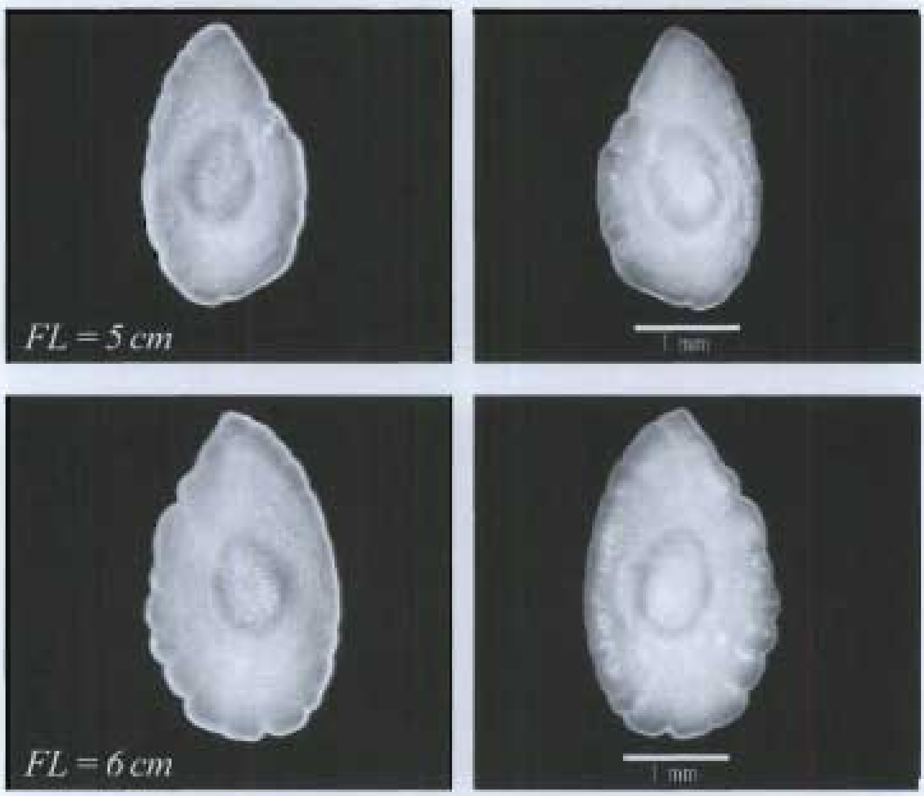


Myctophiformes

Myctophidae: *Ceratoscopelus maderensis*

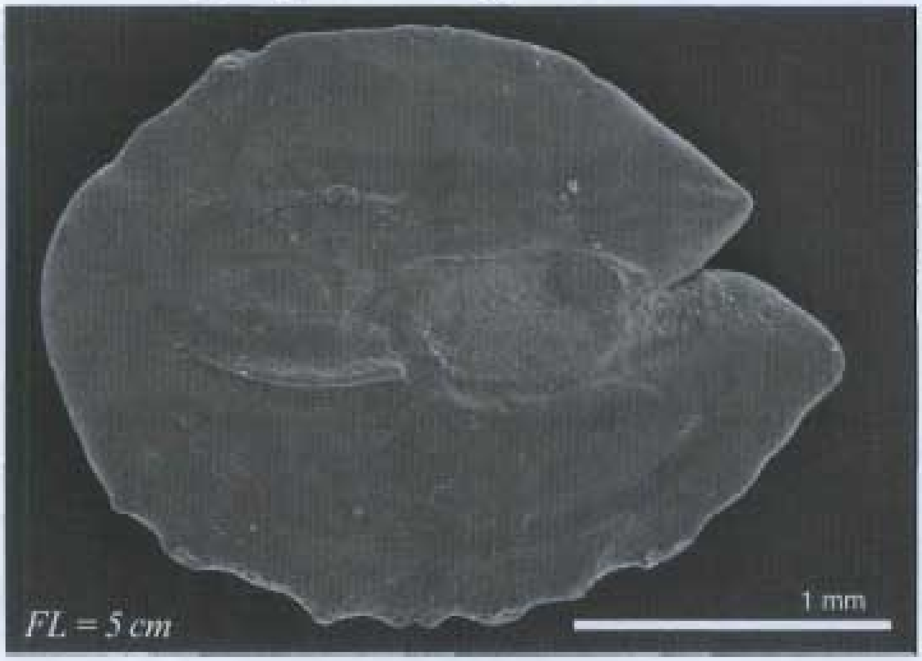


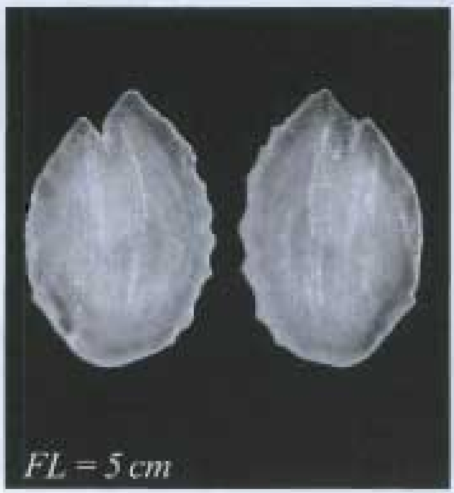
Myctophidae: *Ceratoscopelus warmingii*

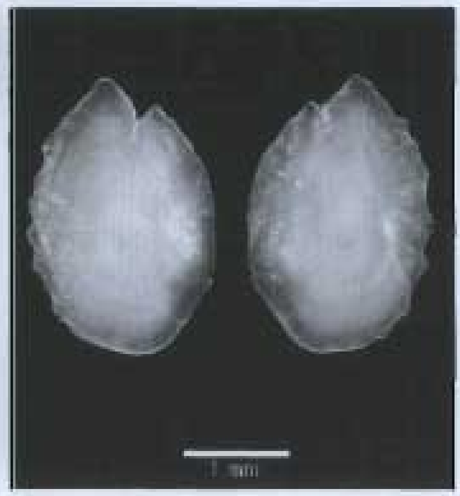


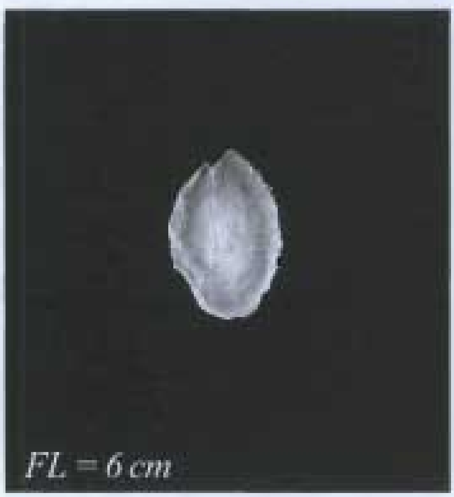
Myctophiformes

Myctophidae: *Diaphus dumerilii*



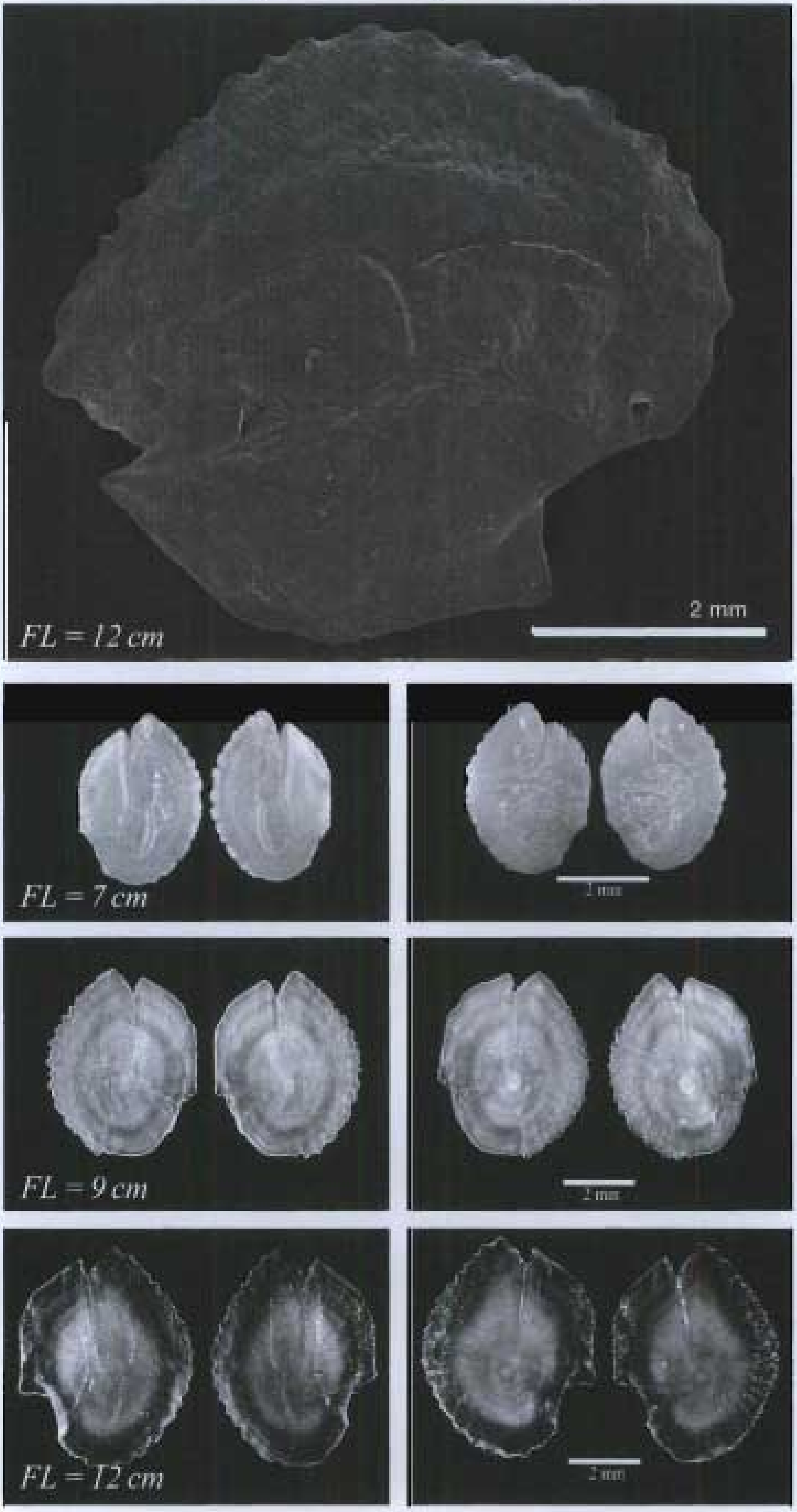






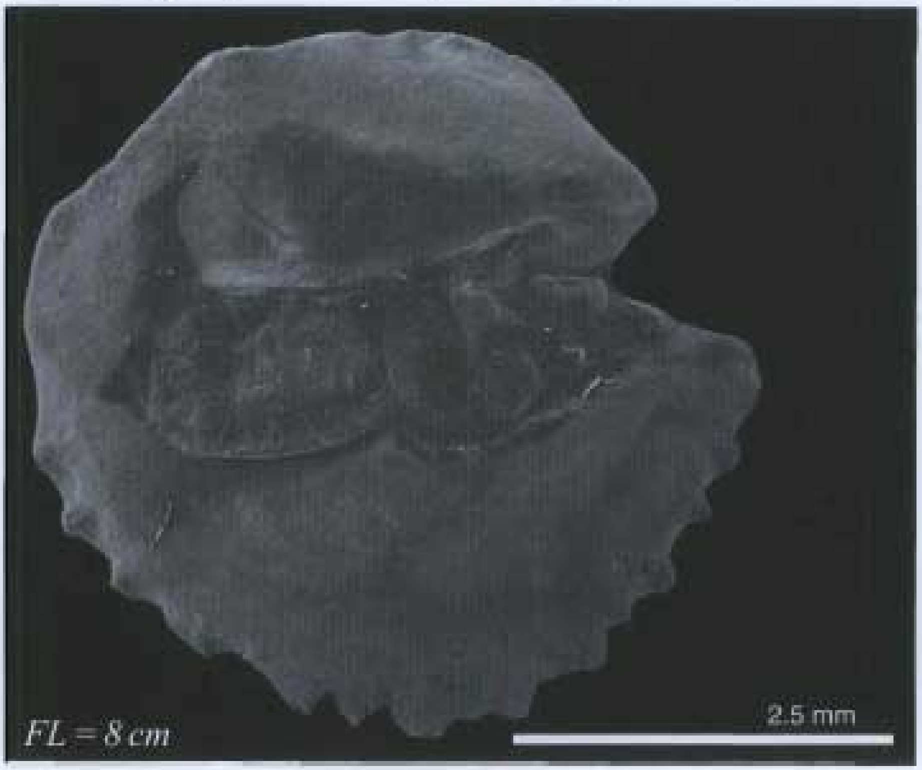
Myctophiformes

Myctophidae: *Diaphus effulgens*



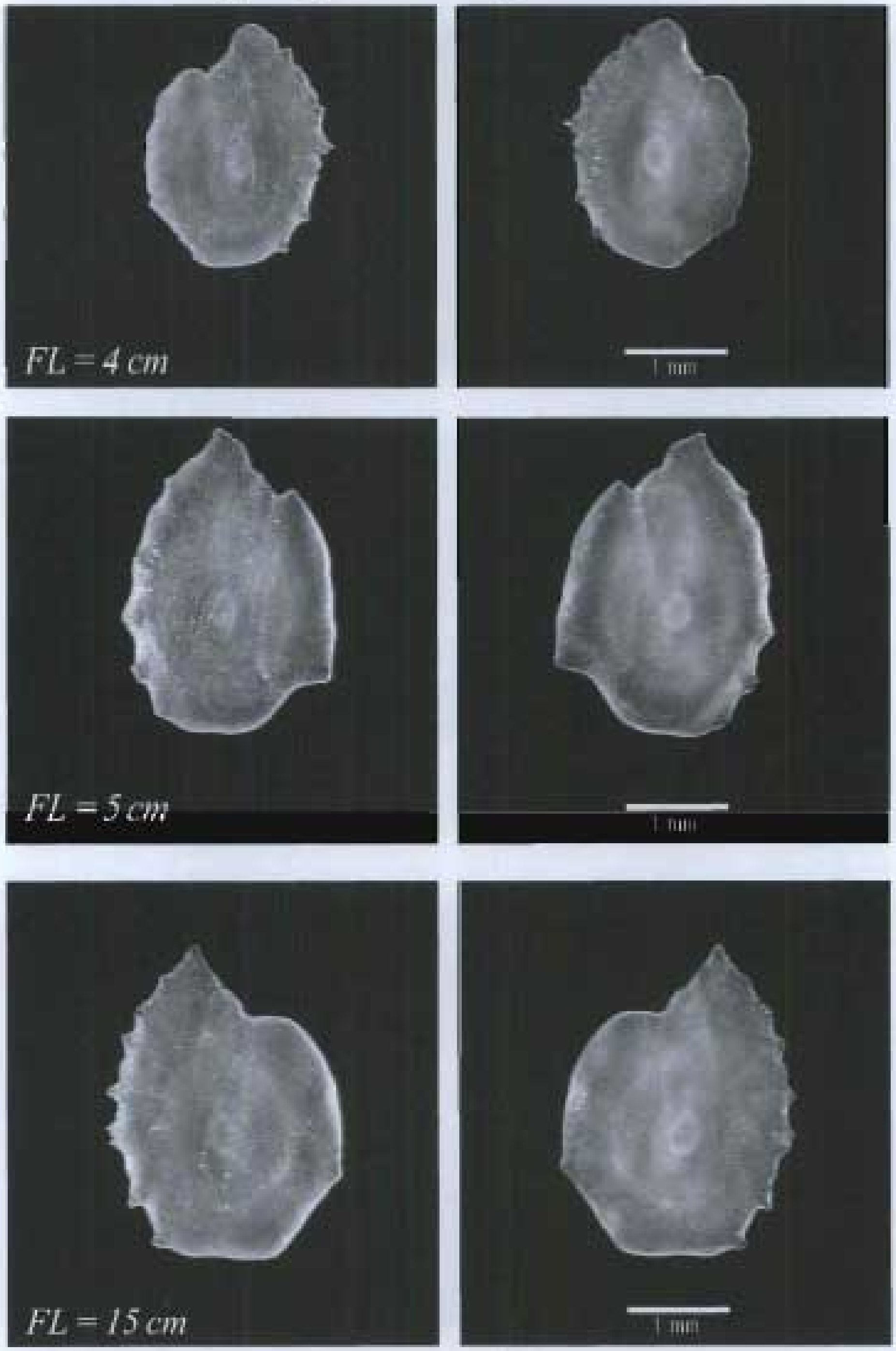
Myctophiformes

Myctophidae: *Diaphus metopoclampus*



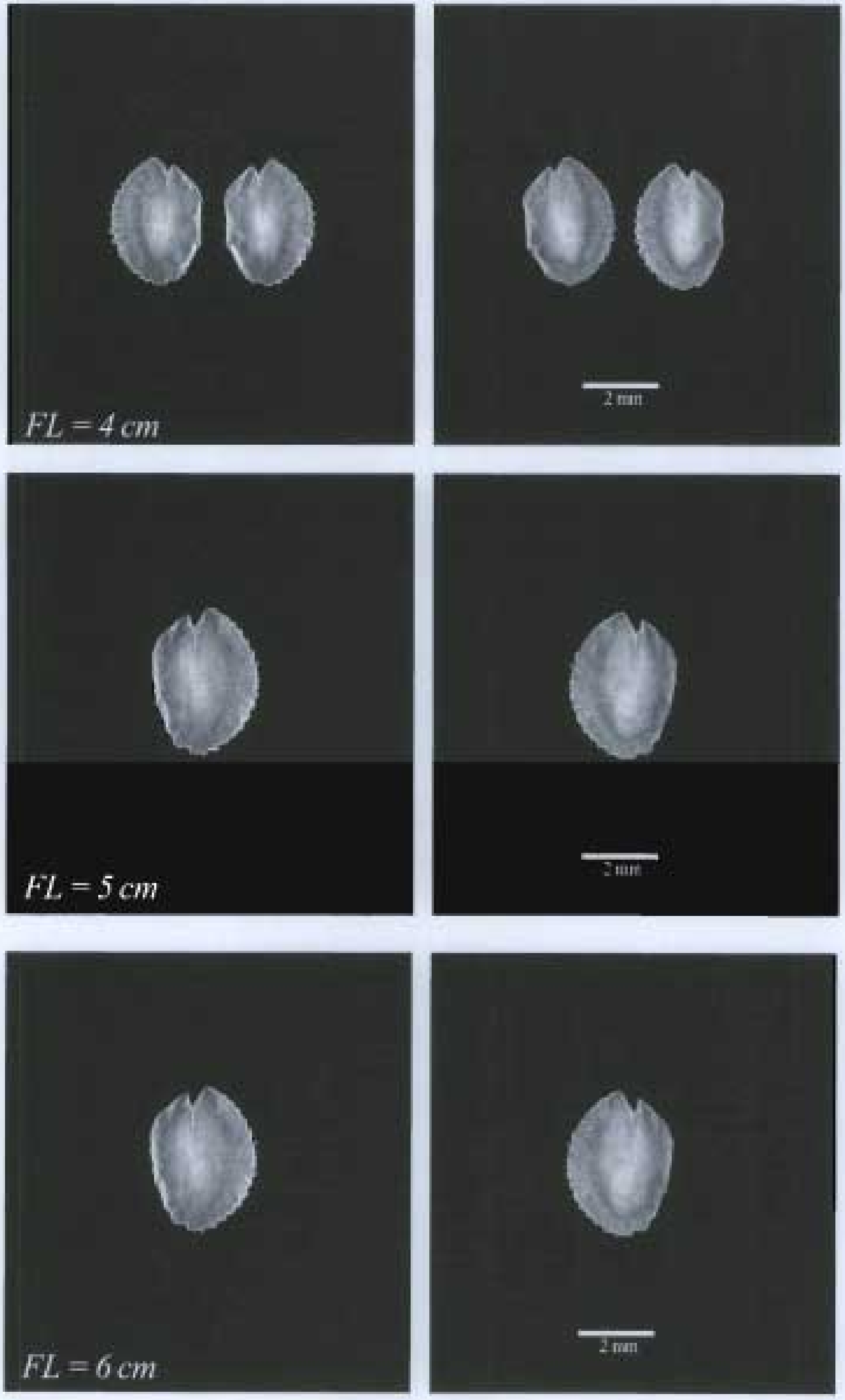
Myctophiformes

Myctophidae: *Diaphus mollis*



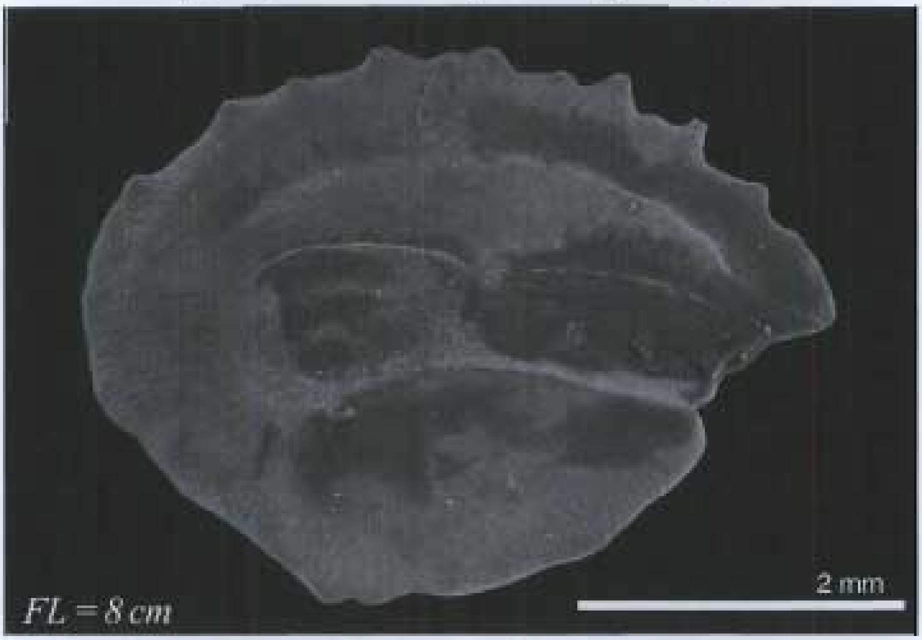
Myctophiformes

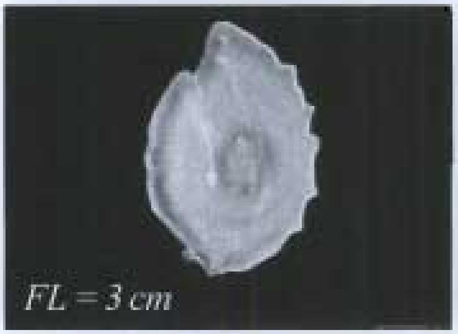
Myctophidae: *Diaphus perspicillatus*

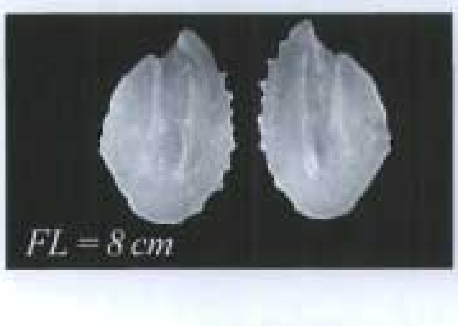


Myctophiformes

Myctophidae: *Diaphus rafinesquii*



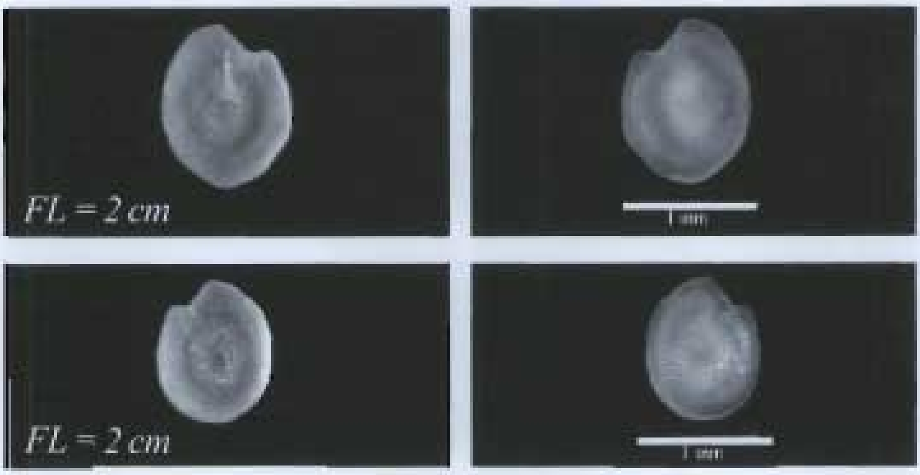




Myctophiformes

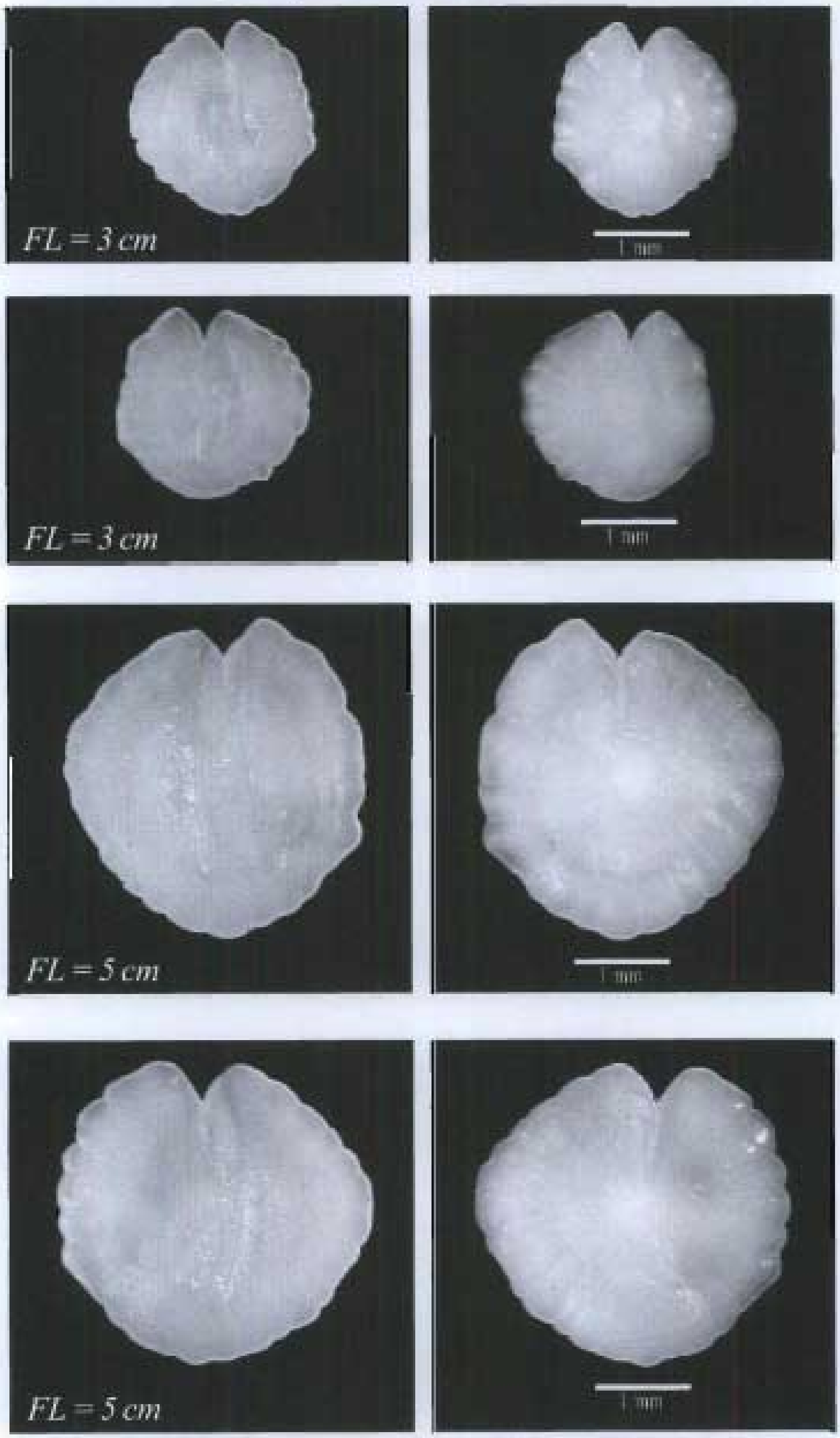
Myctophidae: *Diaphus termophilus*

Myctophidae: *Diogenichthys atlanticus*

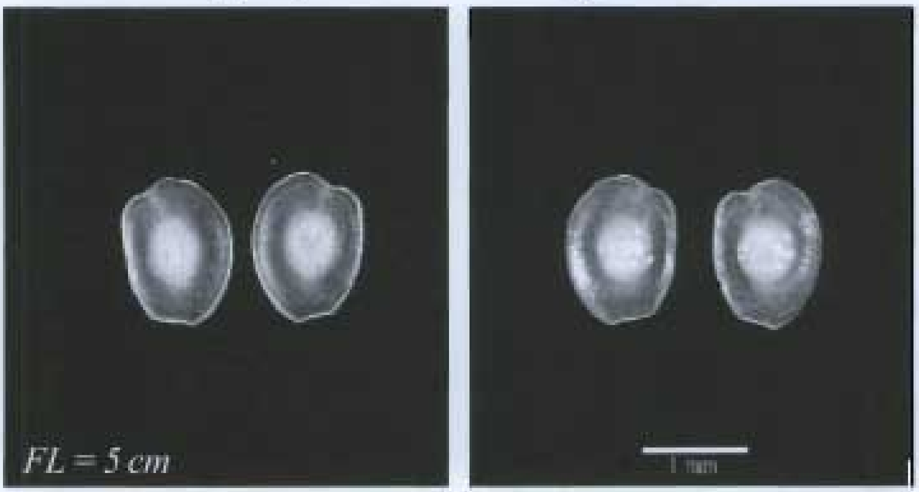


Myctophiformes

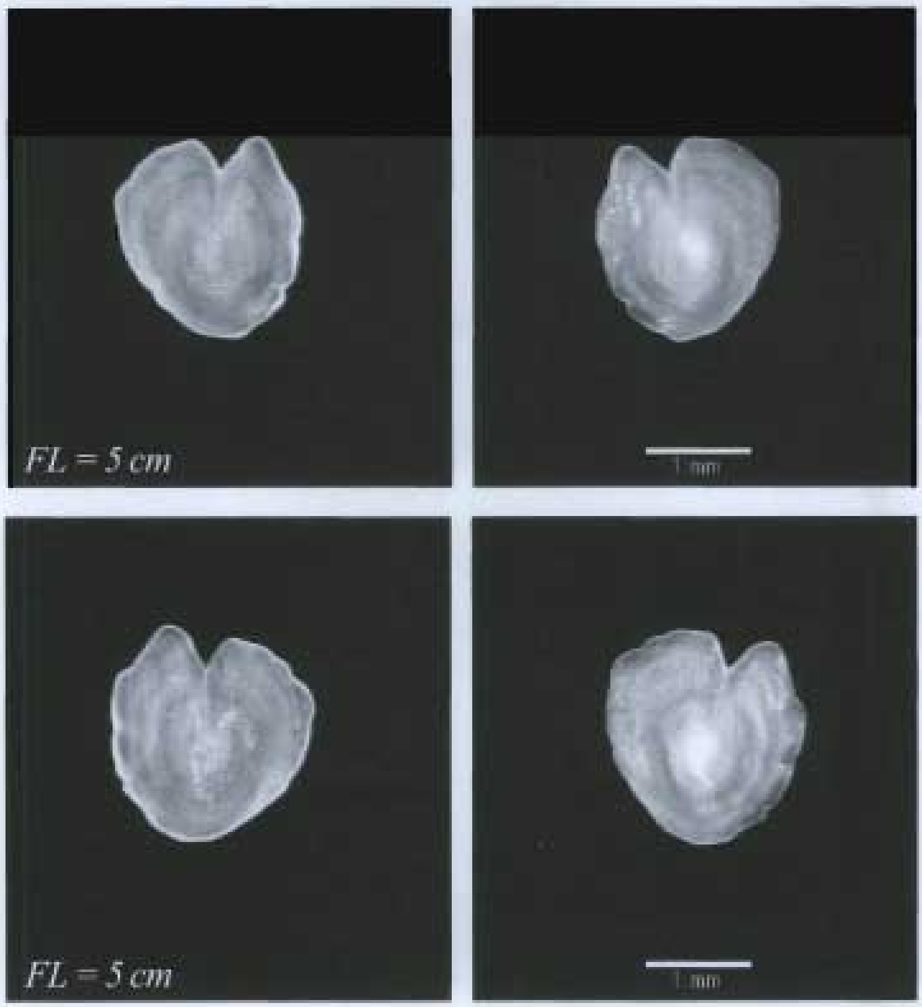
Myctophidae: *Electrona risso*



Myctophidae: *Gonichthys cocco*

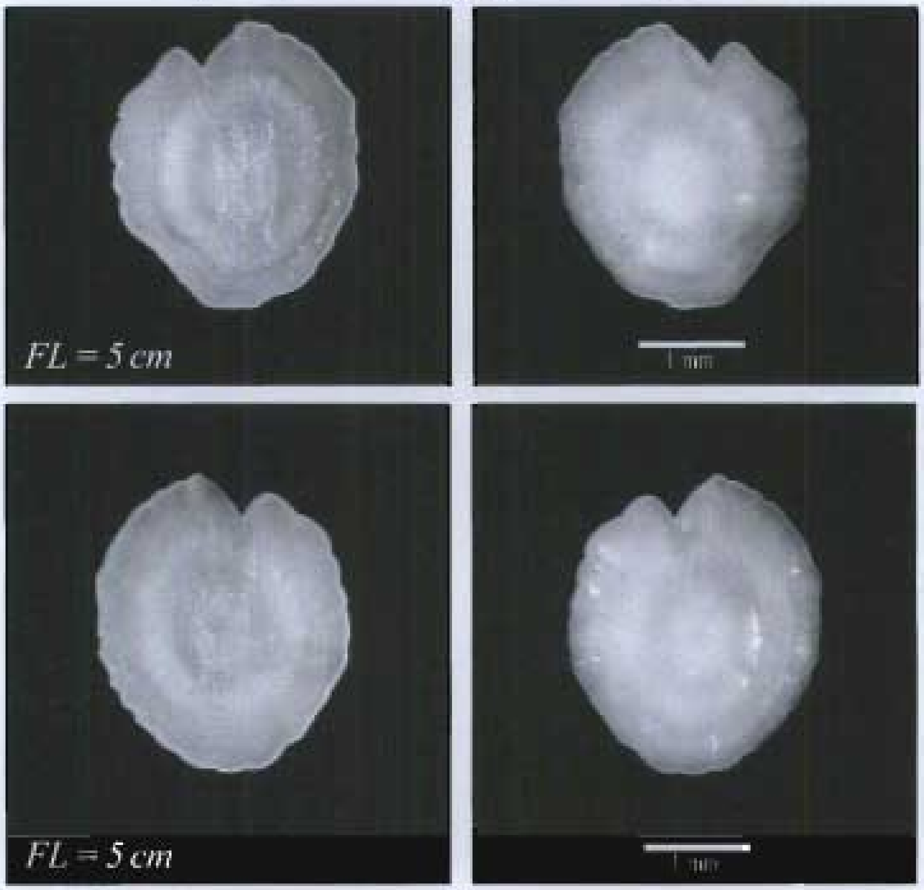


Myctophidae: *Hygophum benoiti*

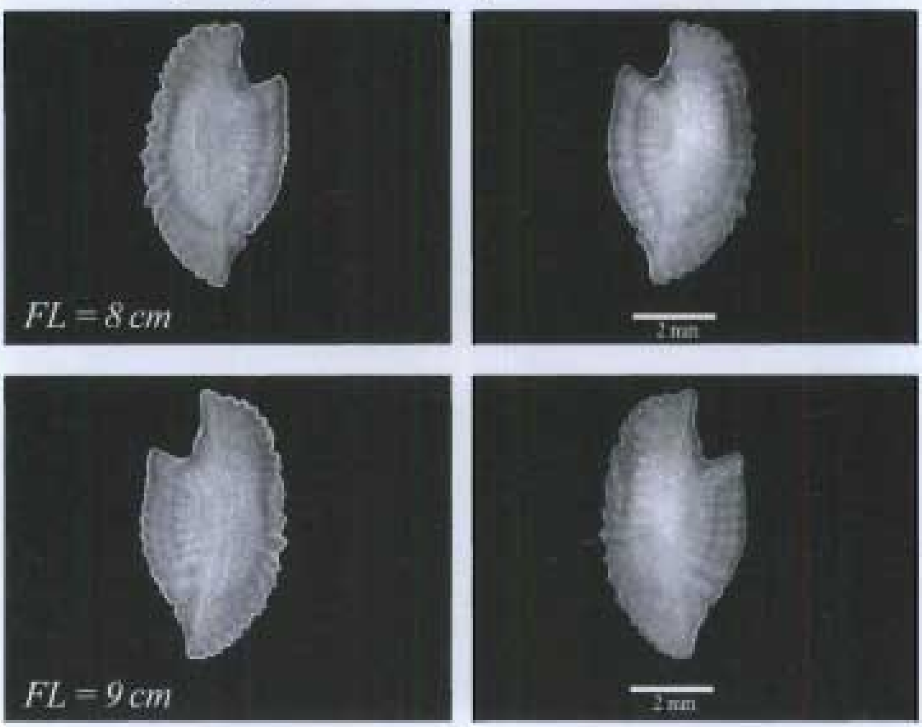


Myctophiformes

Myctophidae: *Hygophum hygomii*

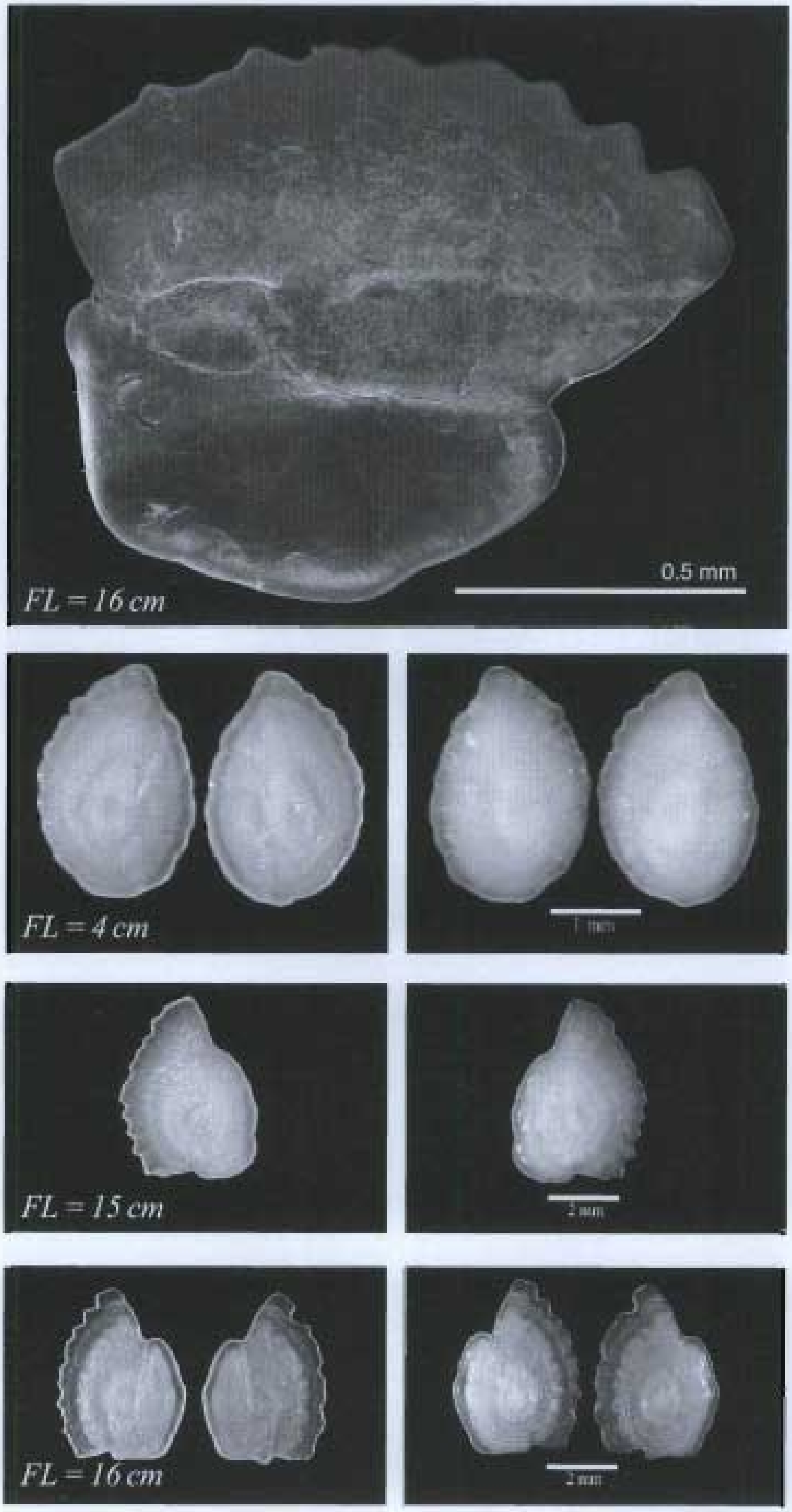


Myctophidae: *Lampadena luminosa*



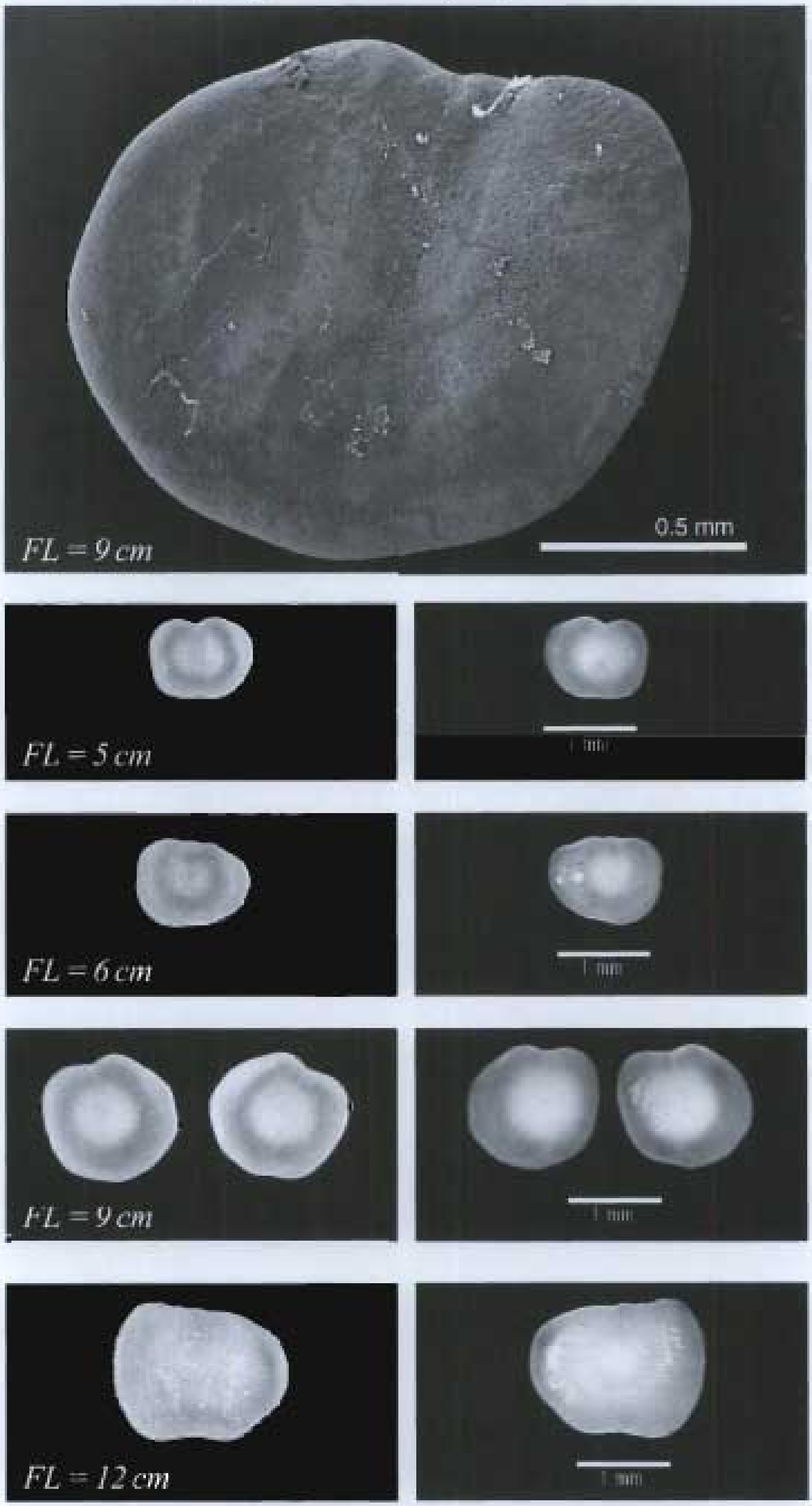
Myctophiformes

Myctophidae: *Lampadena speculigera*



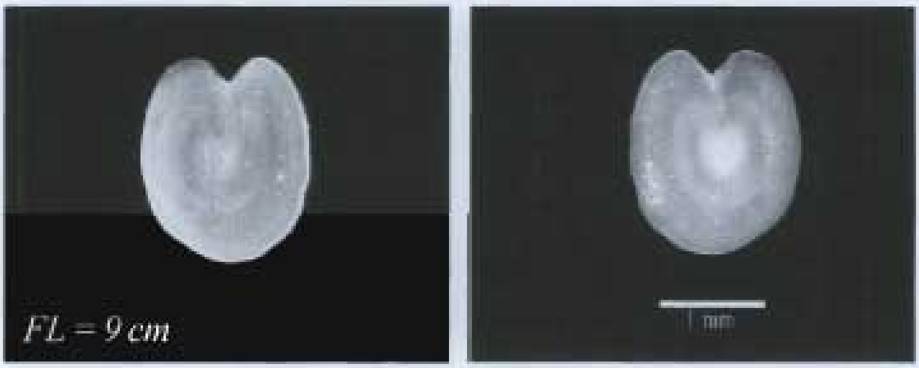
Myctophiformes

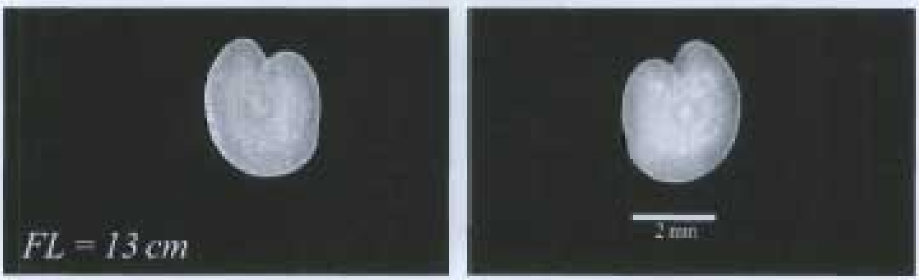
Myctophidae: *Lampanyctus ater*



Myctophiformes

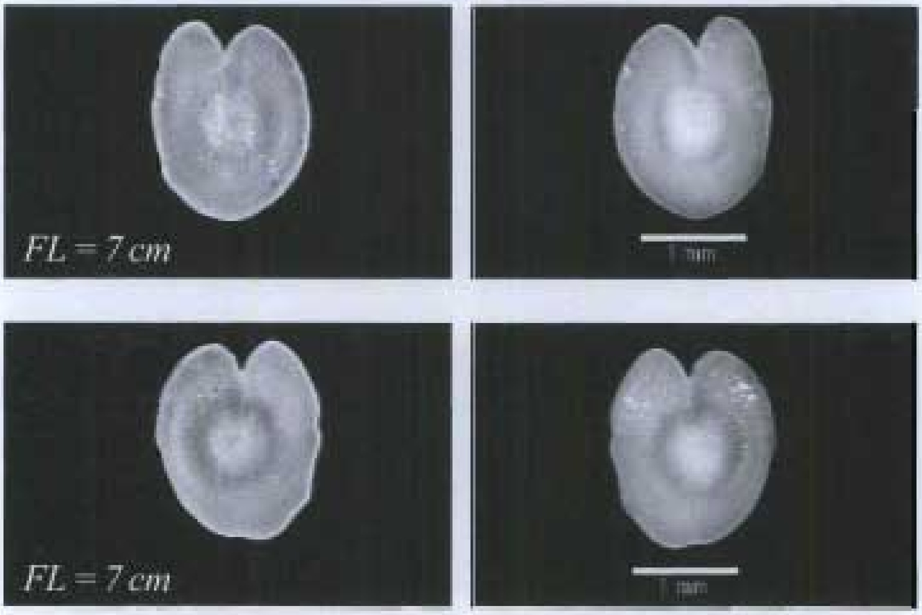
Myctophidae: *Lampanyctus crocodilus*



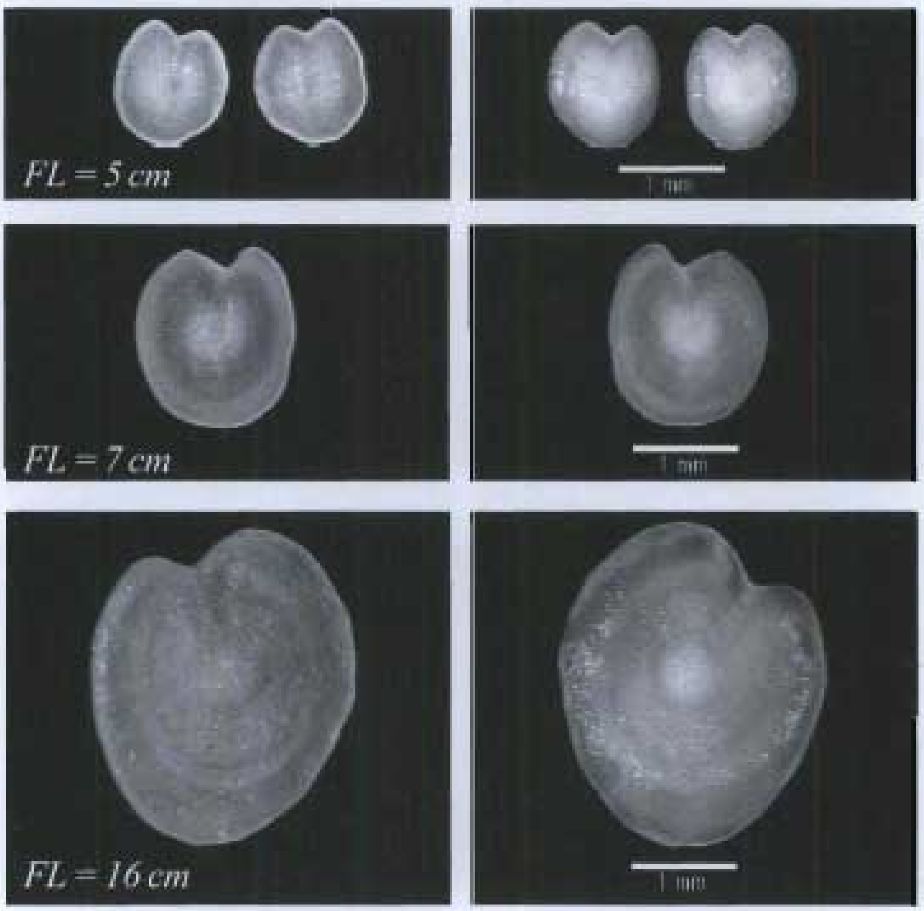


Myctophiformes

Myctophidae: *Lampanyctus festivus*

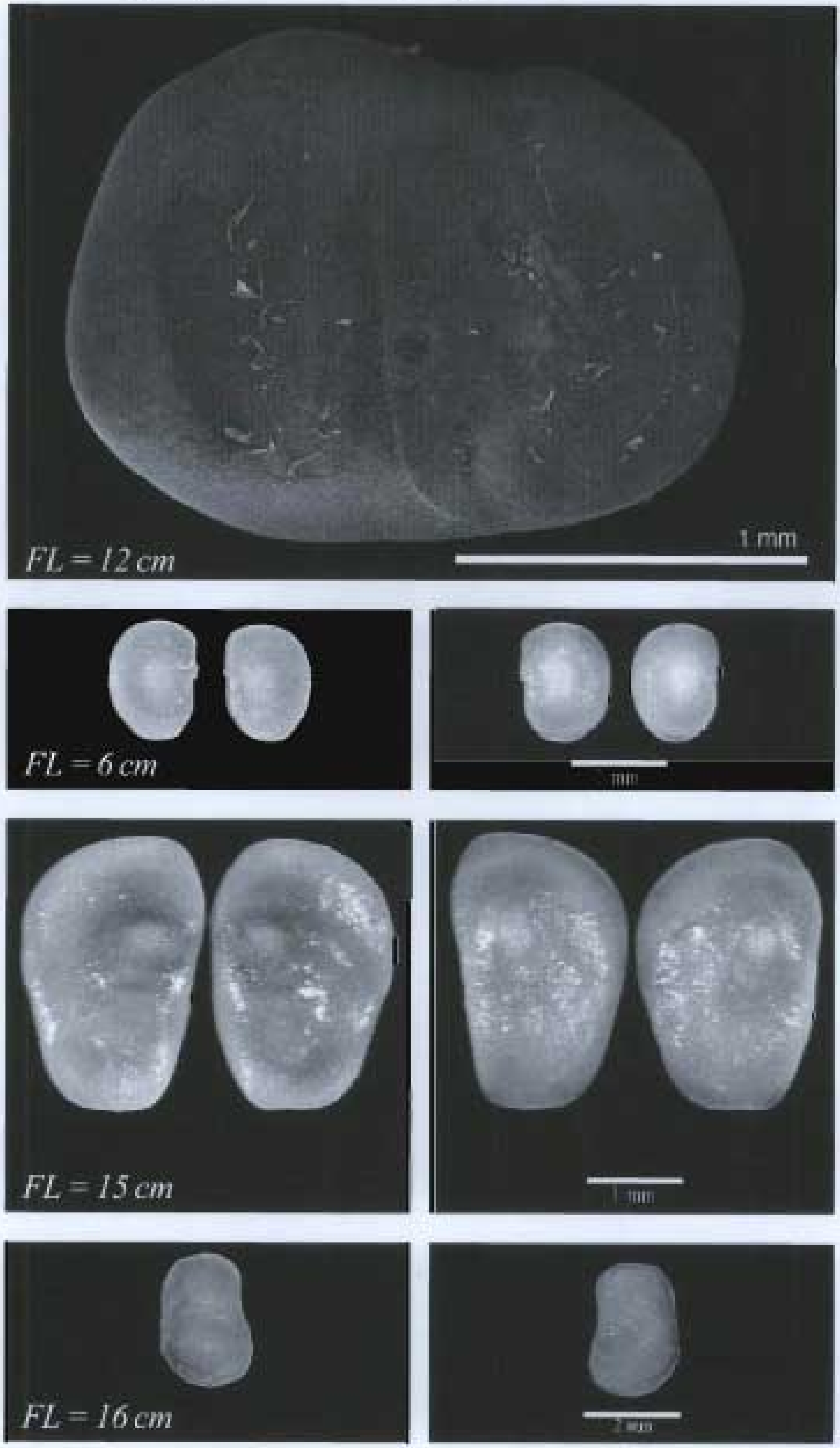


Myctophidae: *Lampanyctus intracarius*



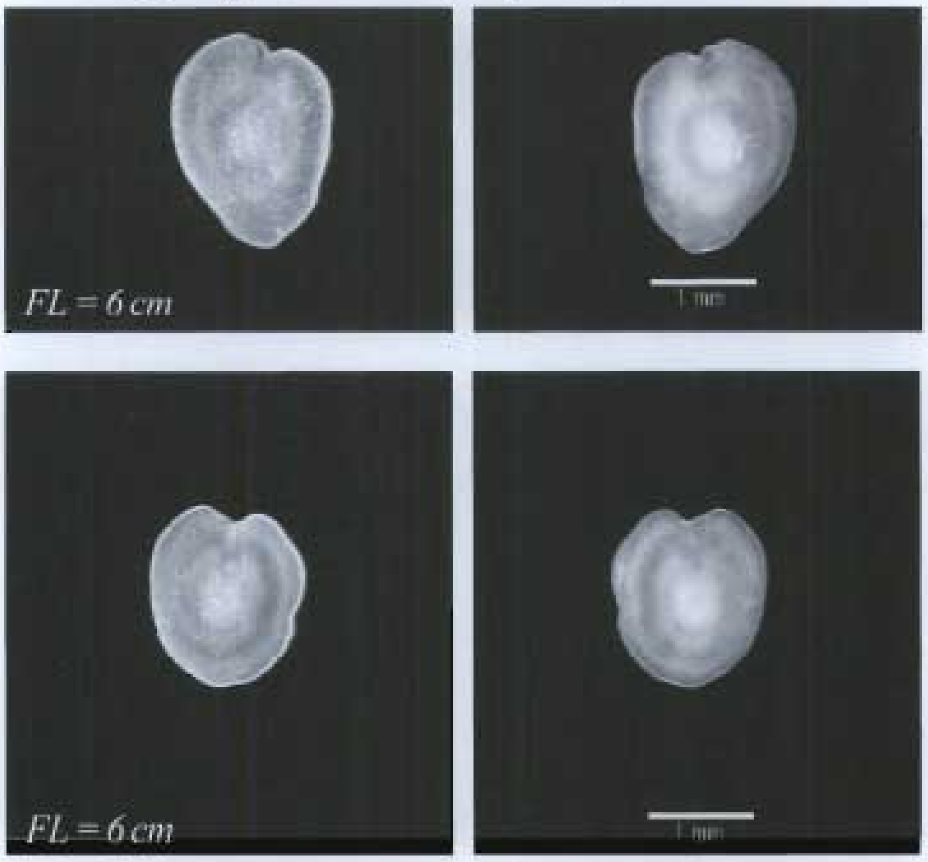
Myctophiformes

Myctophidae: *Lampanyctus macdonaldi*

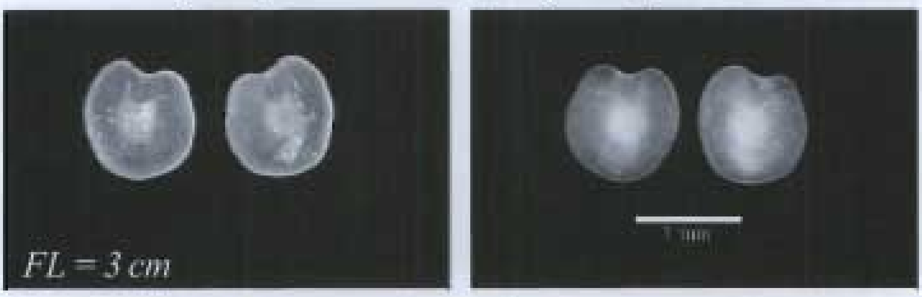


Myctophiformes

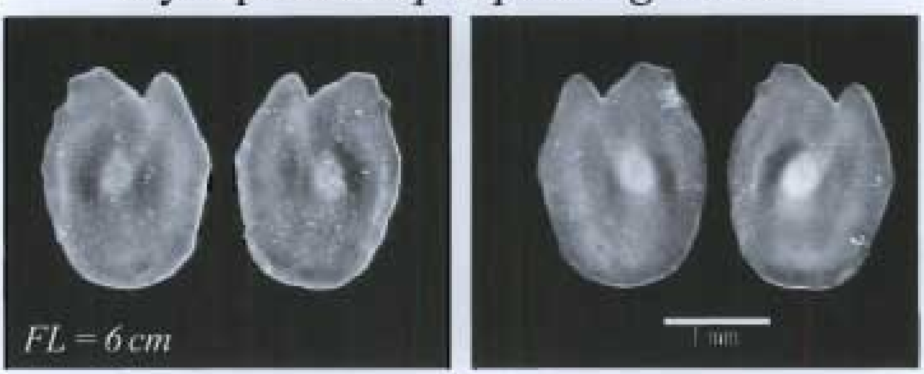
Myctophidae: *Lampanyctus photonotus*



Myctophidae: *Lampanyctus pusillus*

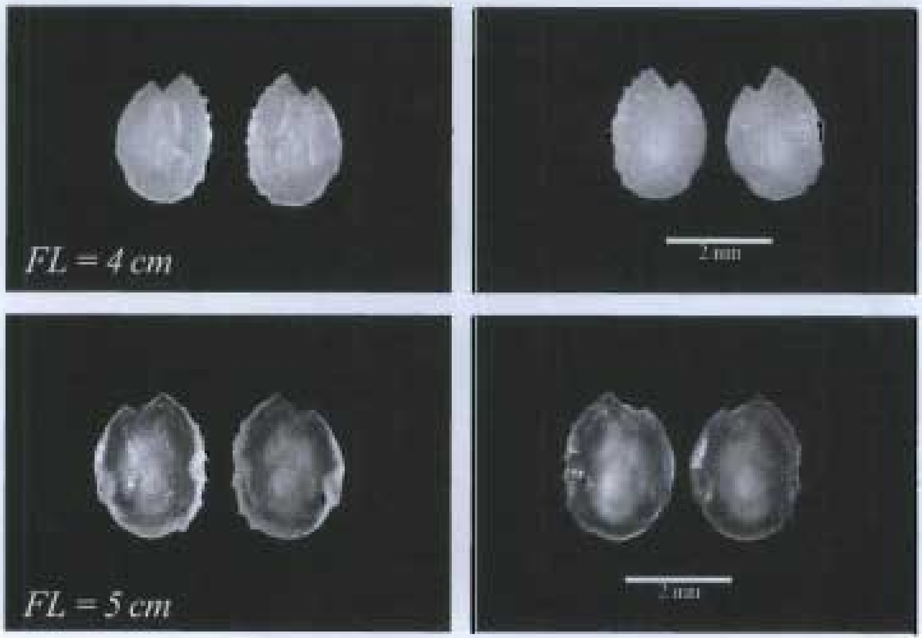


Myctophidae: *Lepidophanes guentheri*



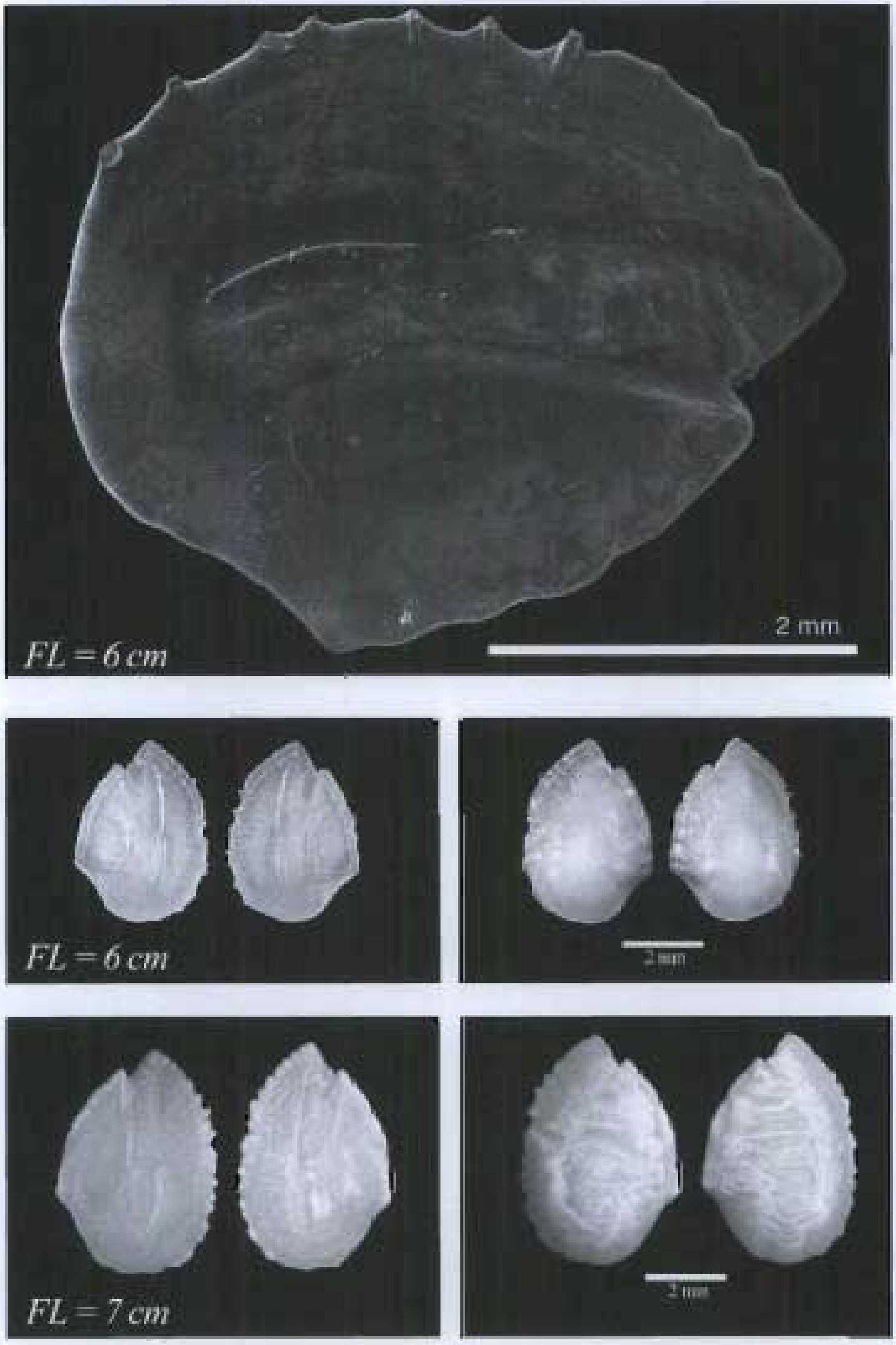
Myctophiformes

Myctophidae: *Lobianchia dofleini*



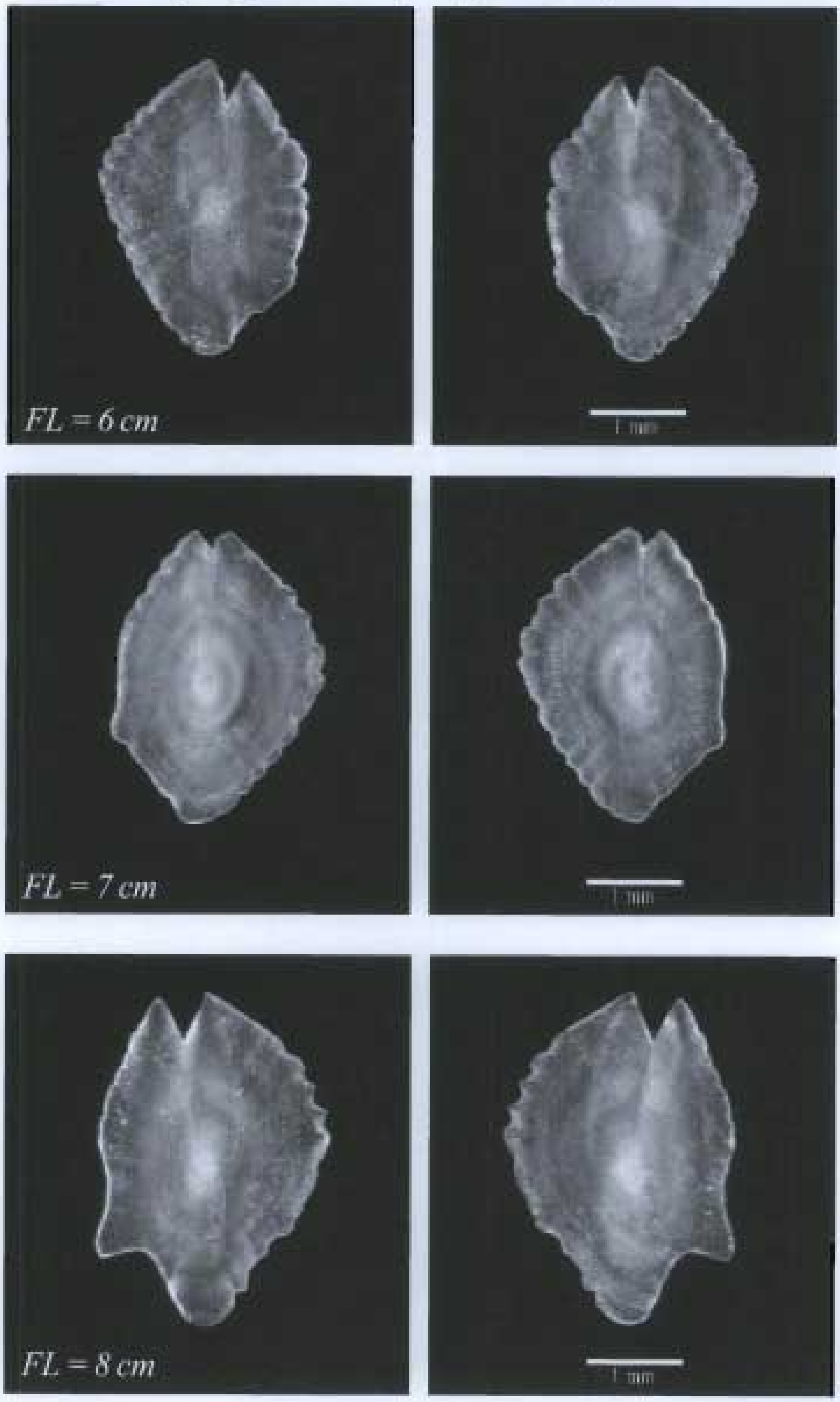
Myctophiformes

Myctophidae: *Lobianchia gemellarii*



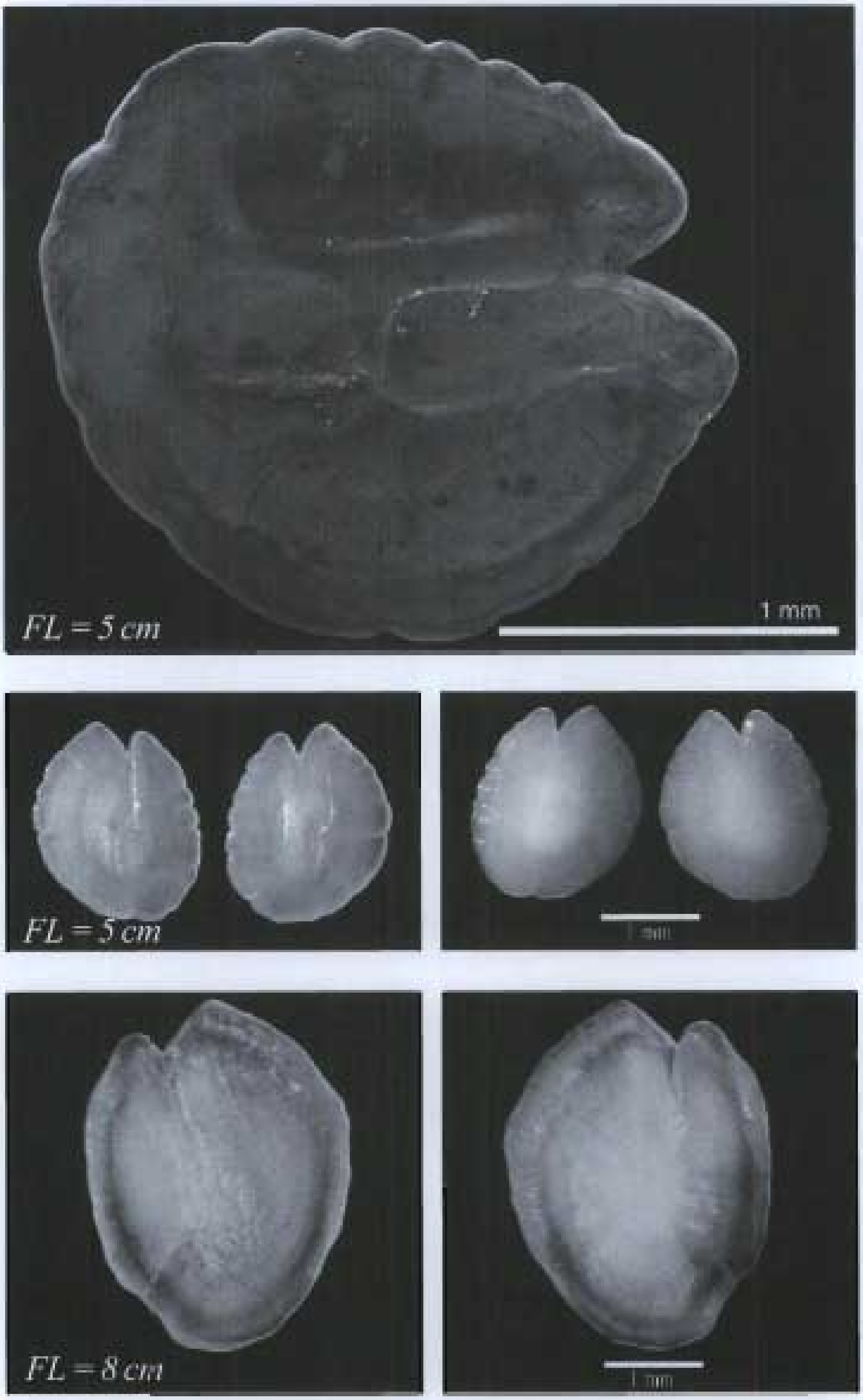
Myctophiformes

Myctophidae: *Myctophum asperum*



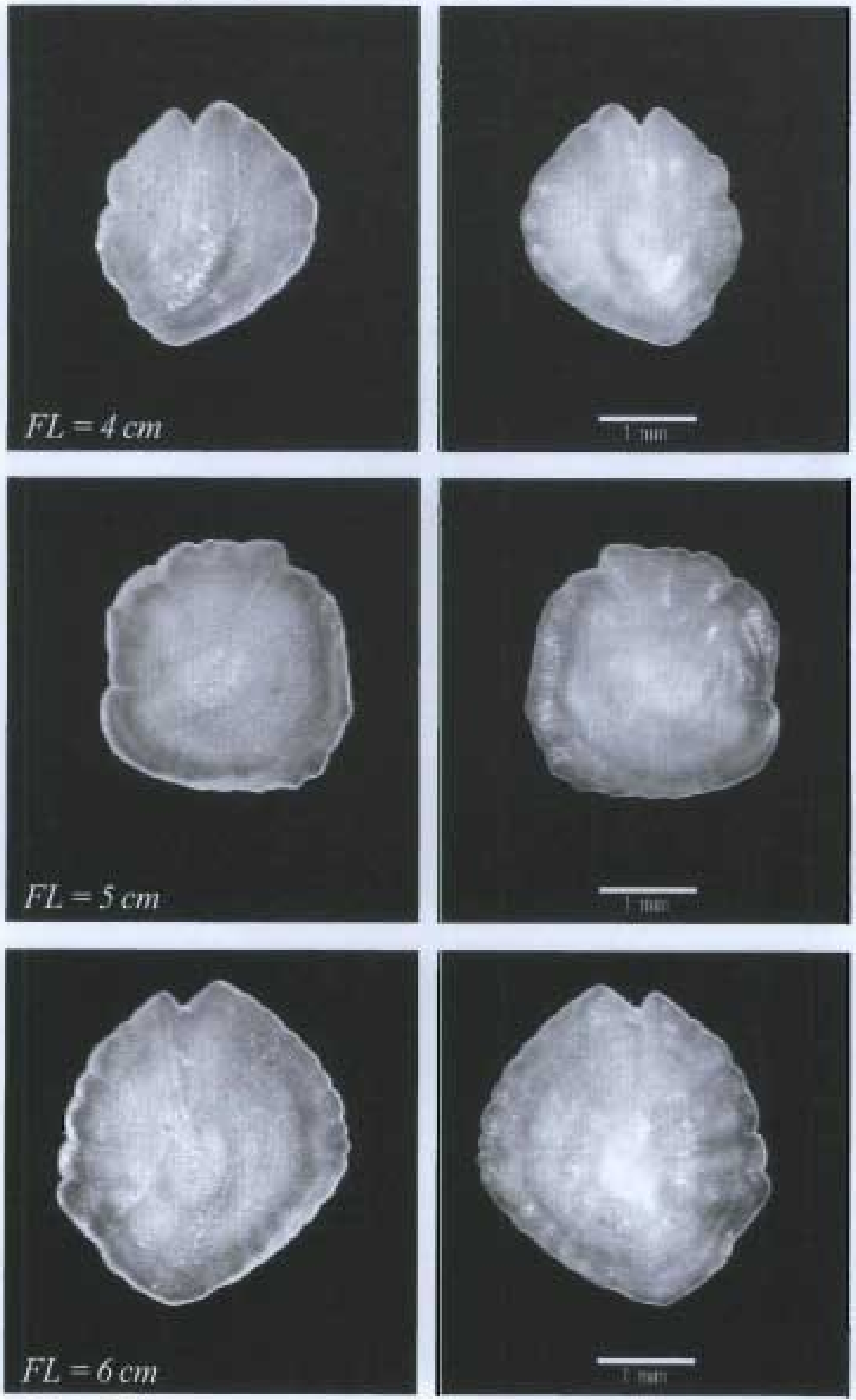
Myctophiformes

Myctophidae: *Myctophum punctatum*



Myctophiformes

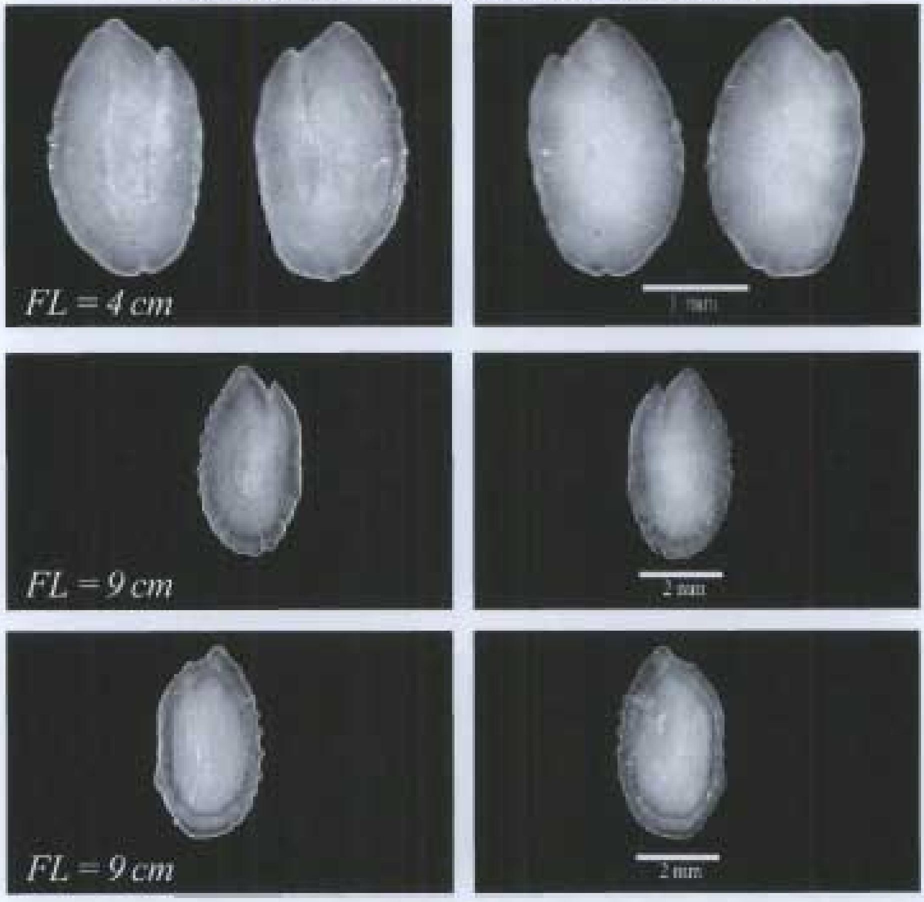
Myctophidae: *Myctophum selenops*



Myctophiformes

Myctophidae: *Notolychnus valdiviae*

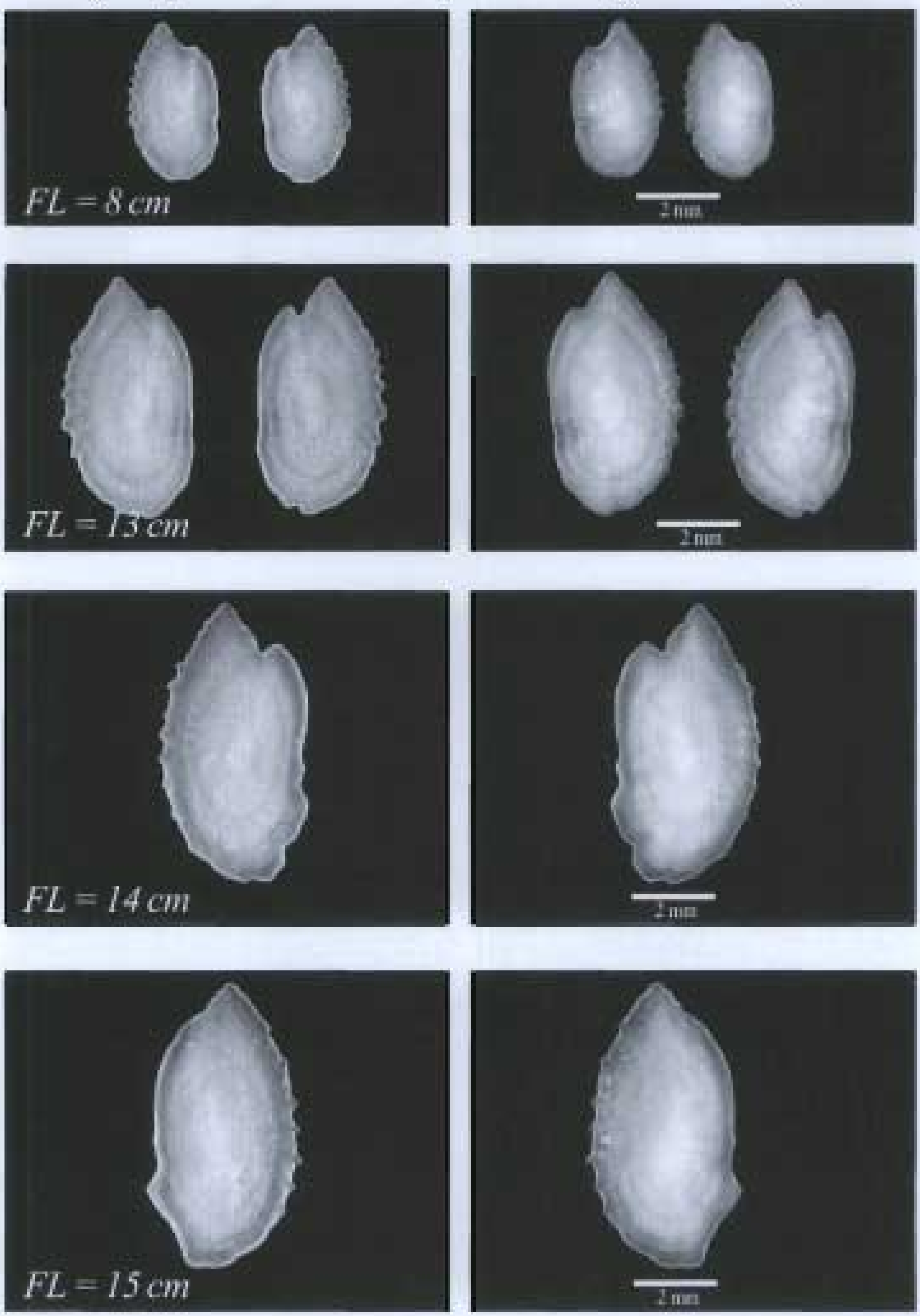
Myctophidae: *Notoscopelus bolini*



Myctophiformes

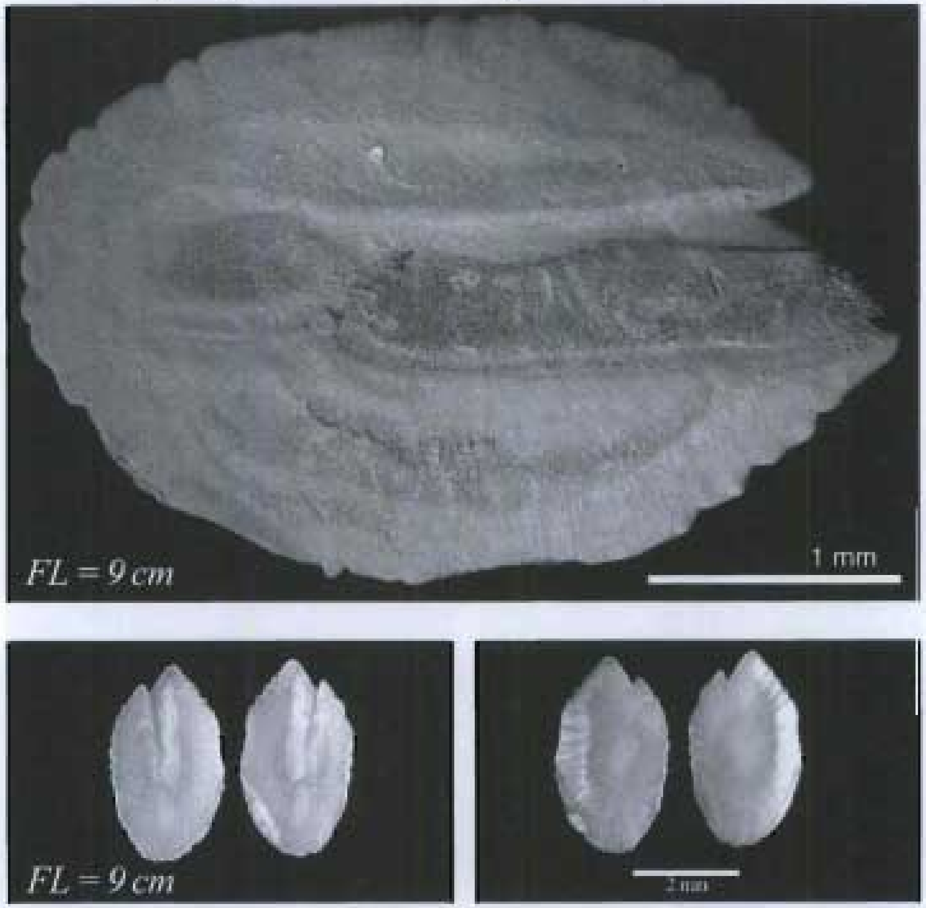
Myctophidae: *Notoscopelus caudispinosus*

Myctophidae: *Notoscopelus elongatus kroeyerii*

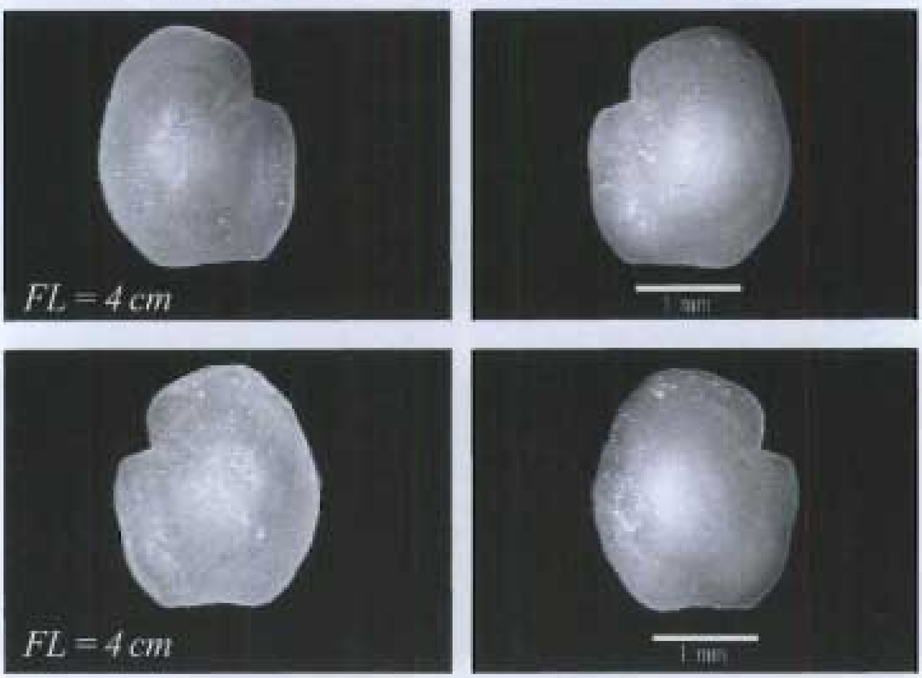


Myctophiformes

Myctophidae: *Notoscopelus resplendens*

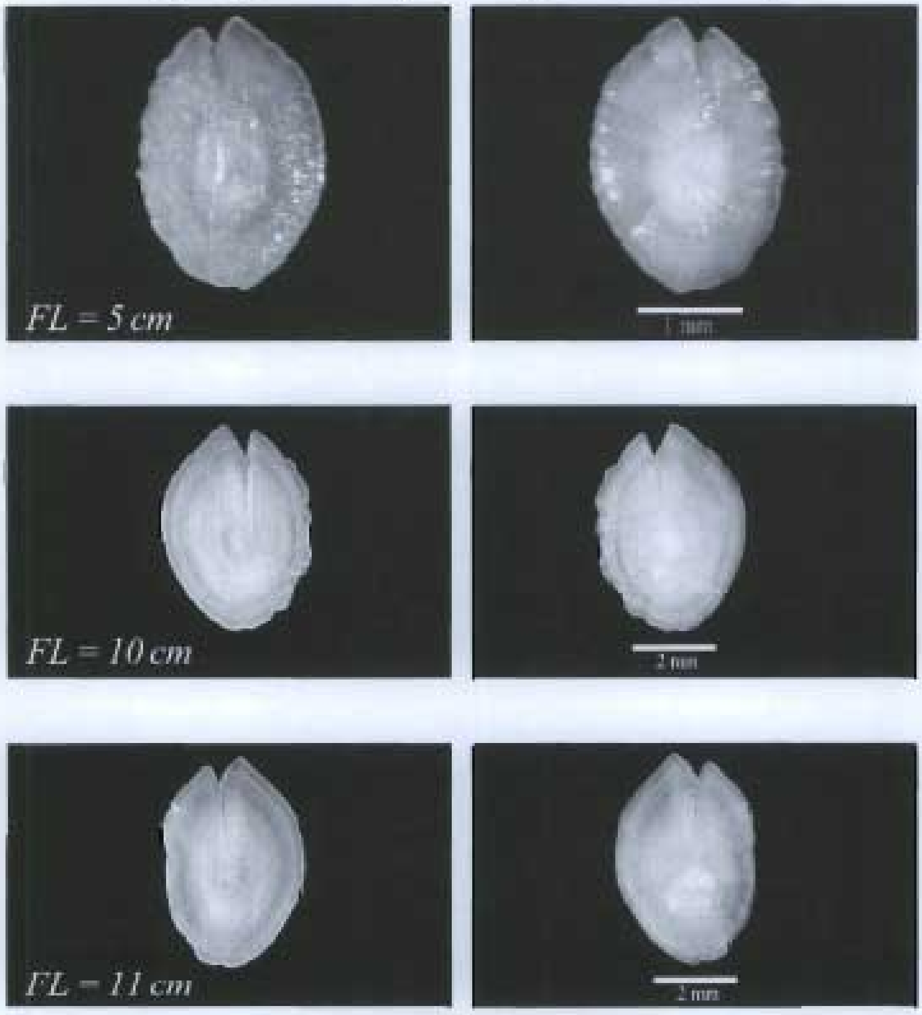


Myctophidae: *Protomyctophum arcticum*



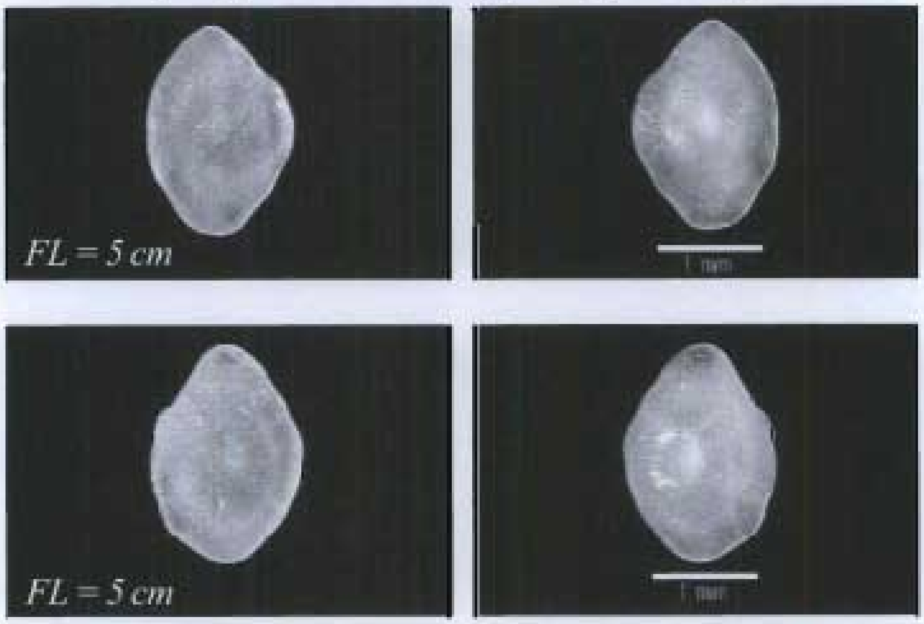
Myctophiformes

Myctophidae: *Symbolophorus veranyi*

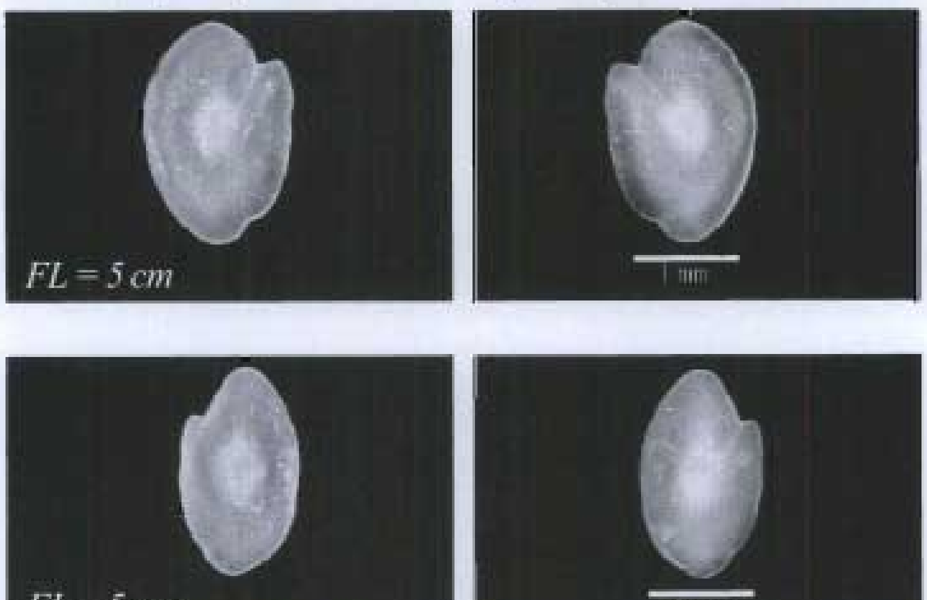


Myctophiformes

Myctophidae: *Taaningichthys bathyphilus*



Myctophidae: *Taaningichthys minimus*



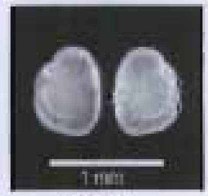
Ophidiiformes

Ophidiidae: *Dicrolene intronigra*

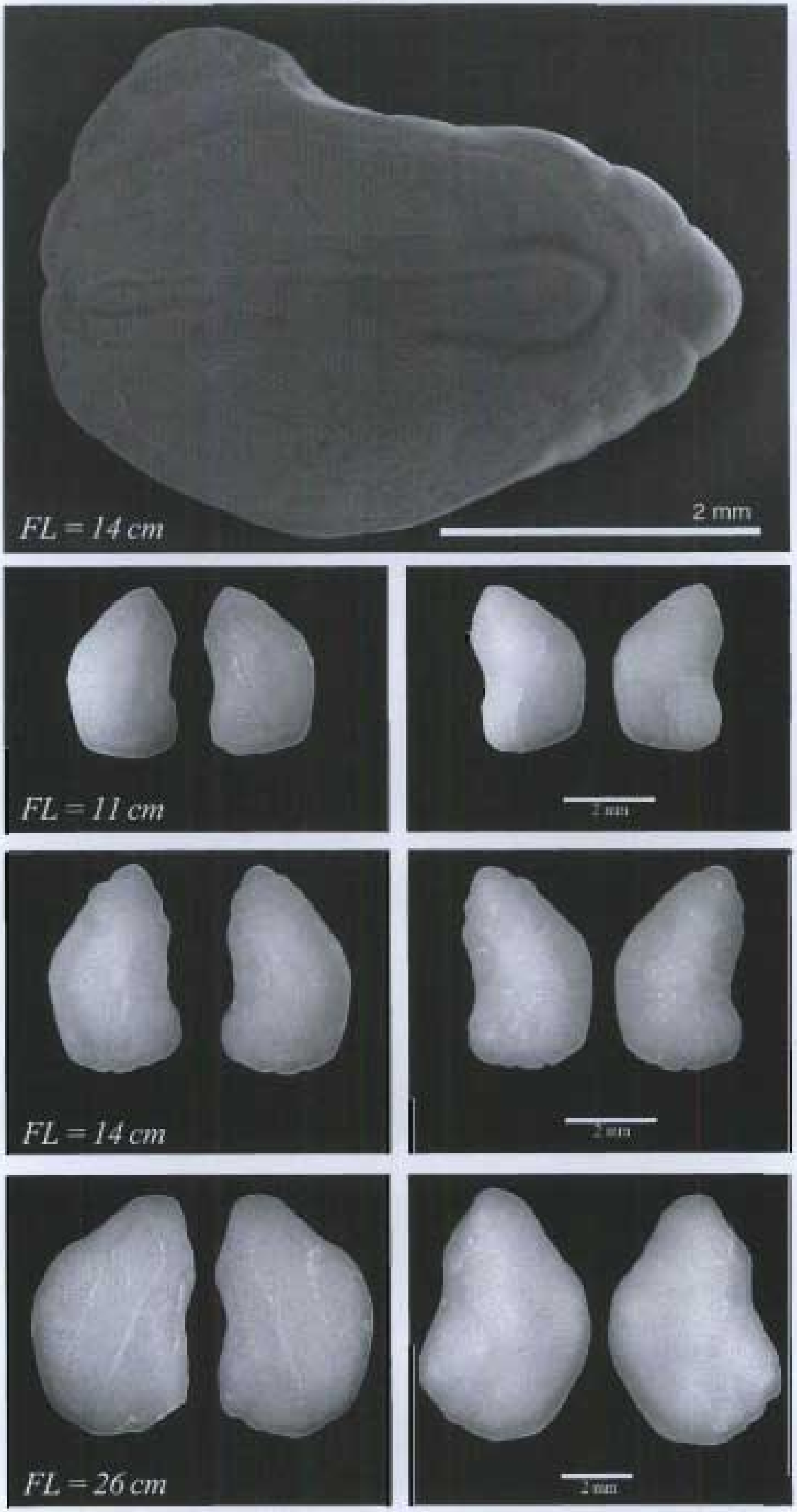
Ophidiiformes

Ophidiidae: *Lepophidium cervinum*

Asteriscii

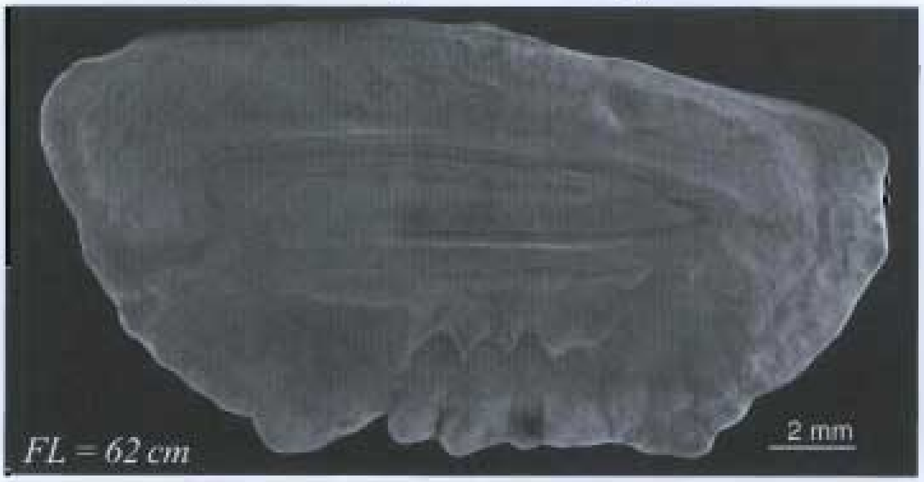


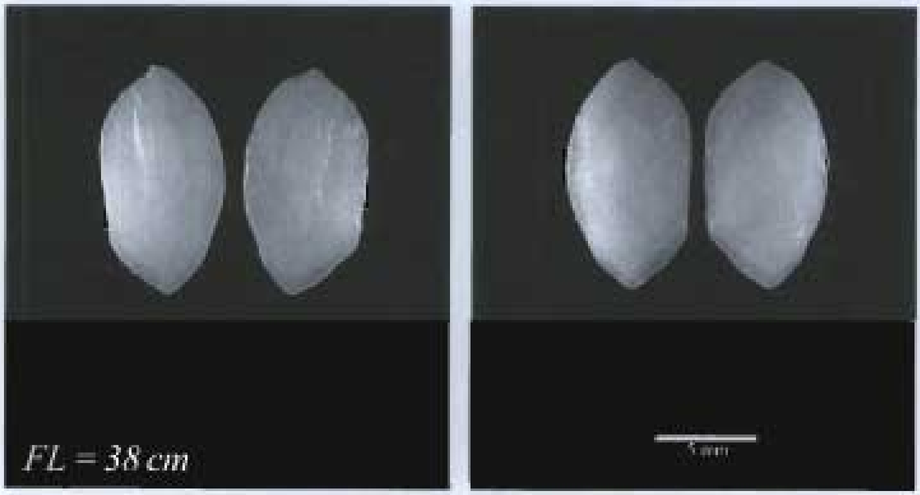
Lapilli

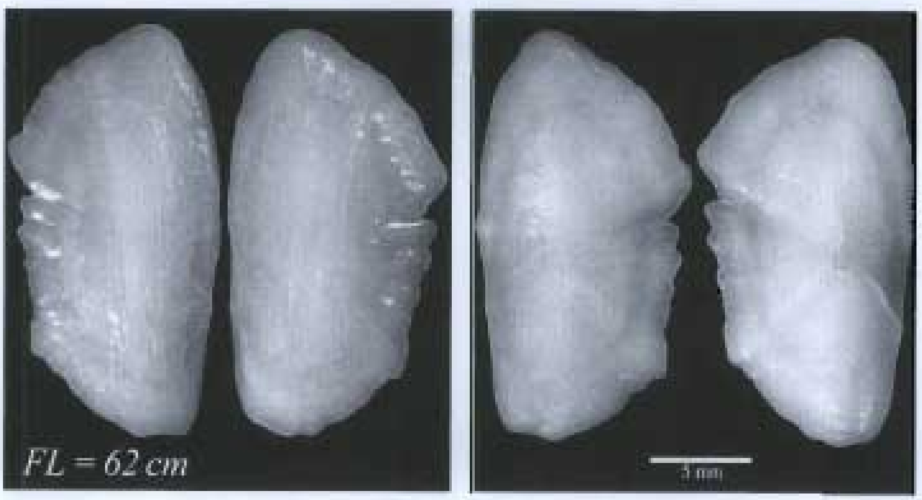


Ophidiiformes

Ophidiidae: *Spectrunculus grandis*

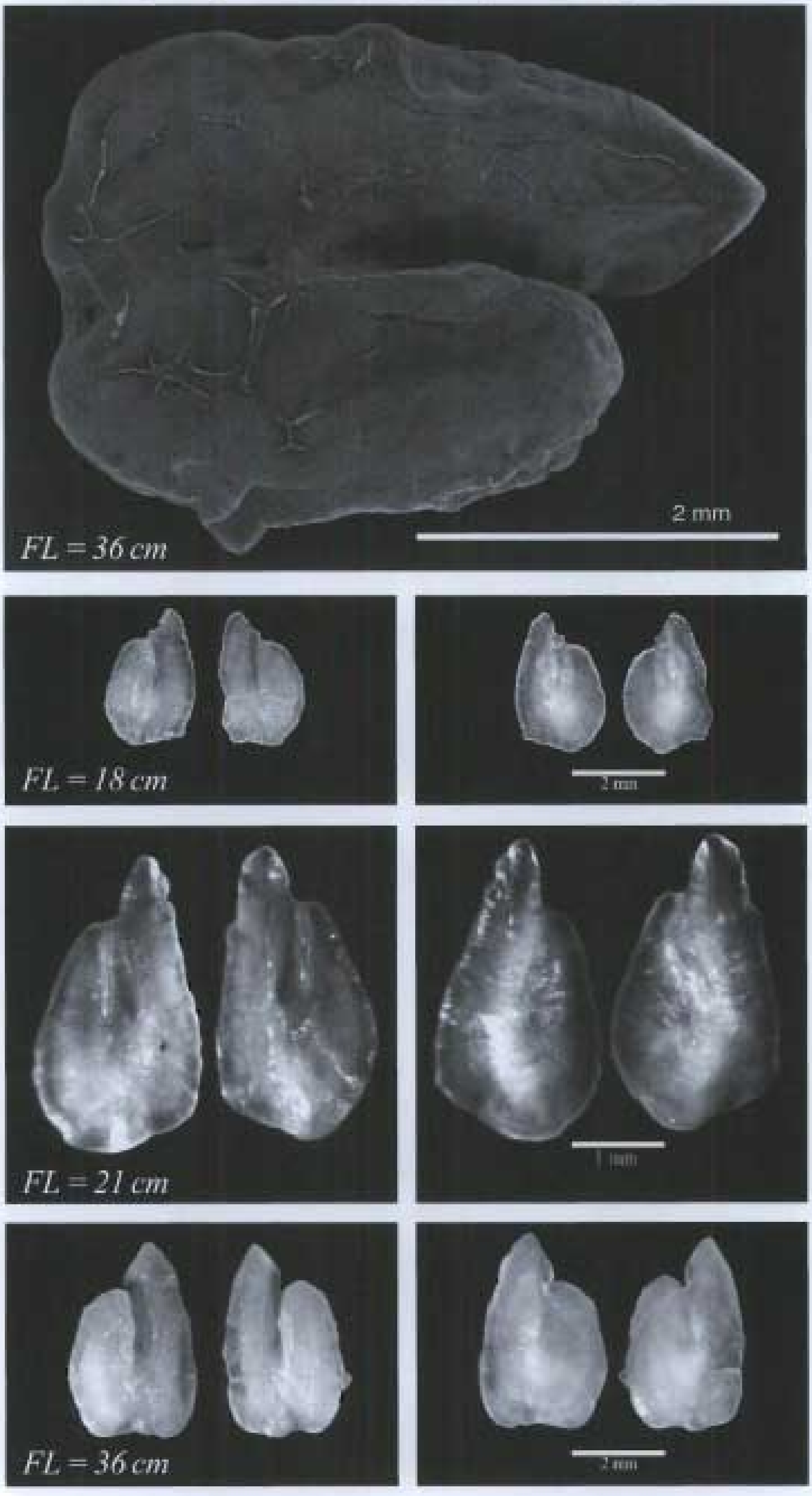






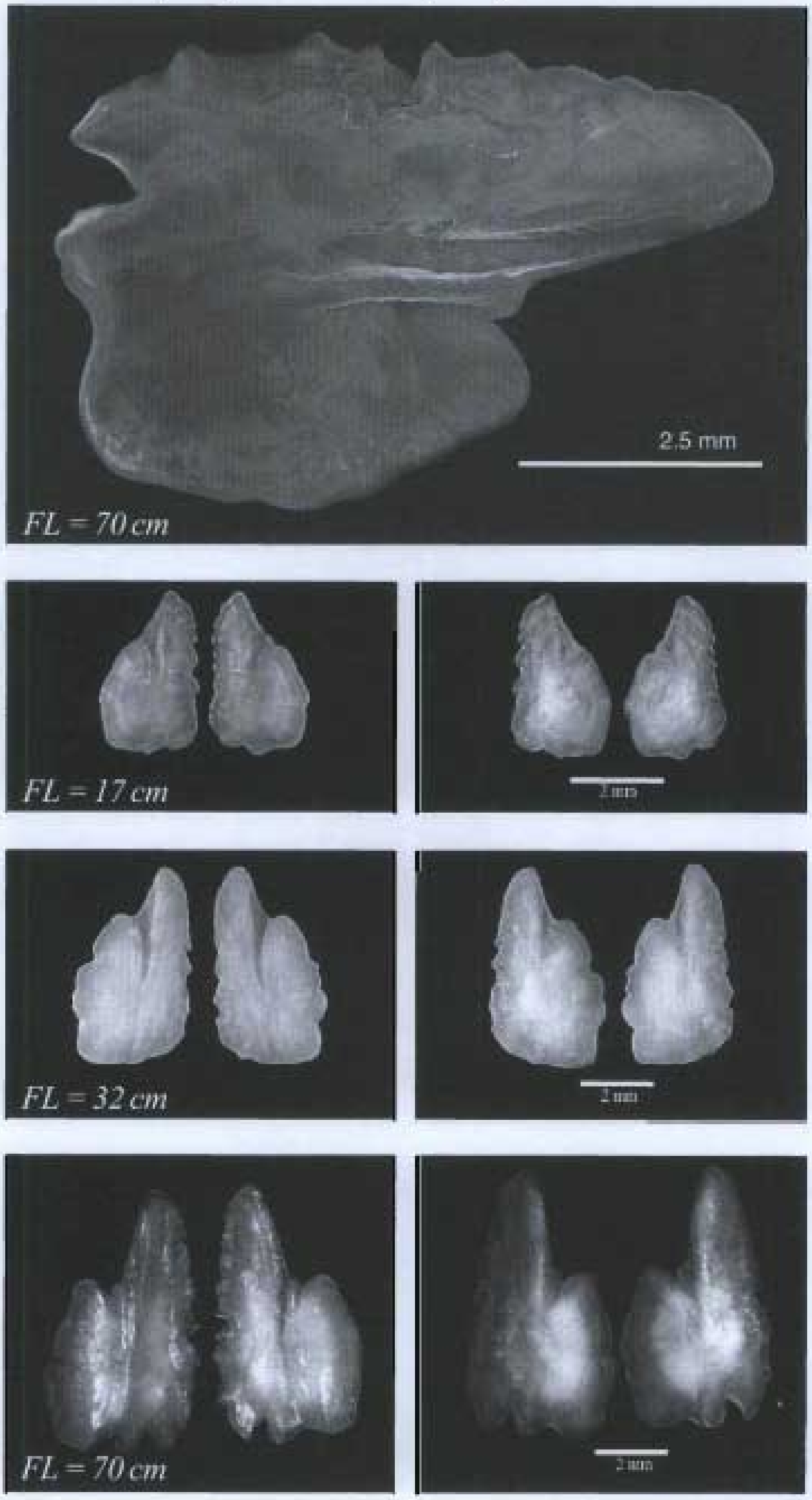
Osmeriformes

Alepocephalidae: *Alepocephalus agassizii*



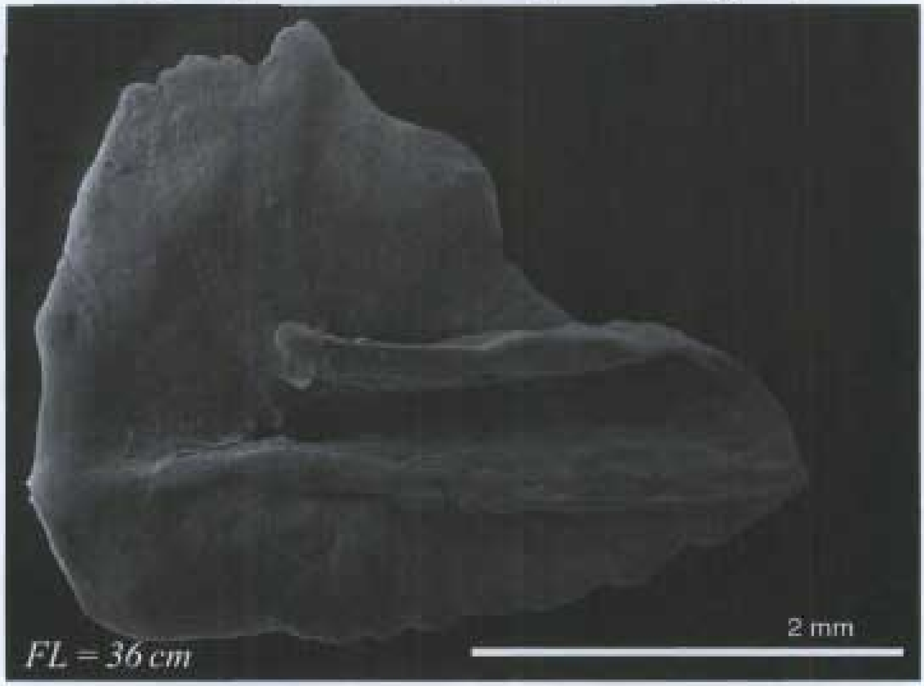
Osmeriformes

Alepocephalidae: *Alepocephalus bairdii*



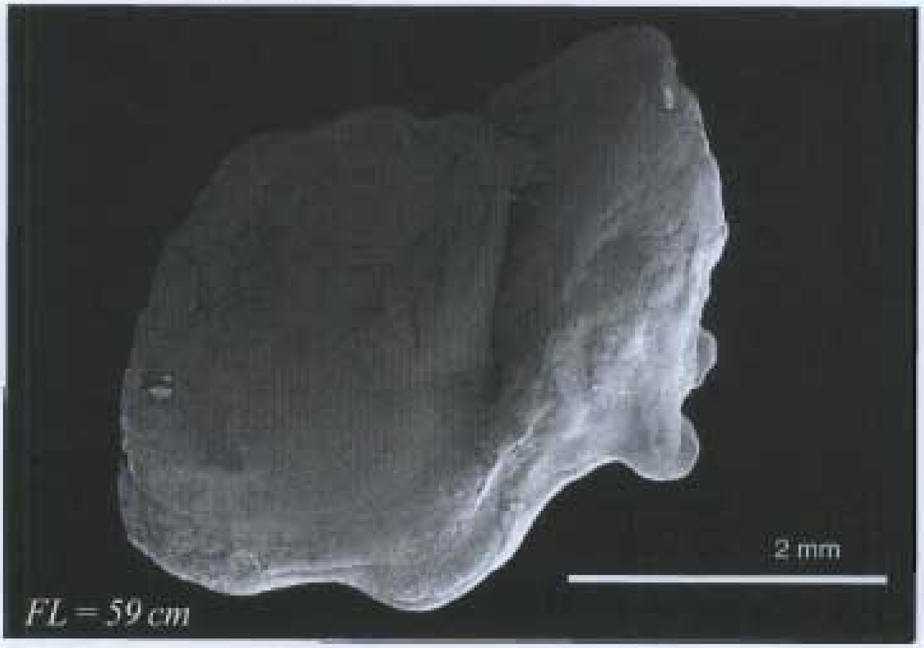
Osmeriformes

Alepocephalidae: *Bajacalifornia megalops*



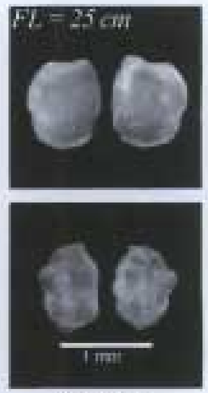
Osmeriformes

Alepocephalidae: *Narcetes stomias*

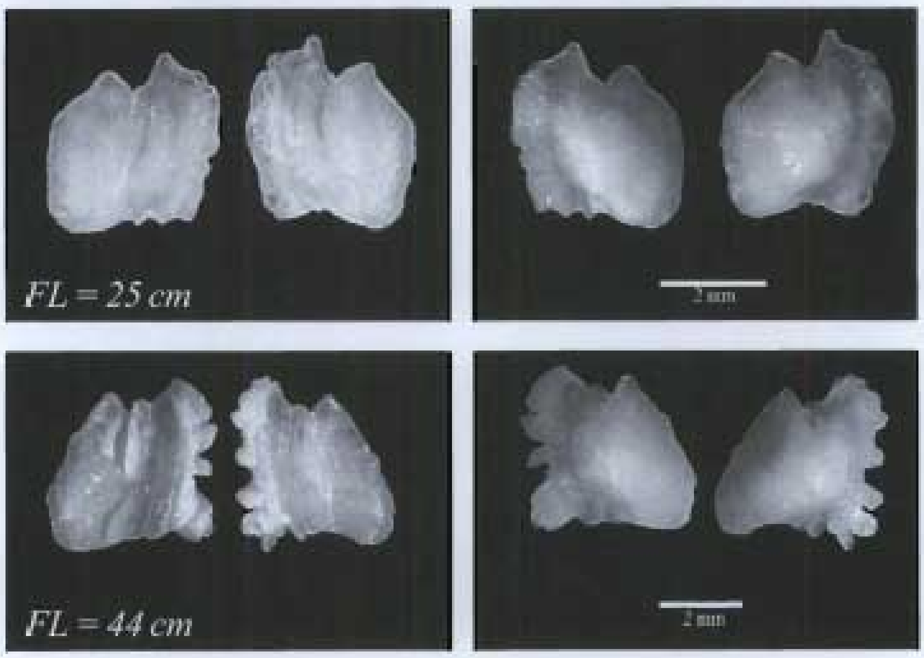


Osmeriformes

Alepocephalidae: *Rouleina attrita*



Asteriscii
& Lapilli

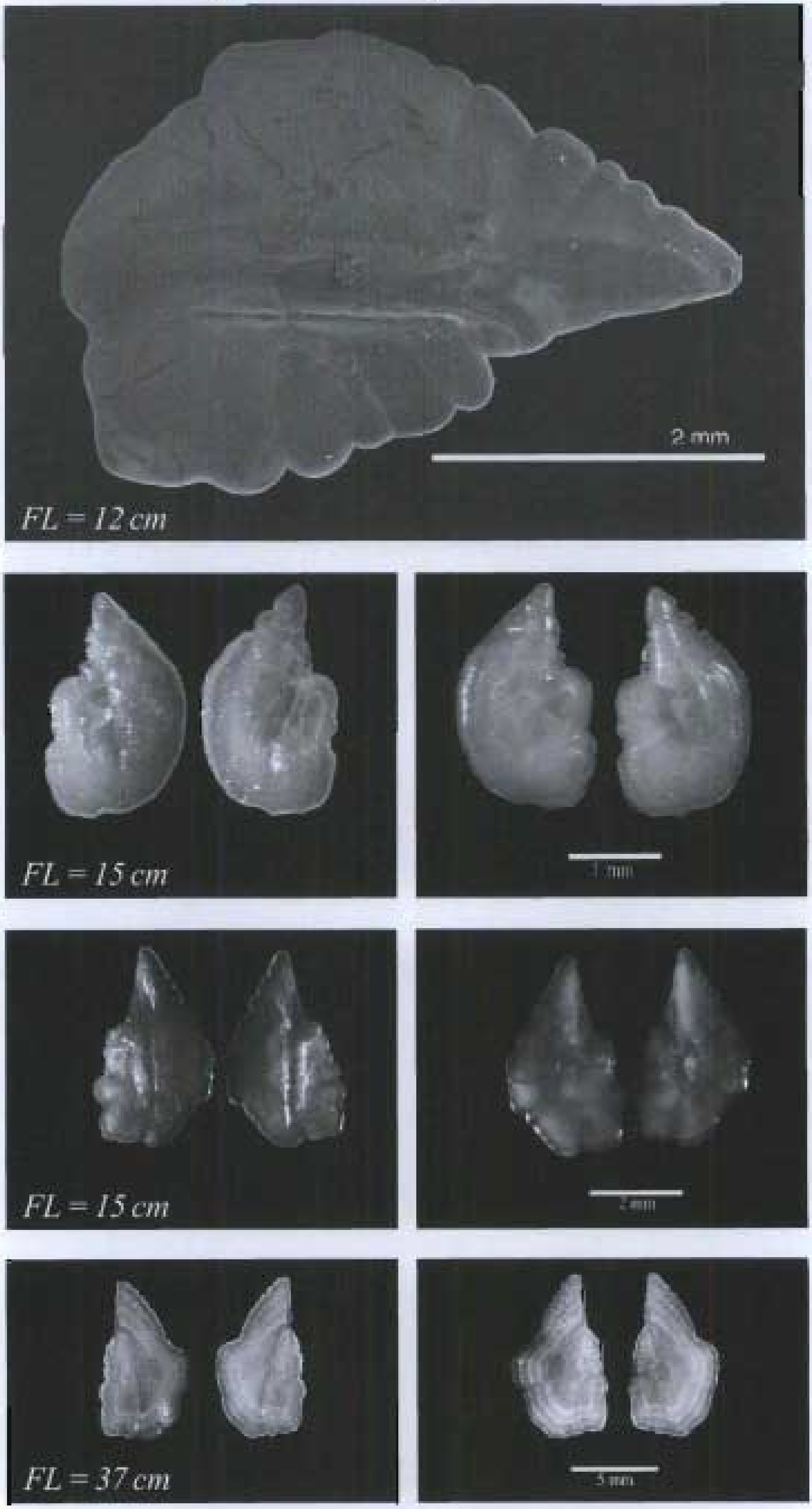


Osmeriformes

Alepocephalidae: *Xenodermichthys copei*

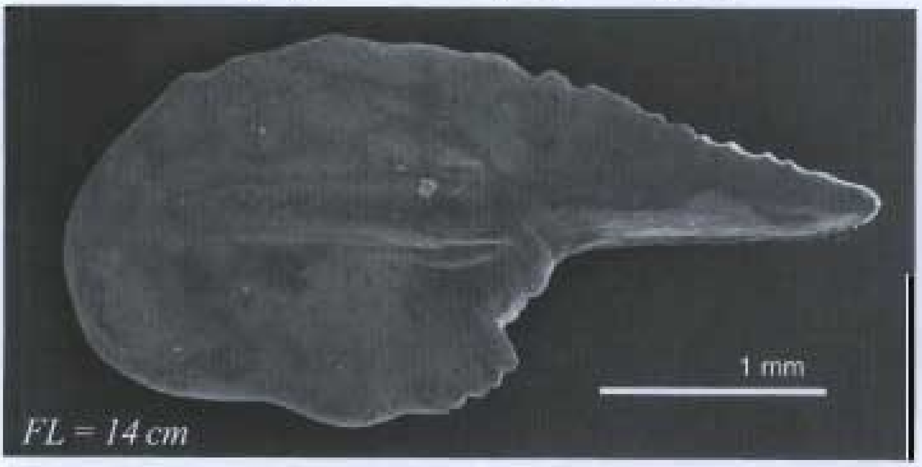
Osmeriformes

Argentinidae: *Argentina silus*



Osmeriformes

Bathylagidae: *Bathylagus euryops*

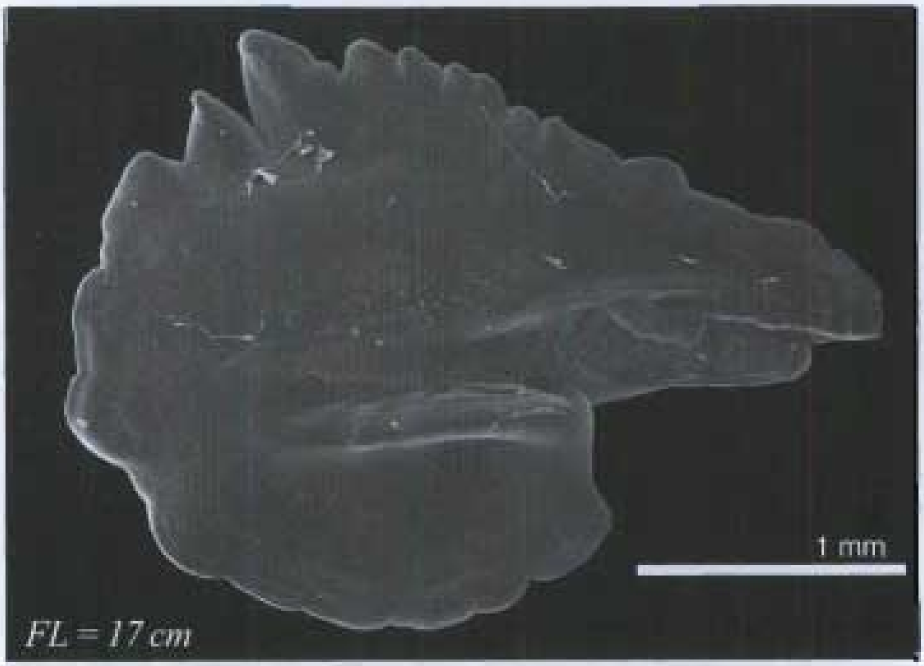


Asteriscii

Lapilli

Osmeriformes

Osmeridae: *Mallotus villosus*



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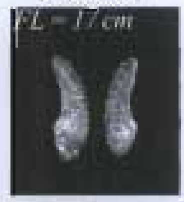

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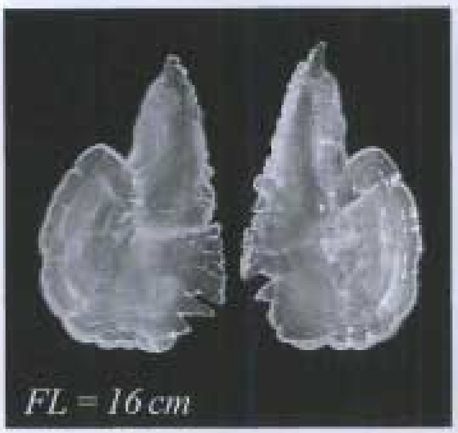
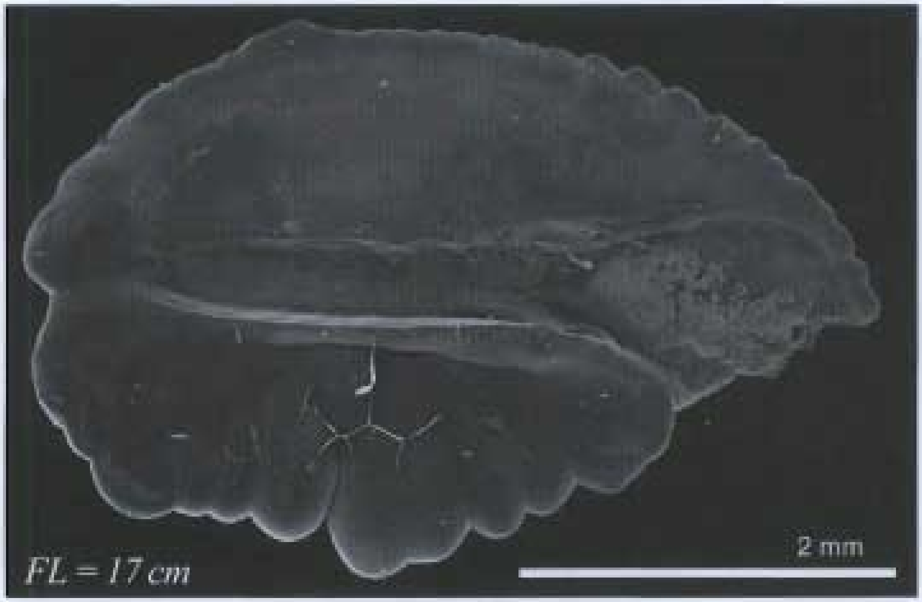


Osmeriformes

Osmeridae: *Osmerus mordax*

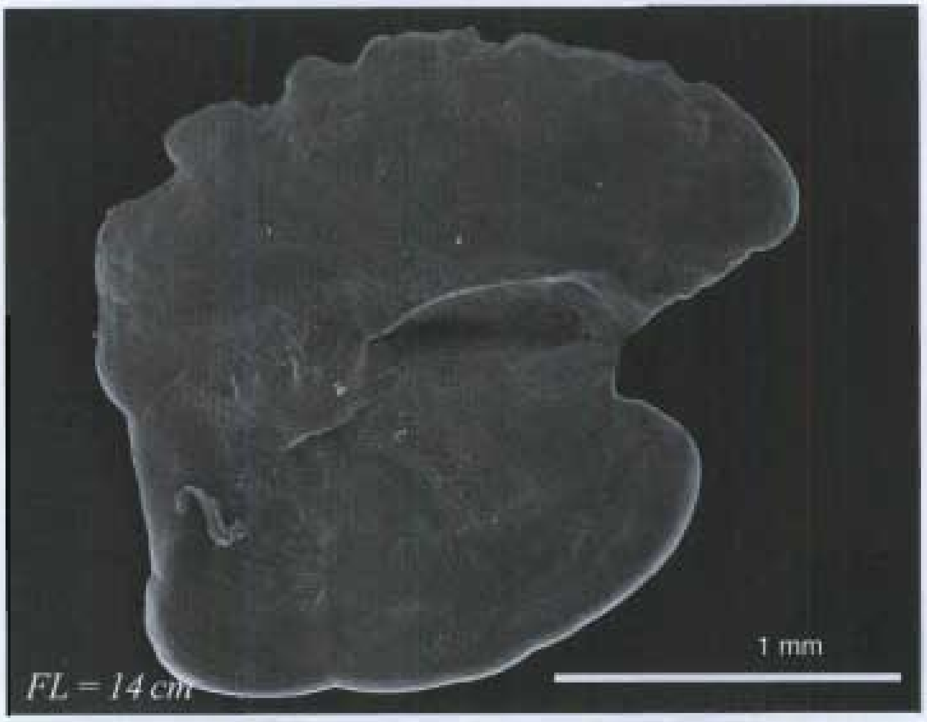


Asteriscii

Lapilli

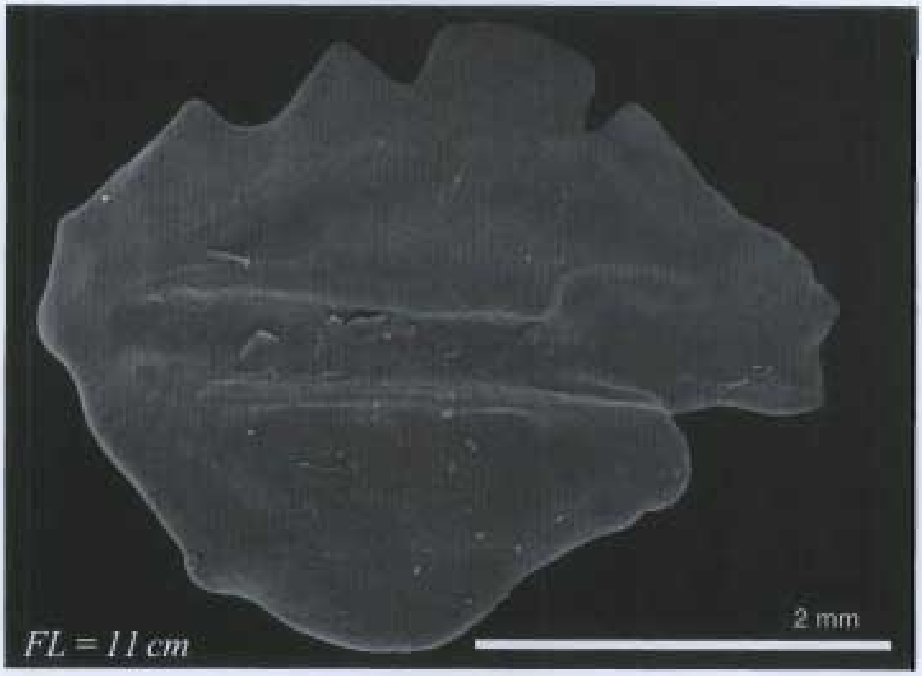
Osmeriformes

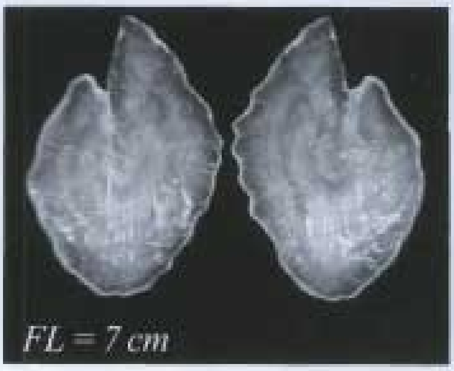
Platytroctidae: *Holtbyrnia macrops*



Perciformes

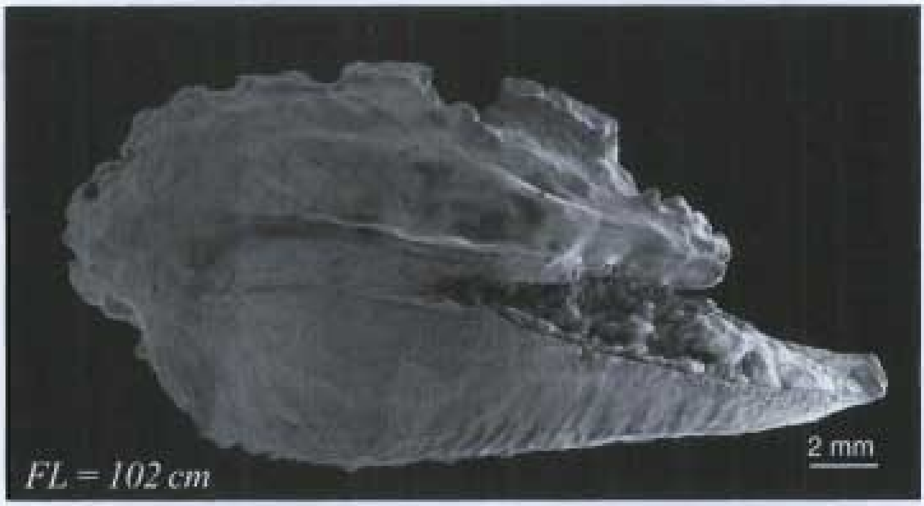
Acropomatidae: *Howella sherborni*





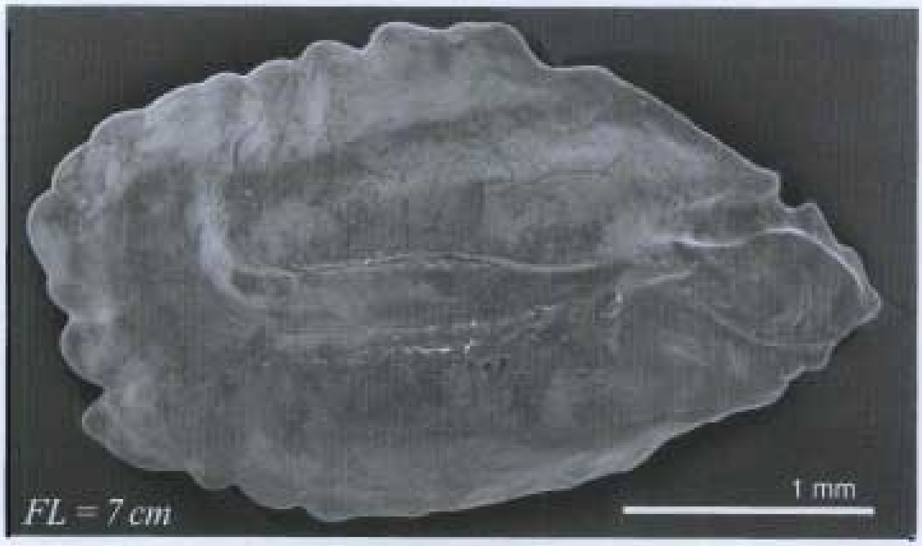
Perciformes

Acropomatidae: *Polyprion americanus*



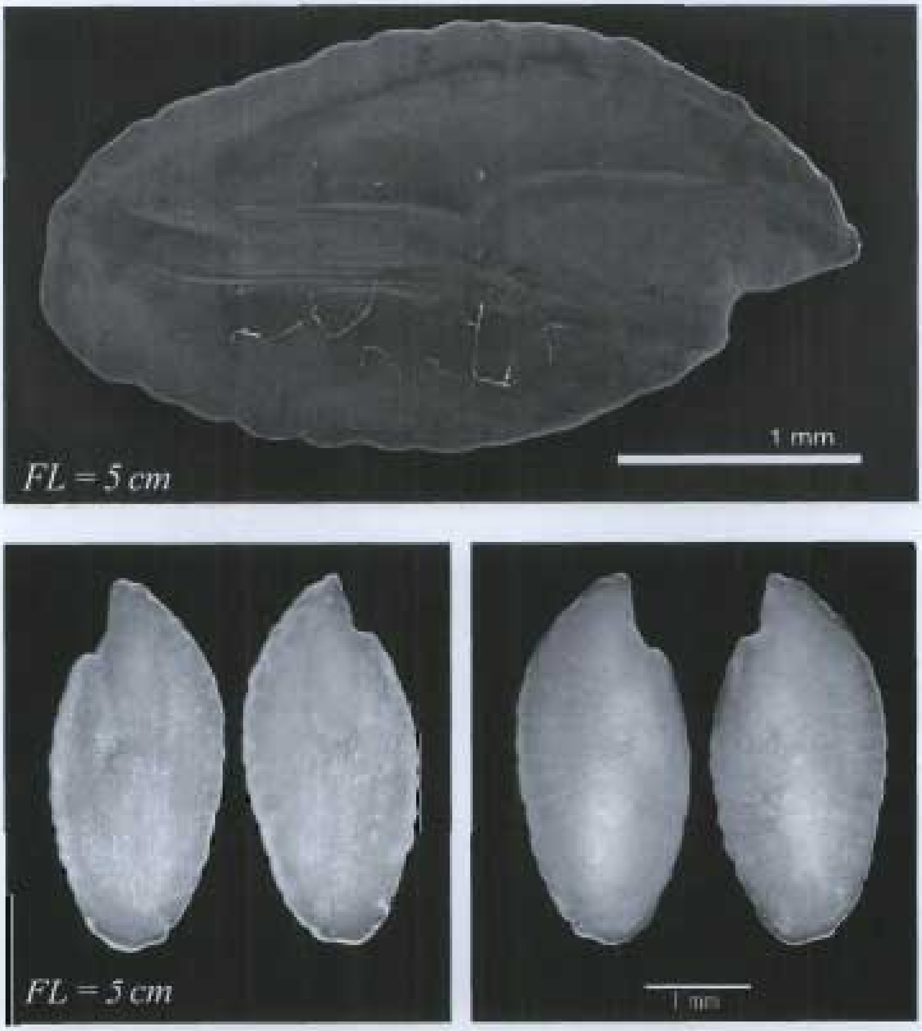
Perciformes

Acropomatidae: *Synagrops bellus*



Perciformes

Acropomatidae: *Synagrops spinosa*

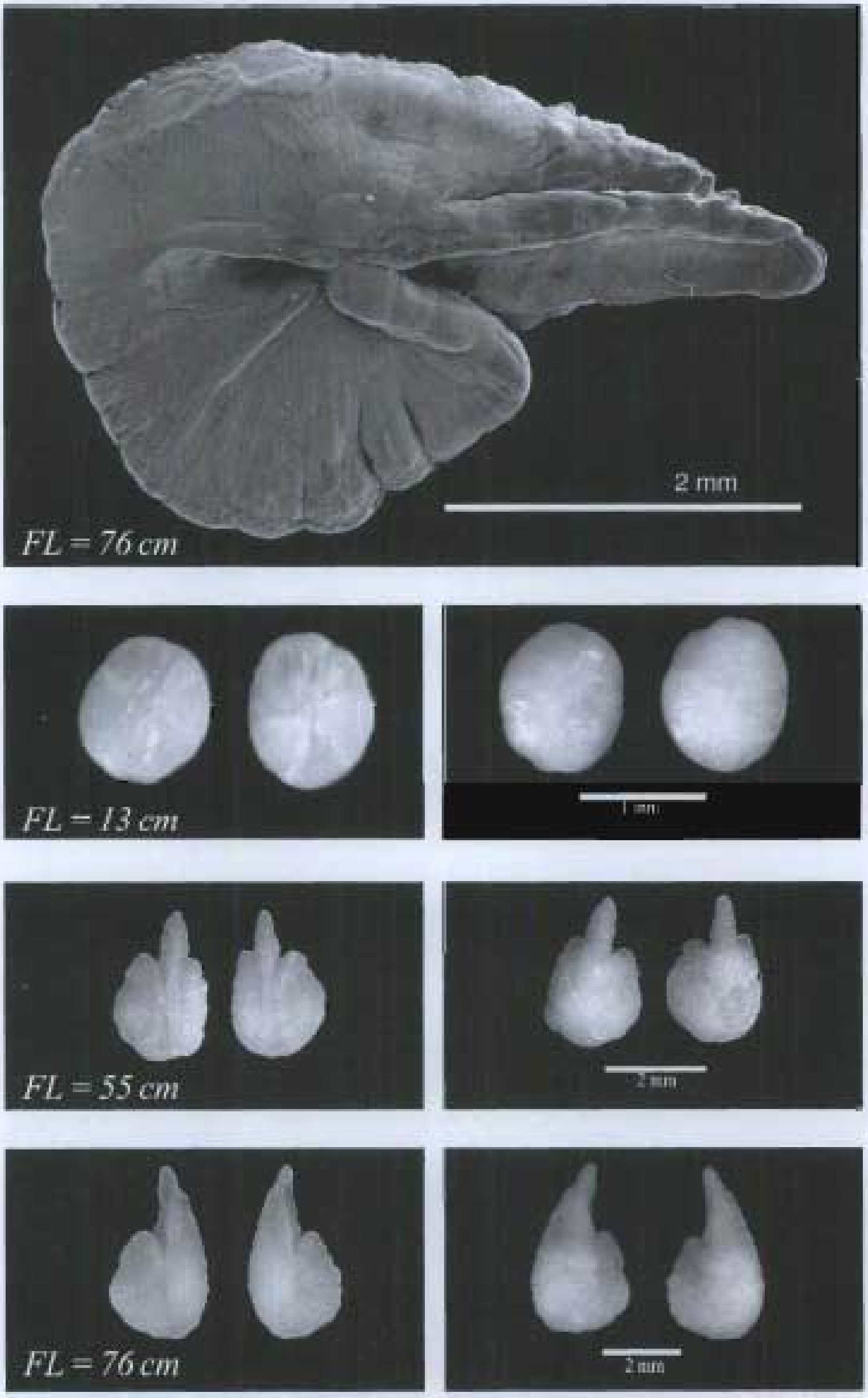


Perciformes

Ammodytidae: *Ammodytes americanus / dubius*

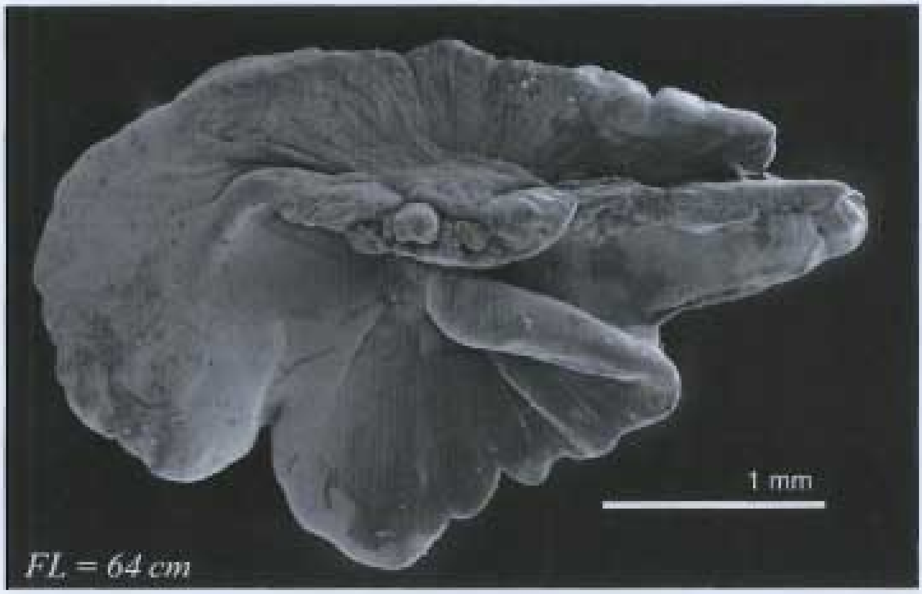
Perciformes

Anarhichadidae: *Anarhichas denticulatus*

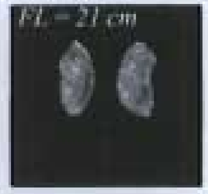


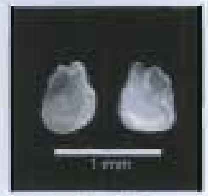
Perciformes

Anarhichadidae: *Anarhichas lupus*

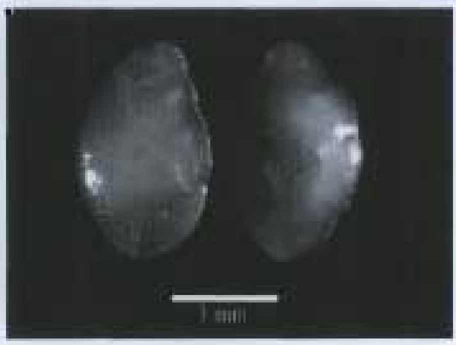


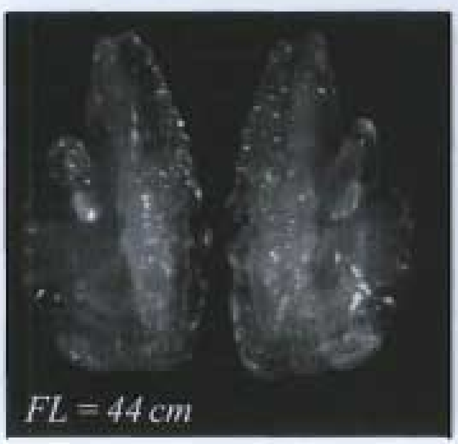
Asteriscii





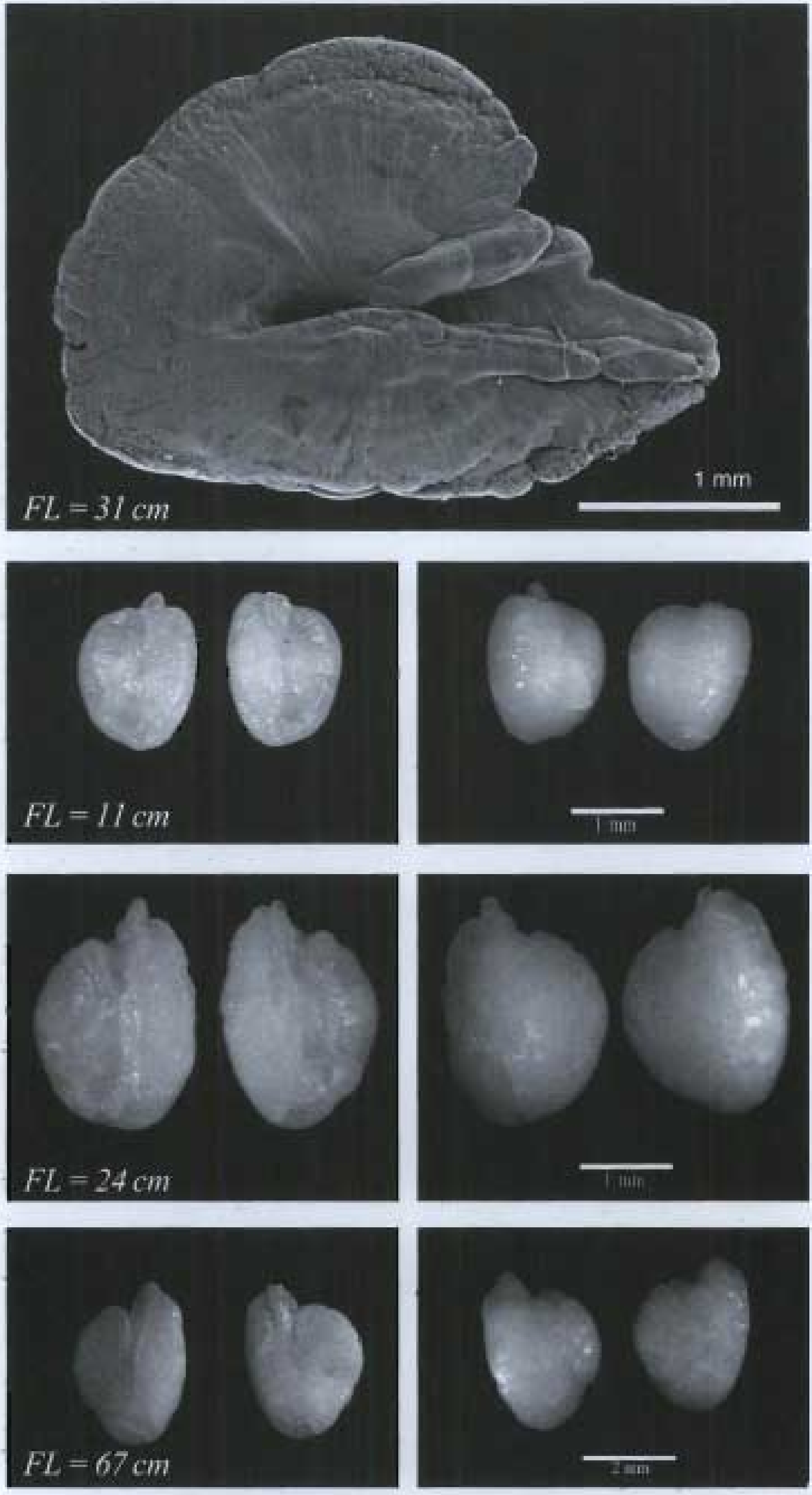
Lapilli





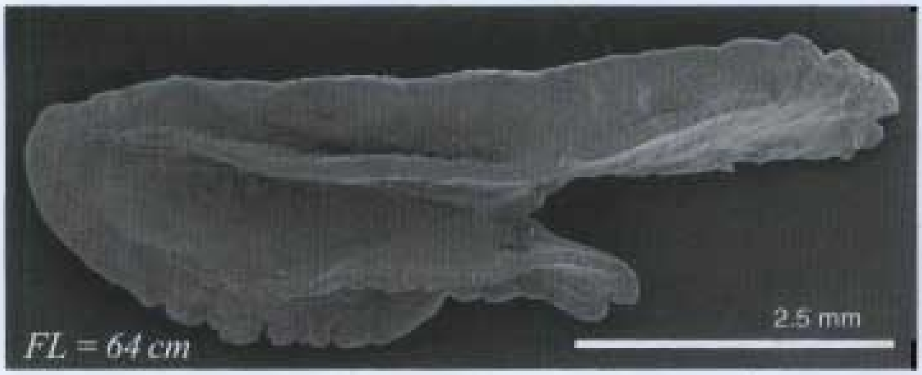
Perciformes

Anarhichadidae: *Anarhichas minor*



Perciformes

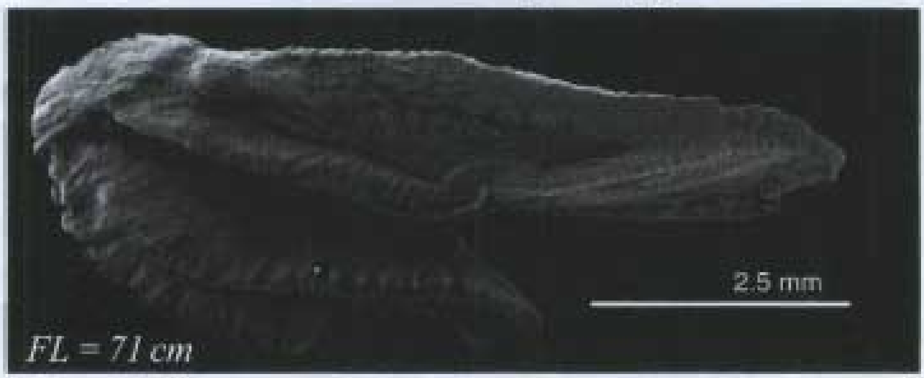
Bramidae: *Brama brama*



Asteriscii

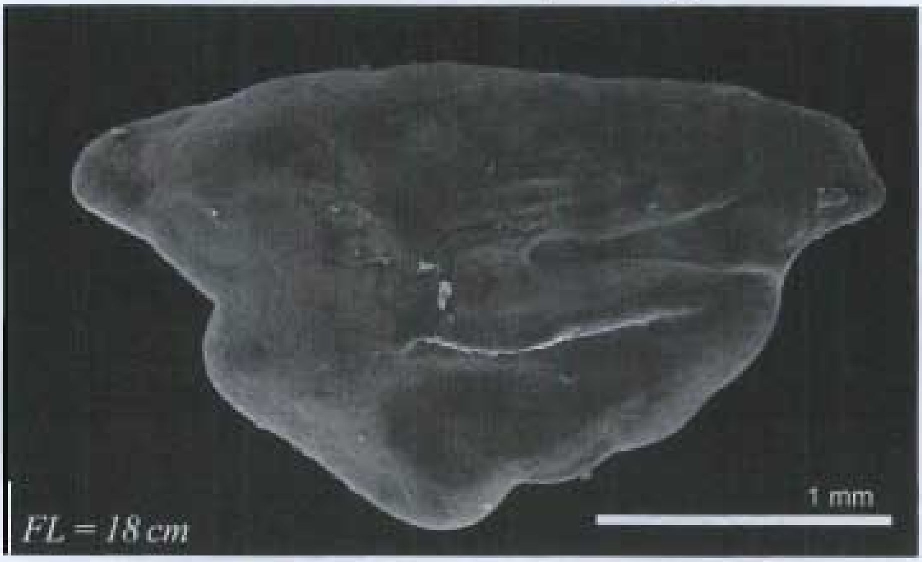
Lapilli

Bramidae: *Taractichthys longipinnis*



Perciformes

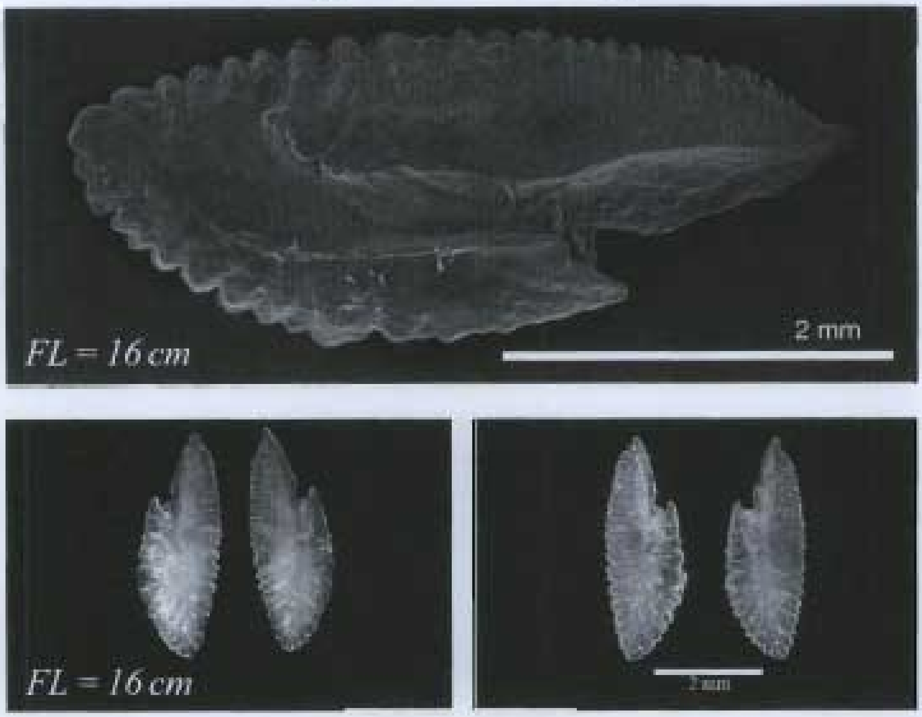
Callionymidae: *Callionymus agassizi*



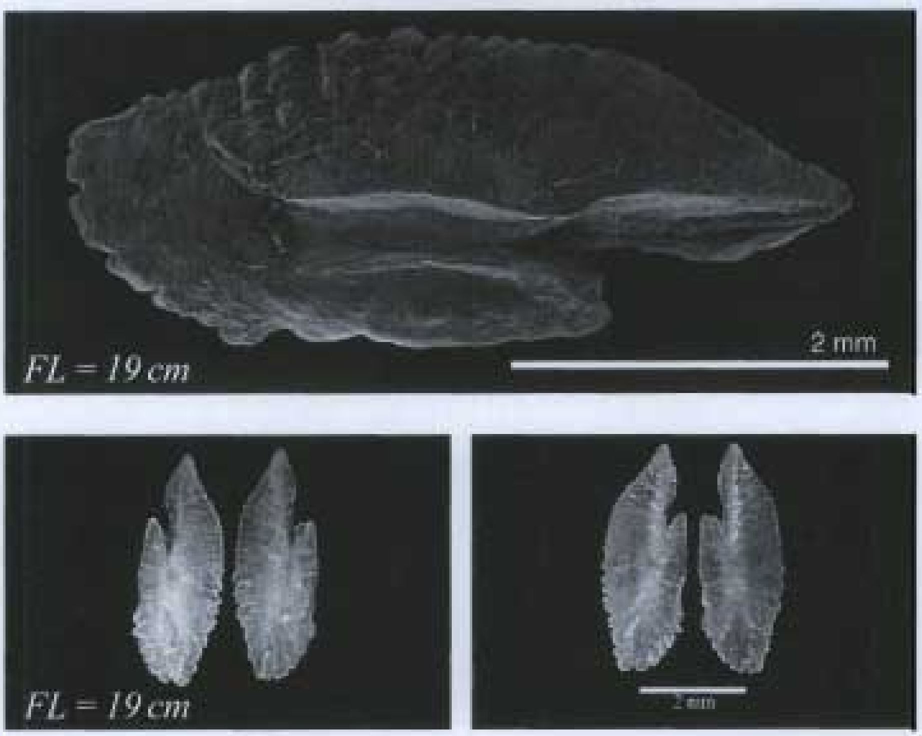
Asteriscii
& Lapilli

Perciformes

Carangidae: *Caranx crysos*



Carangidae: *Caranx hippos*



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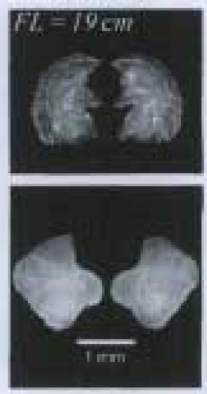
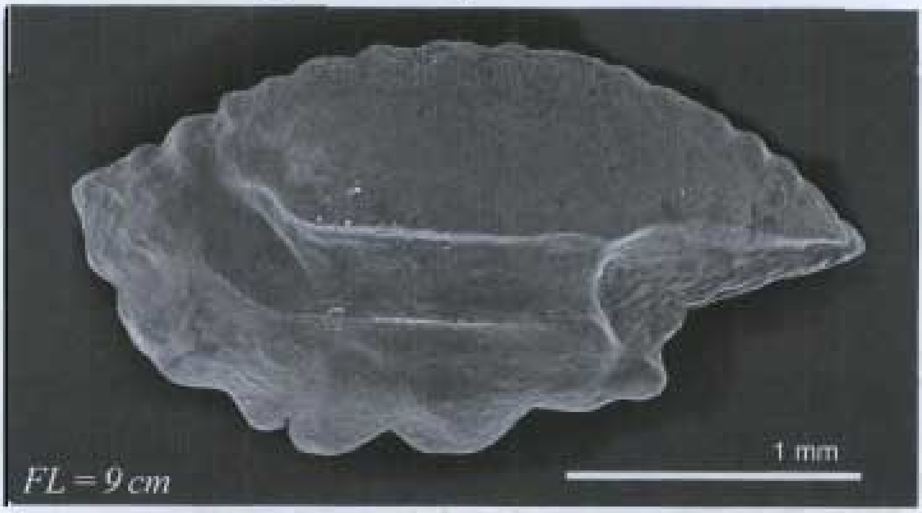
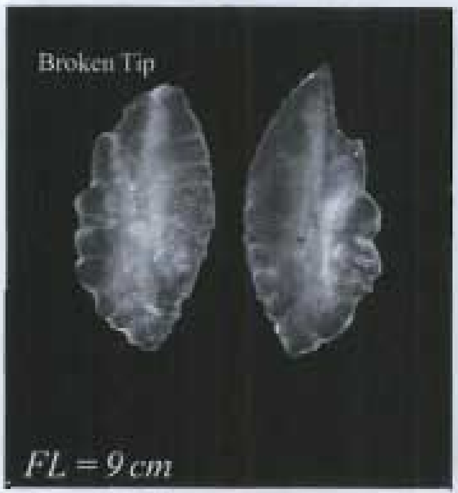


Lapilli

Perciformes

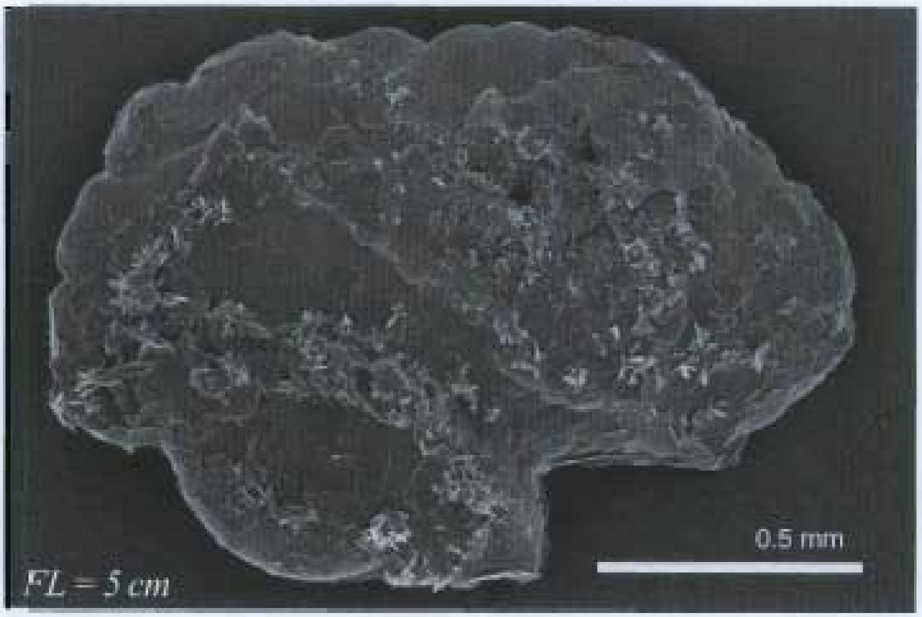
Carangidae: *Decapterus macarellus*

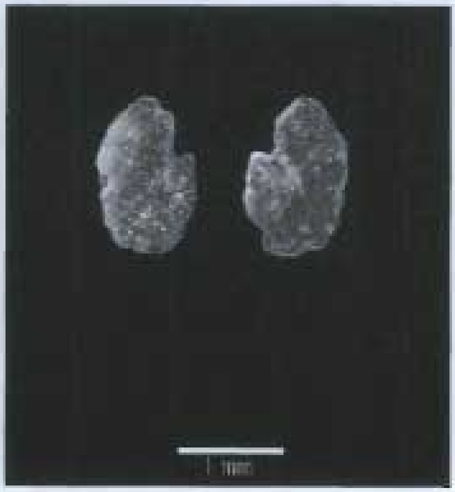




Perciformes

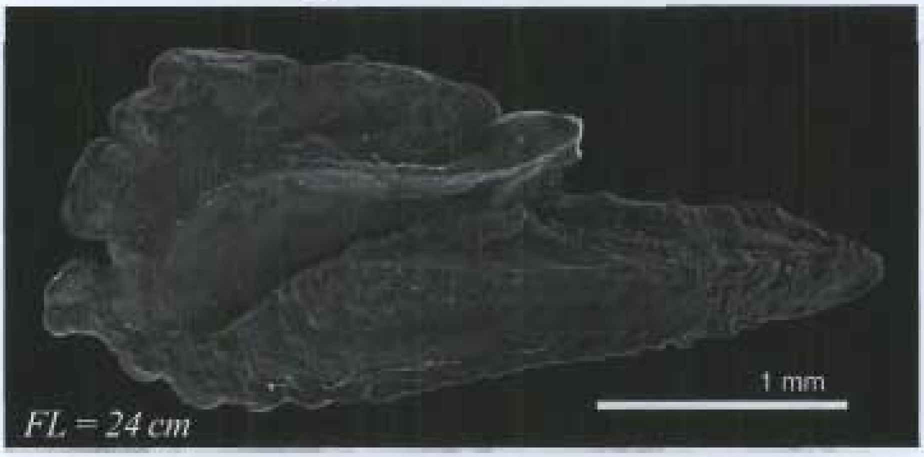
Carangidae: *Selene setapinnis*

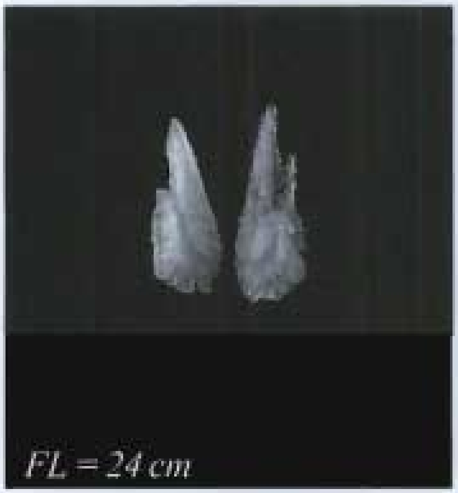




Perciformes

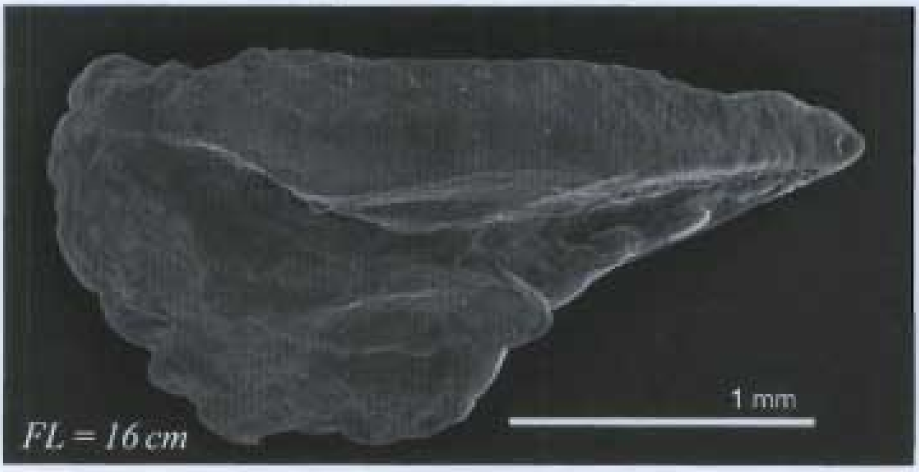
Carangidae: *Seriola dumerili*





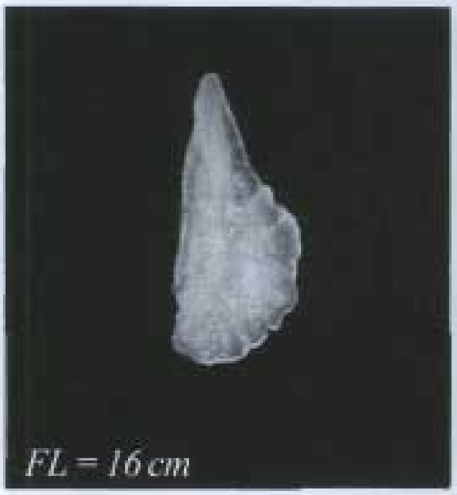
Perciformes

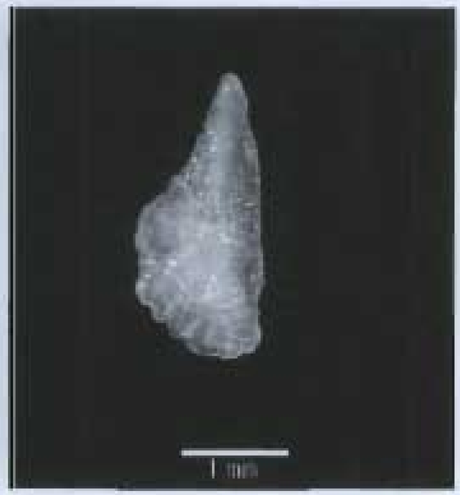
Carangidae: *Seriola zonata*



Asteriscii

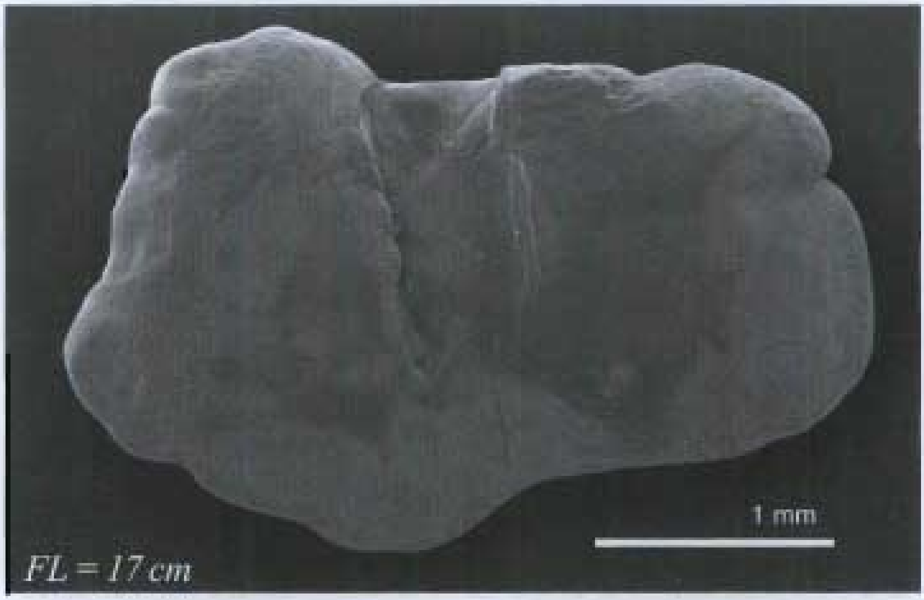
Lapilli





Perciformes

Caristiidae: *Caristius groenlandicus*



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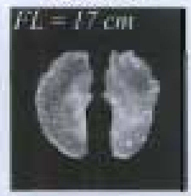

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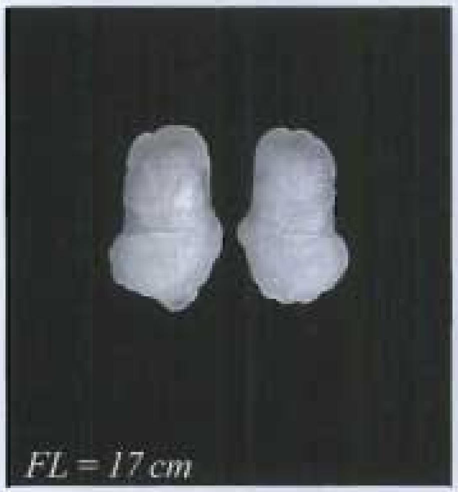
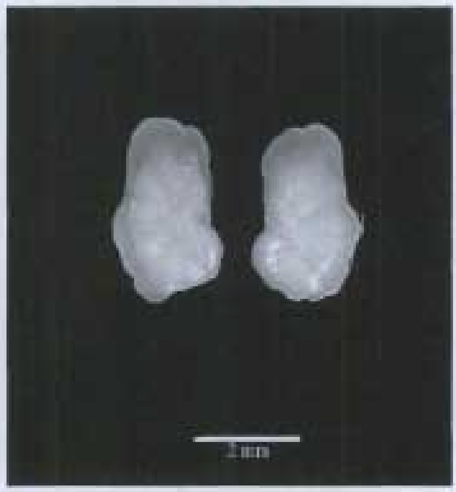
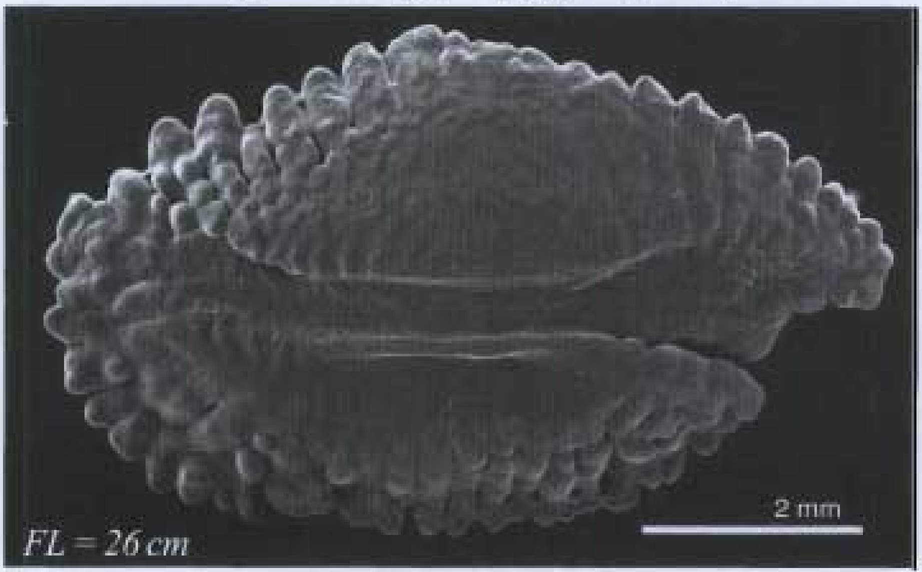




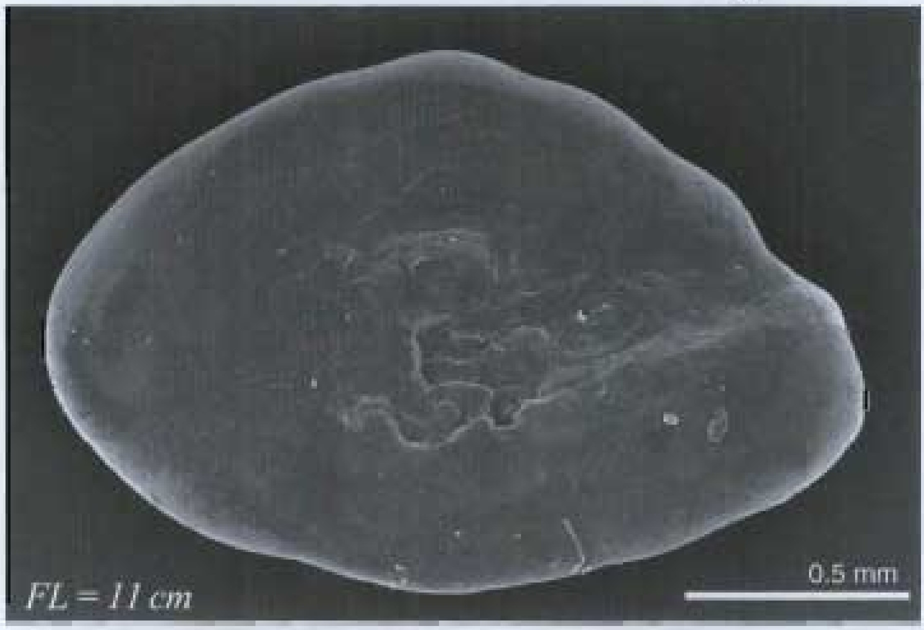
Perciformes

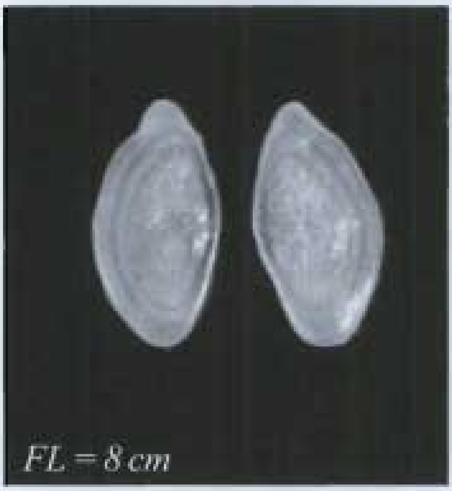
Centrolophidae: *Hyperoglyphe perciformis*

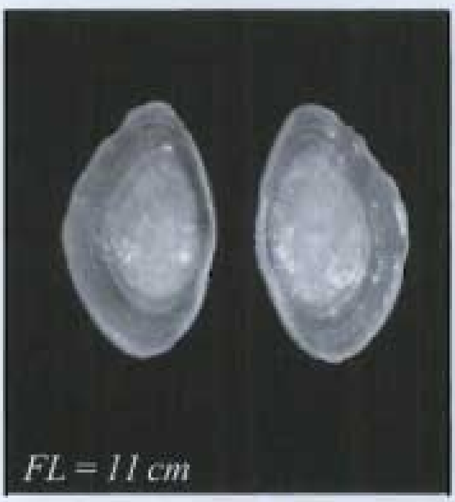


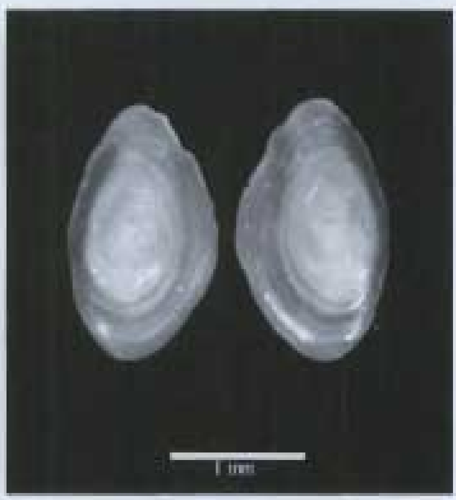
Perciformes

Chiasmodontidae: *Chiasmodon niger*

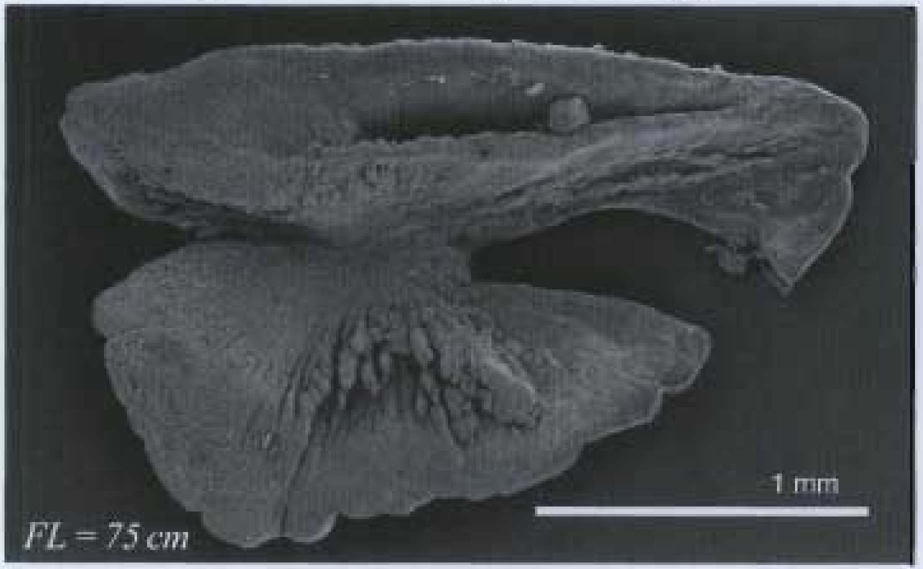




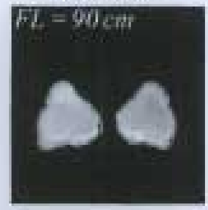




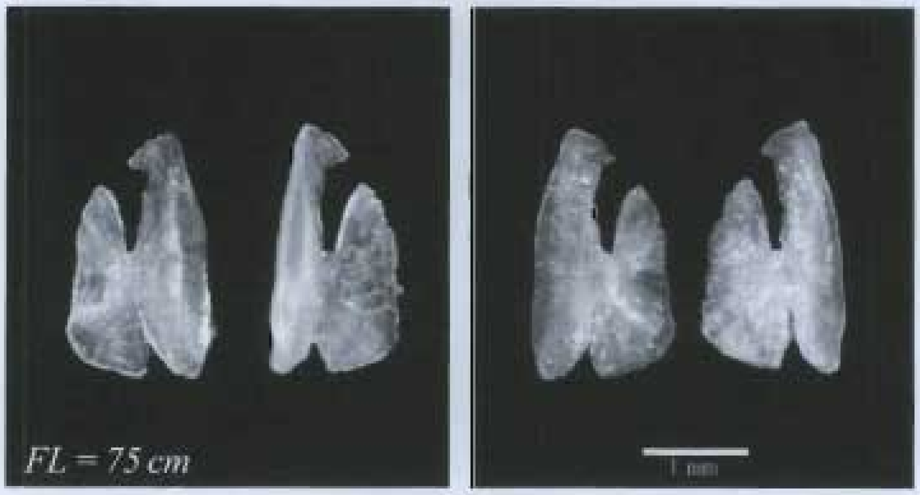
Coryphaenidae: *Coryphaena hippurus*

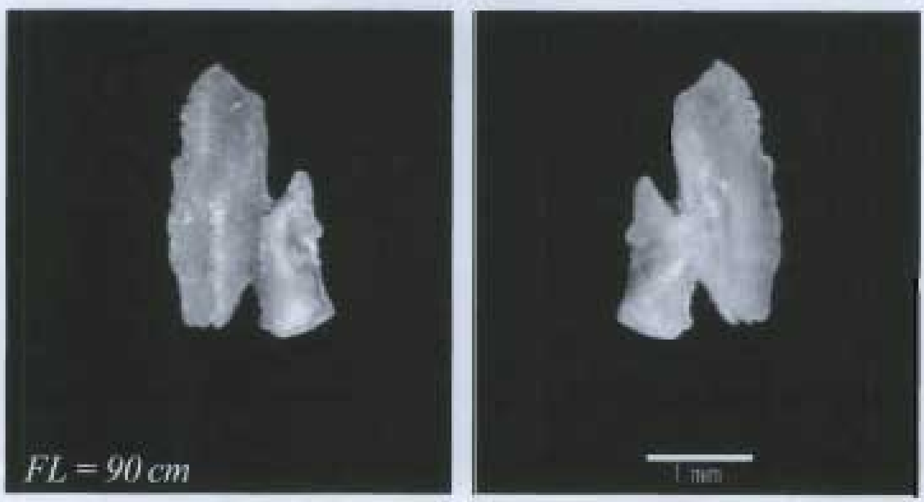


Asteriscii



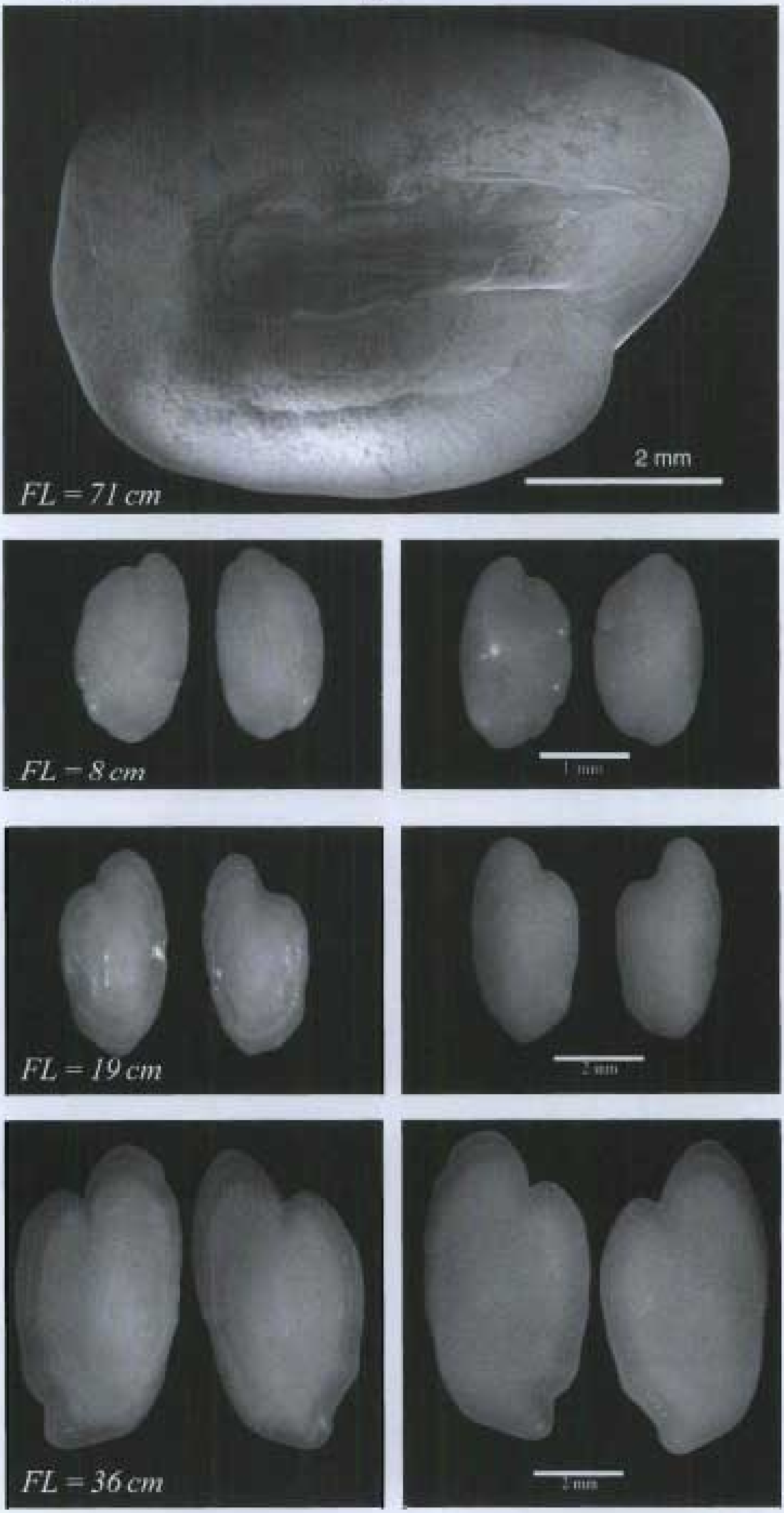
Lapilli





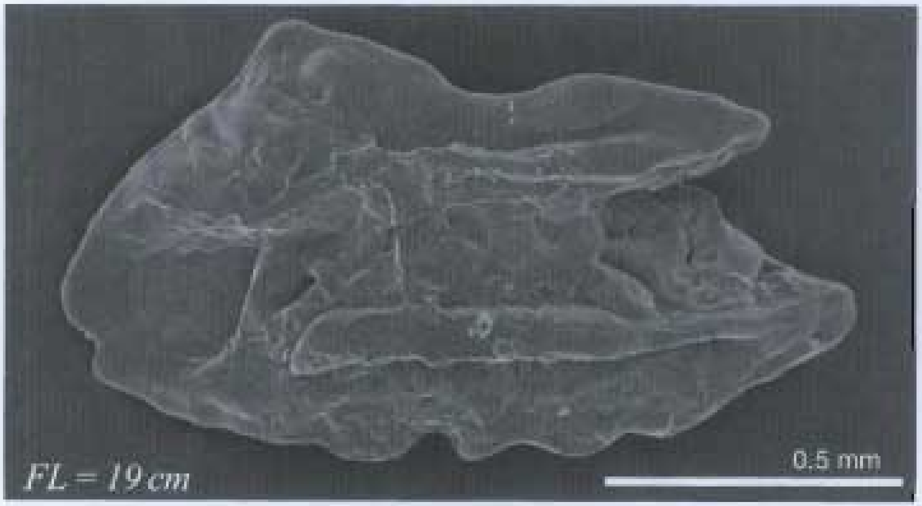
Perciformes

Cryptacanthodidae: *Cryptacanthodes maculatus*

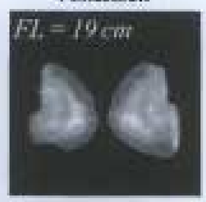


Perciformes

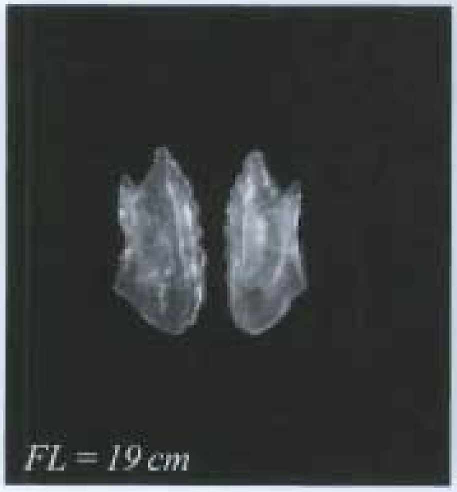
Echeneidae: *Echeneis naucrates*



Asterisci

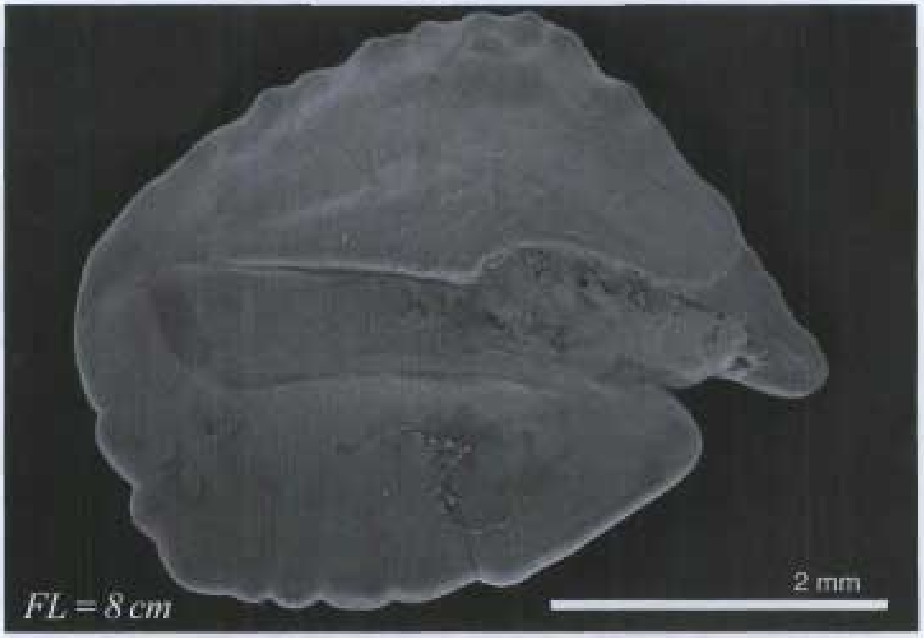


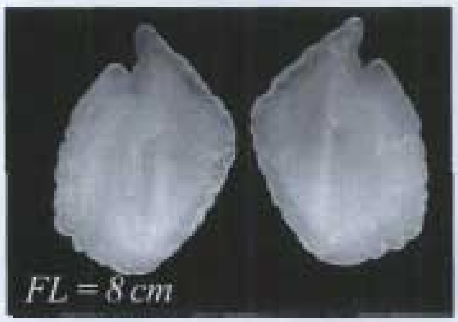
Lapilli



Perciformes

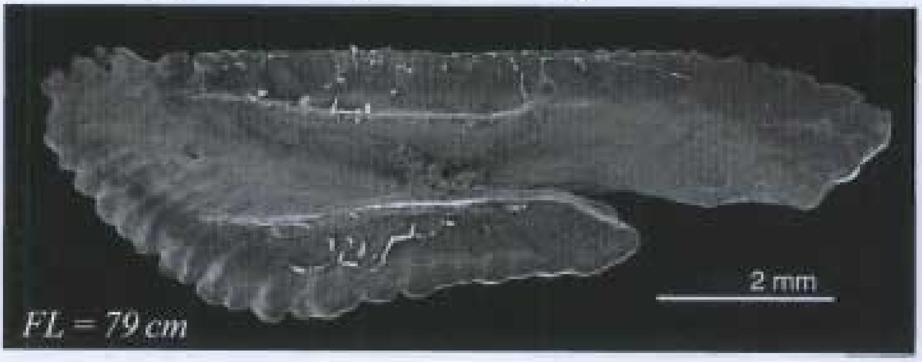
Epigonidae: *Epigonus telescopus*





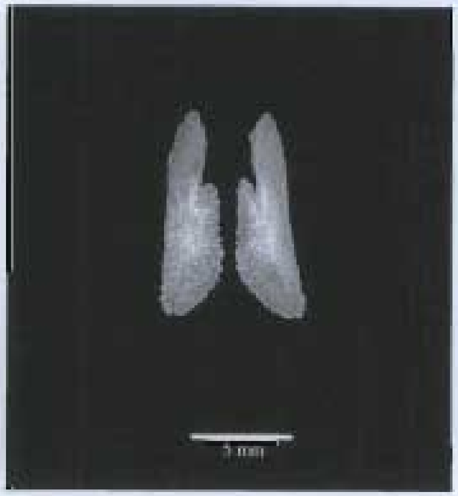
Perciformes

Gempylidae: *Lepidocybium flavobrunneum*



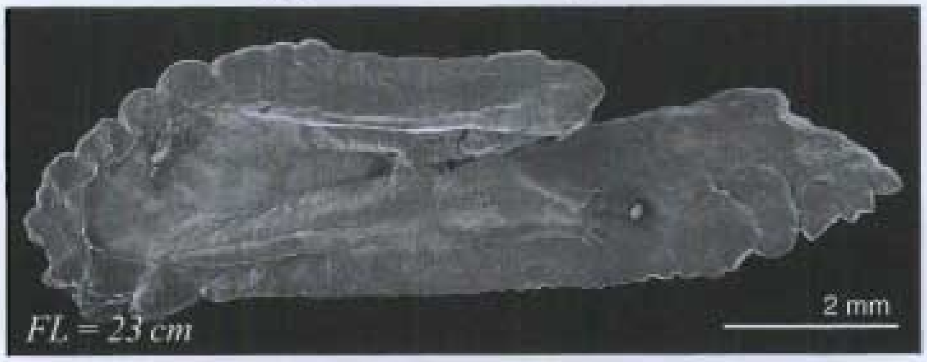
Asterisci

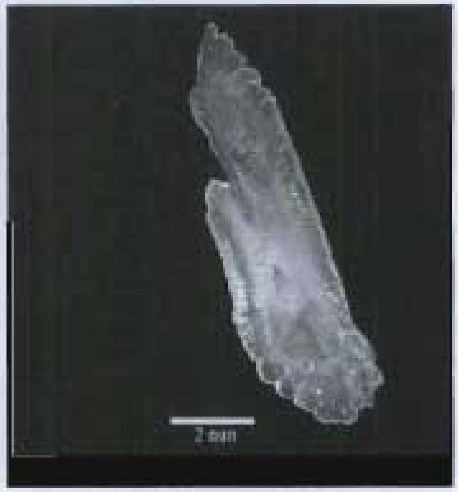
Lapilli



Perciformes

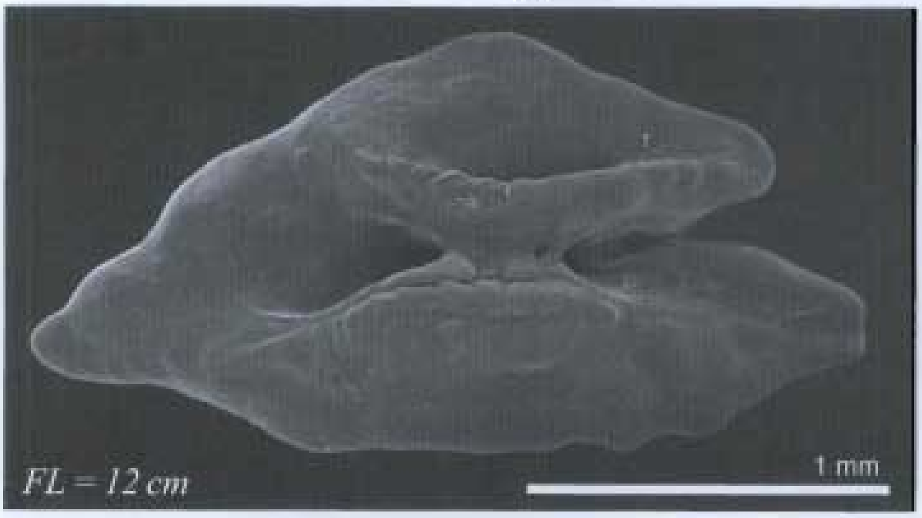
Gempylidae: *Ruvettus pretiosus*



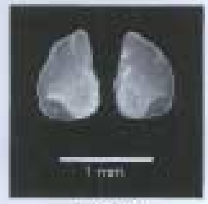


Perciformes

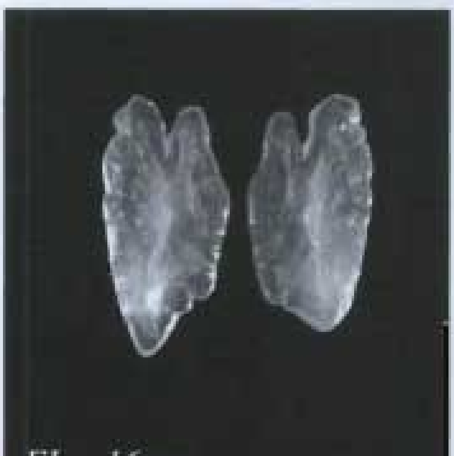
Labridae: *Tautoga onitis*



Asteriscii

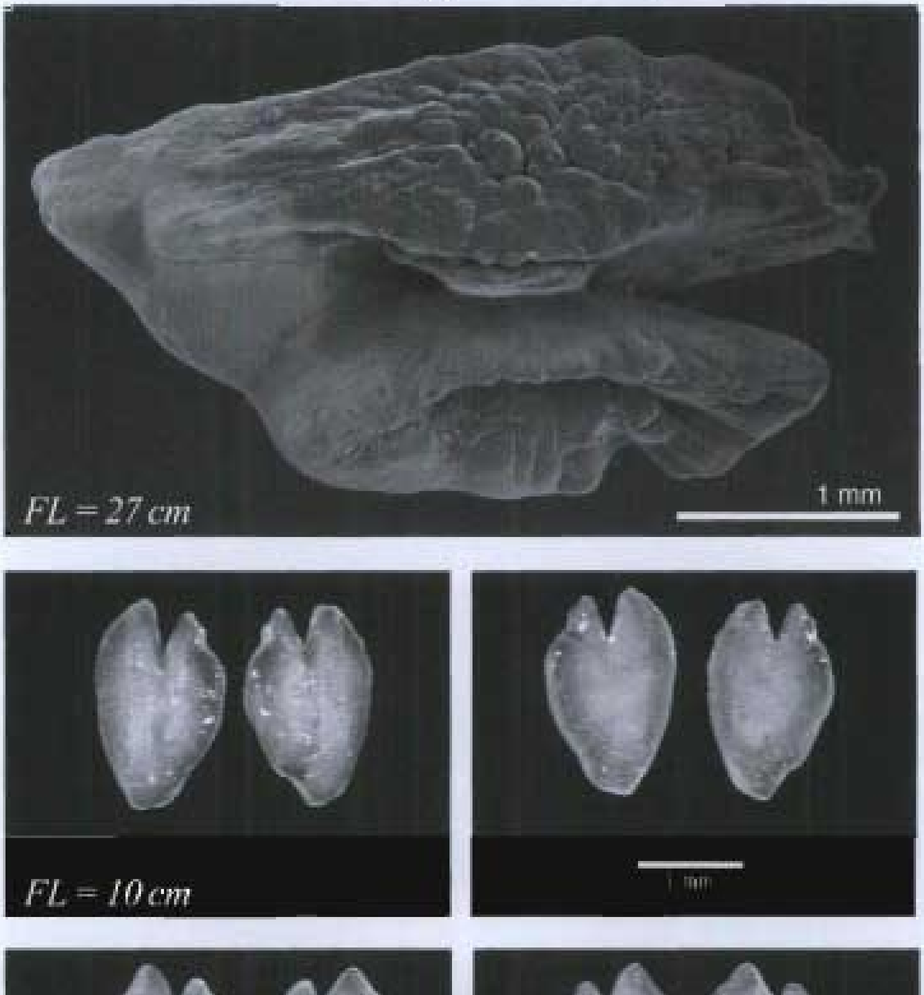


Lapilli



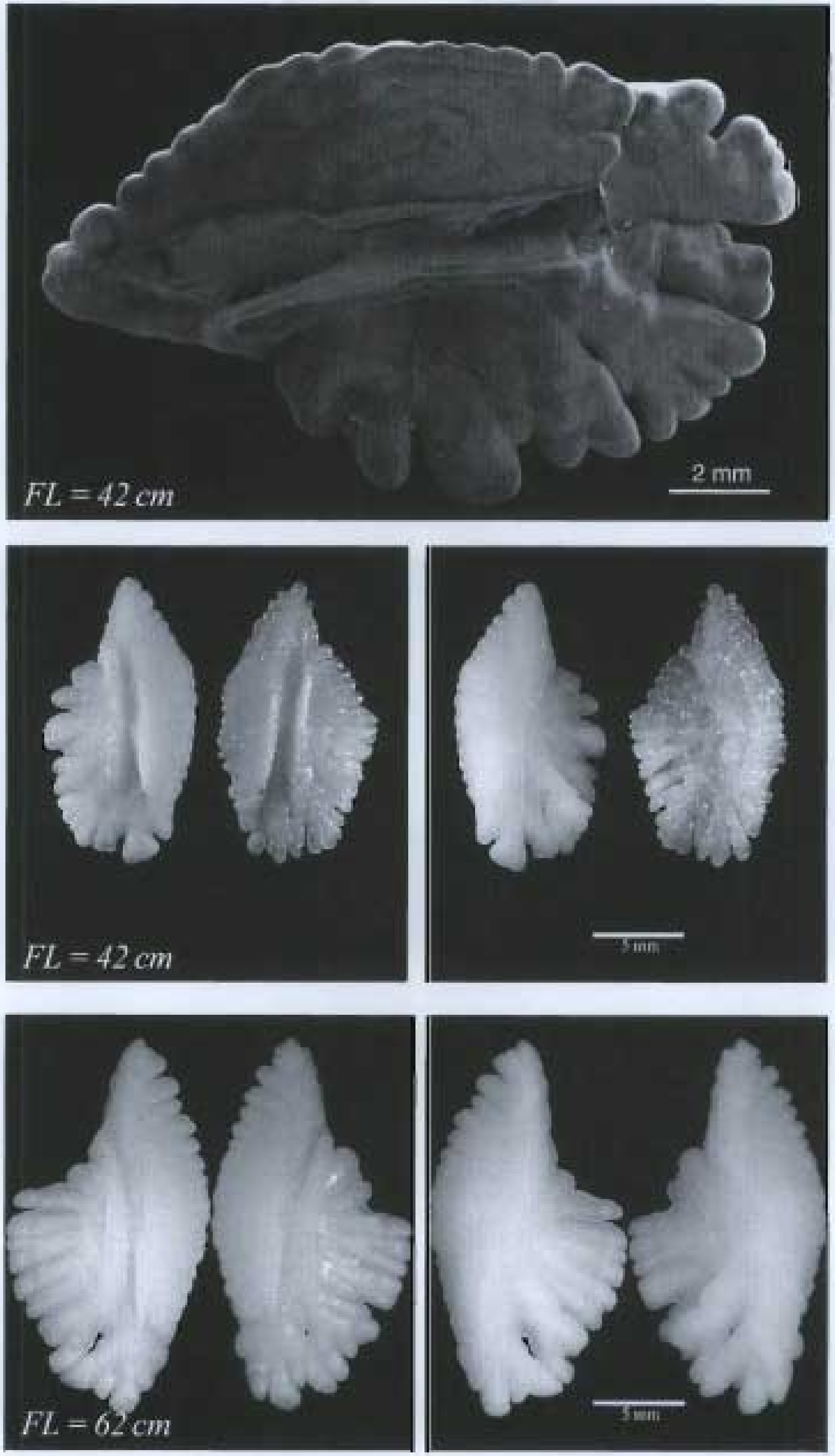
Perciformes

Labridae: *Tautogolabrus adspersus*



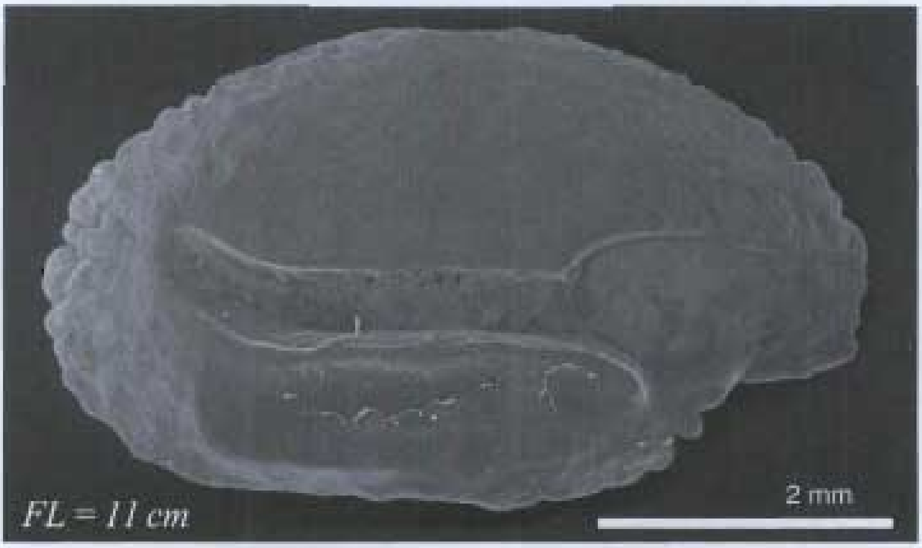
Perciformes

Malacanthidae: *Lopholatilus chamaeleonticeps*



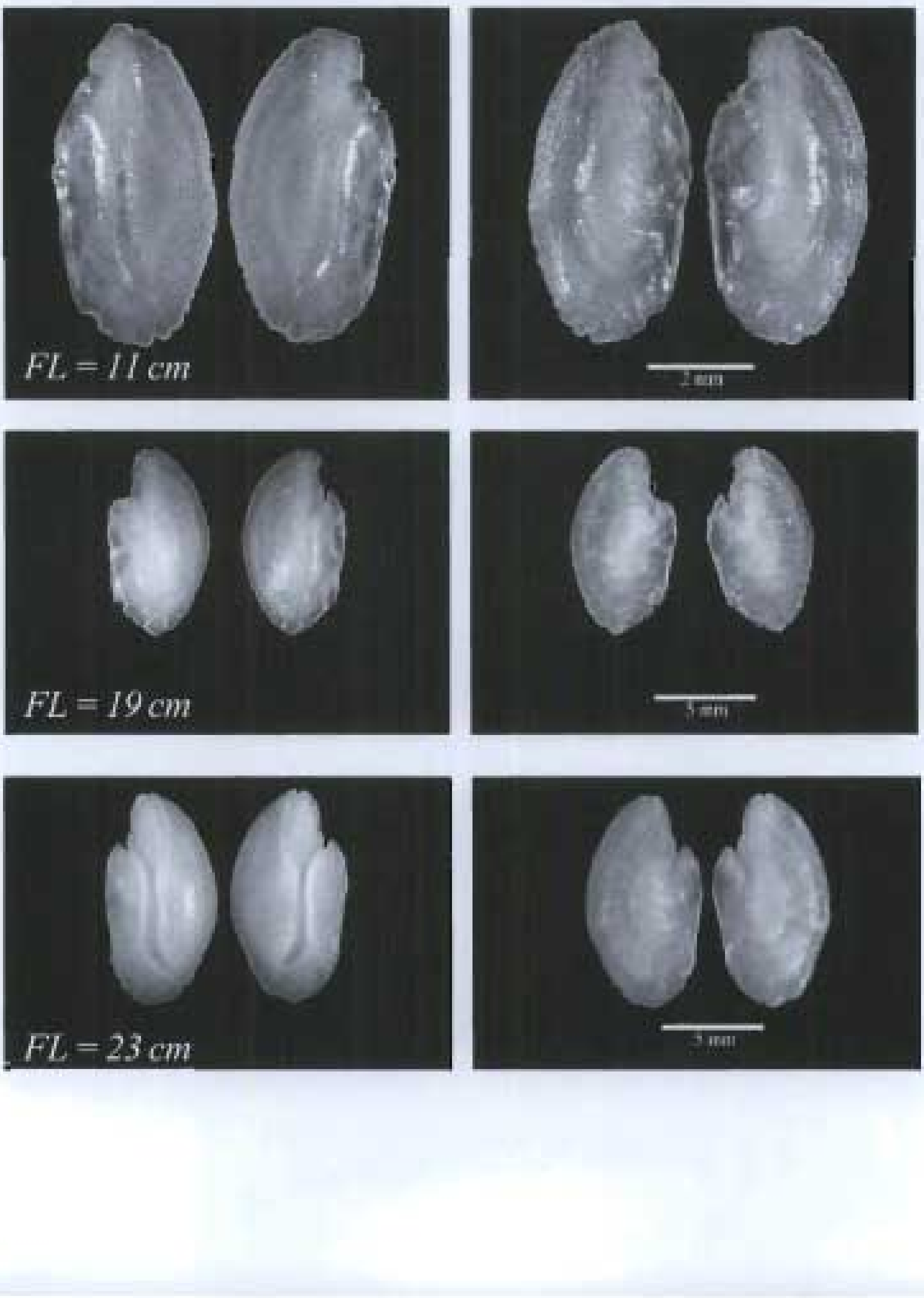
Perciformes

Moronidae: *Morone americana*



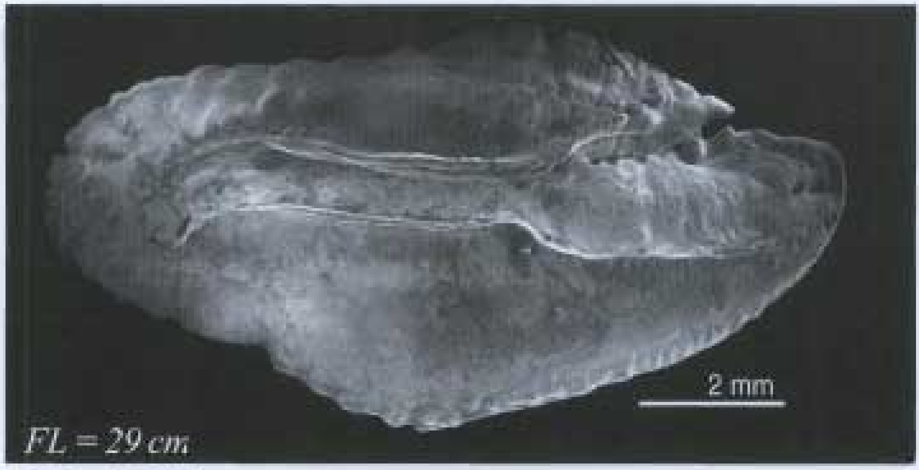
Asterisci

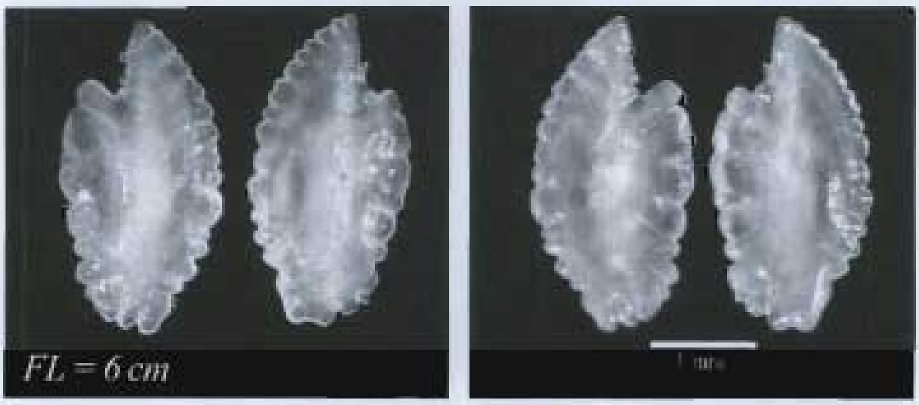
Lapilli

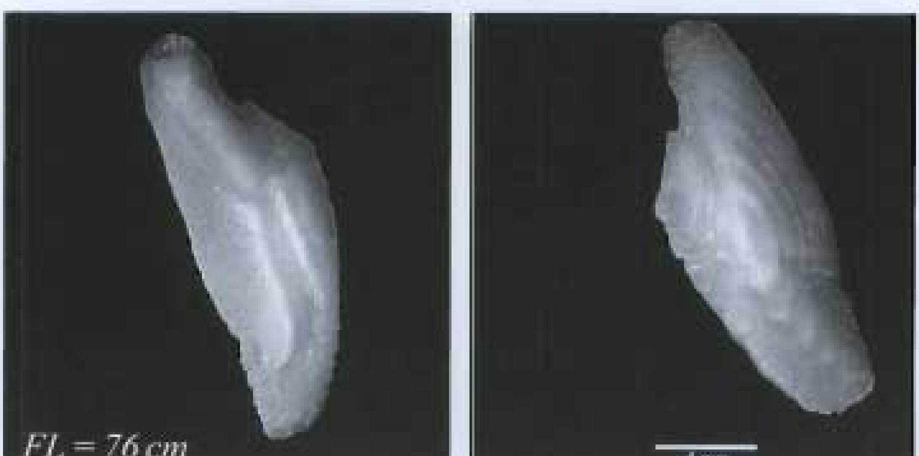


Perciformes

Moronidae: *Morone saxatilis*

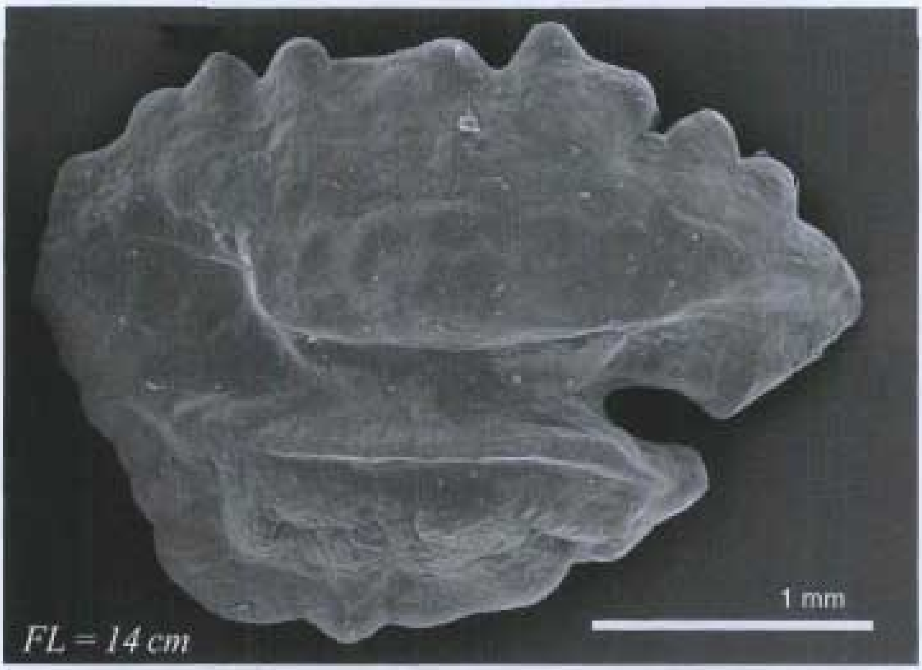


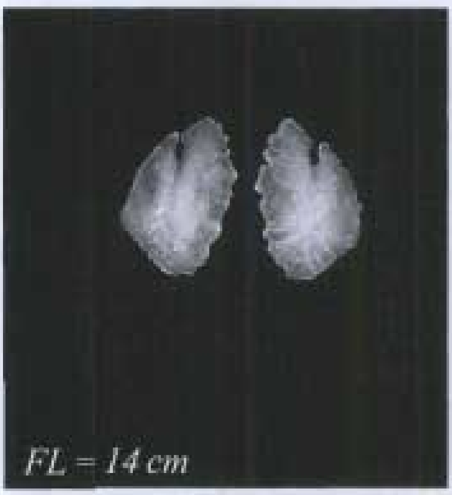


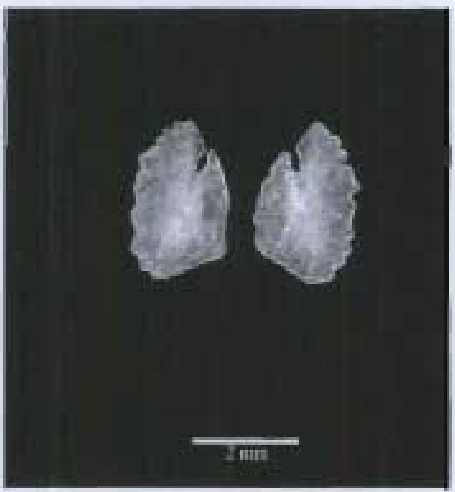


Perciformes

Mullidae: *Mullus auratus*

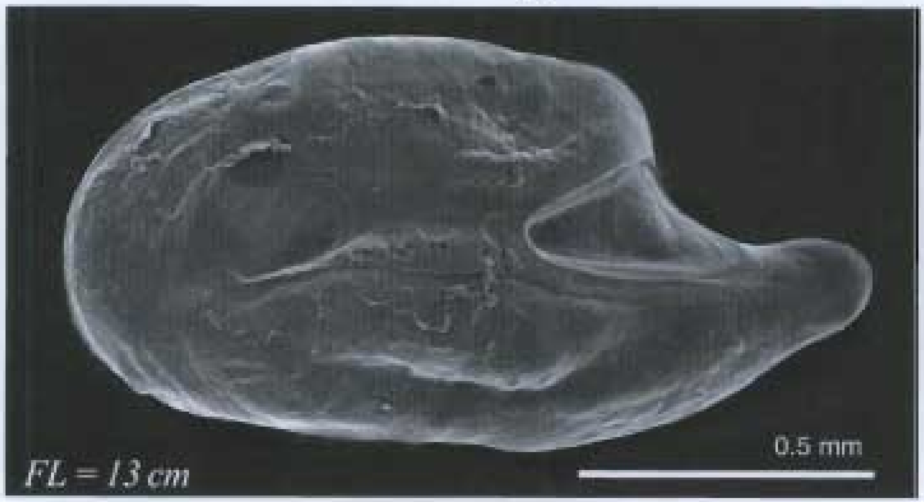




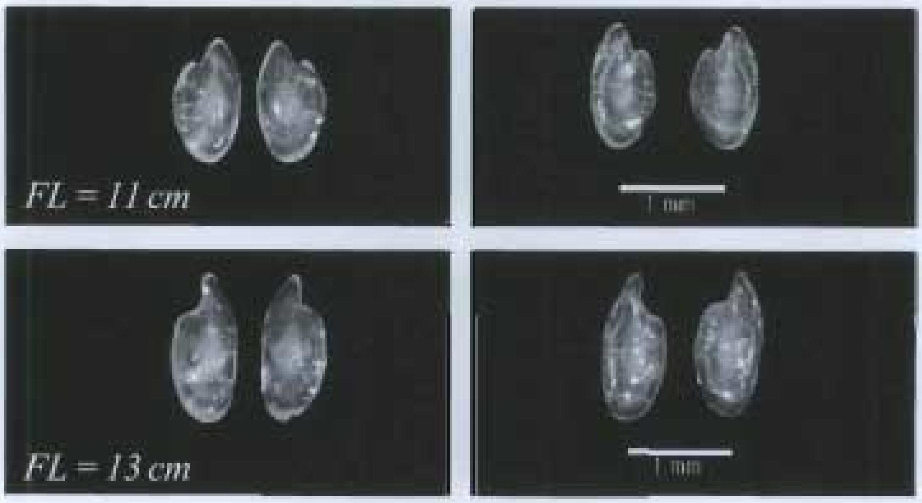


Perciformes

Pholidae: *Pholis gunnellus*

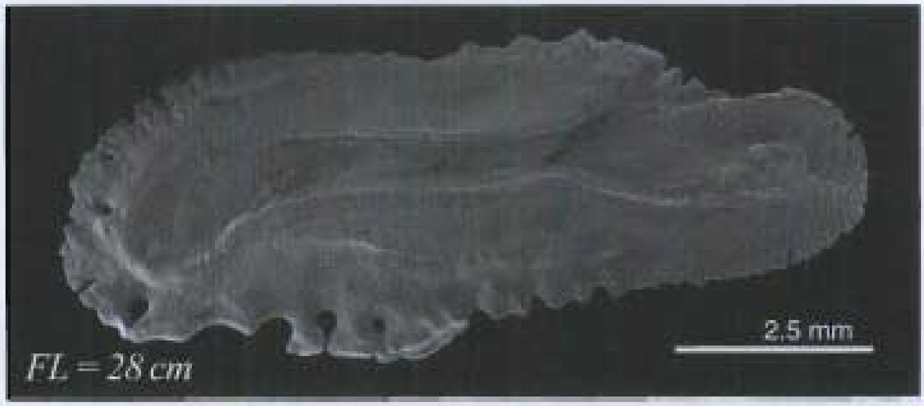


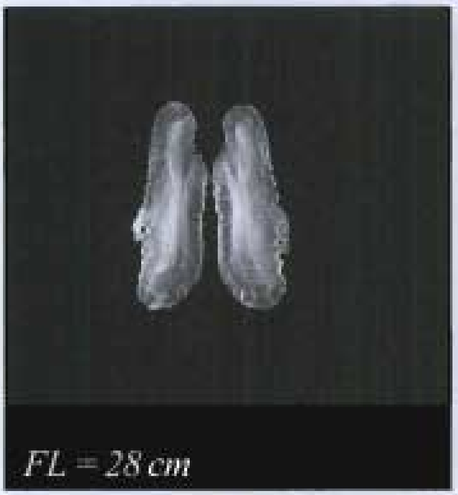
Asteriscii
& Lapilli

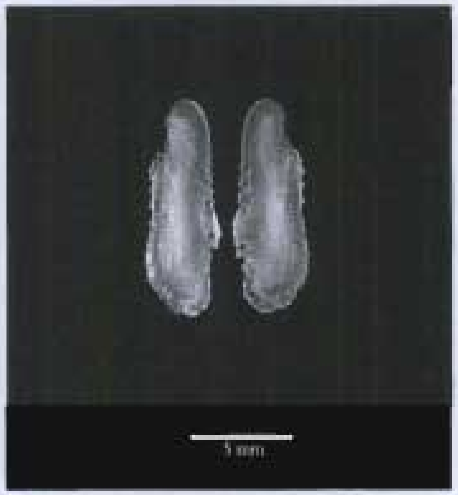


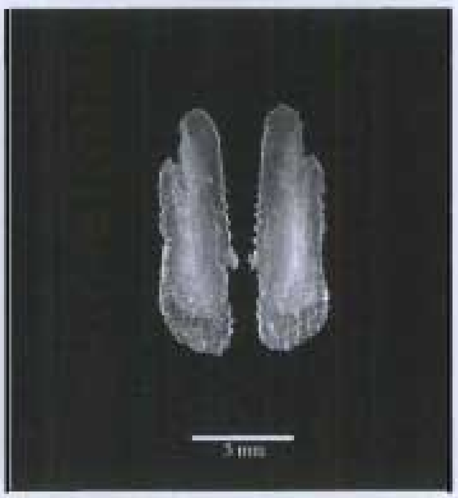
Perciformes

Pomatomidae: *Pomatomus saltatrix*



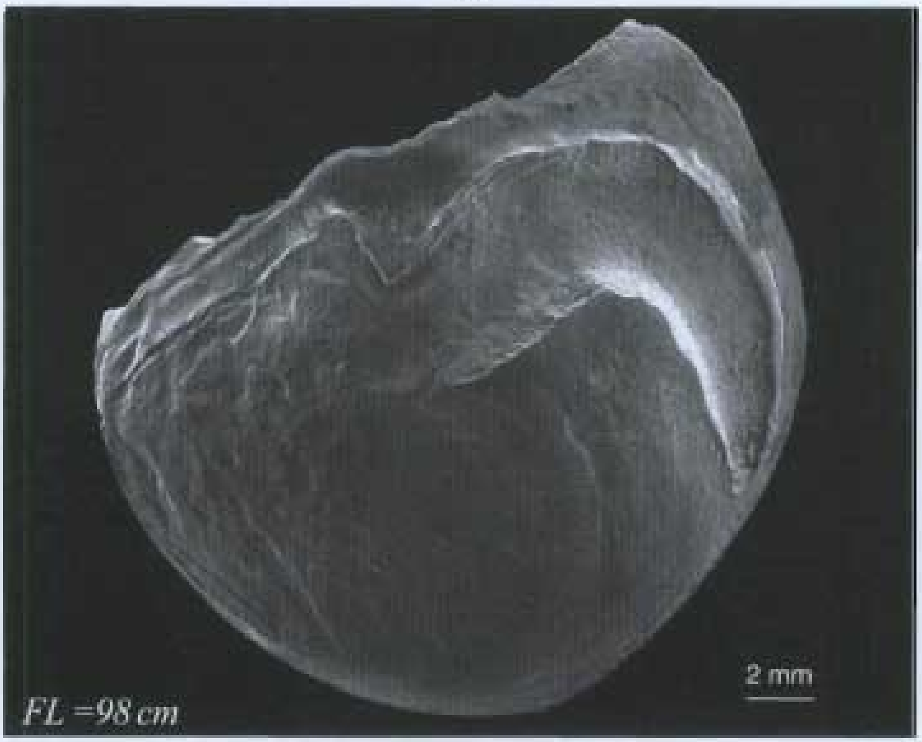






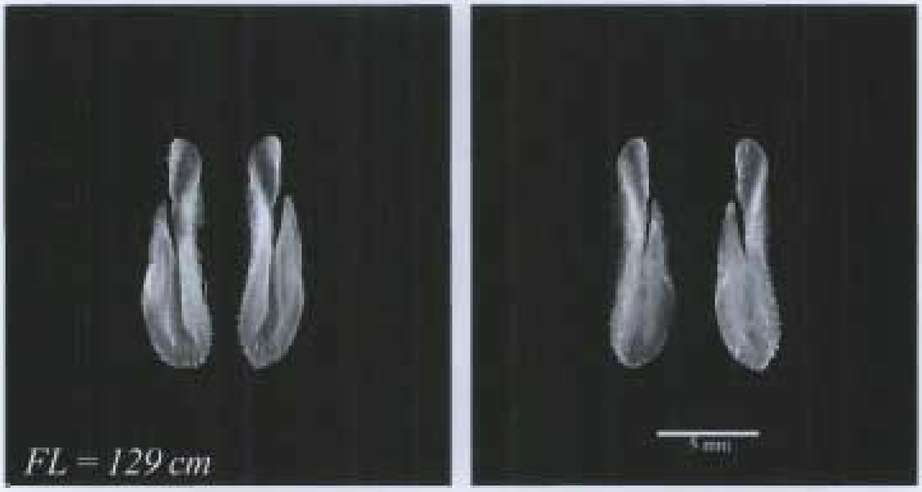
Perciformes

Sciaenidae: *Pogonias cromis*

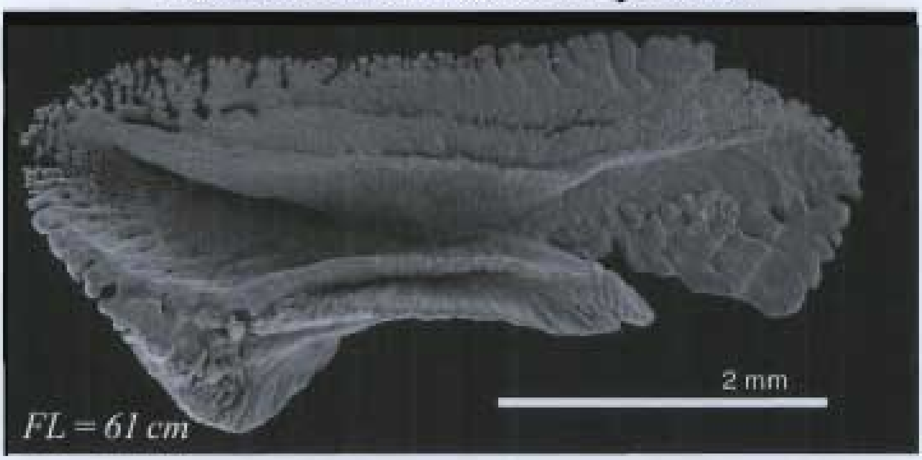


Perciformes

Scombridae: *Acanthocybium solandri*

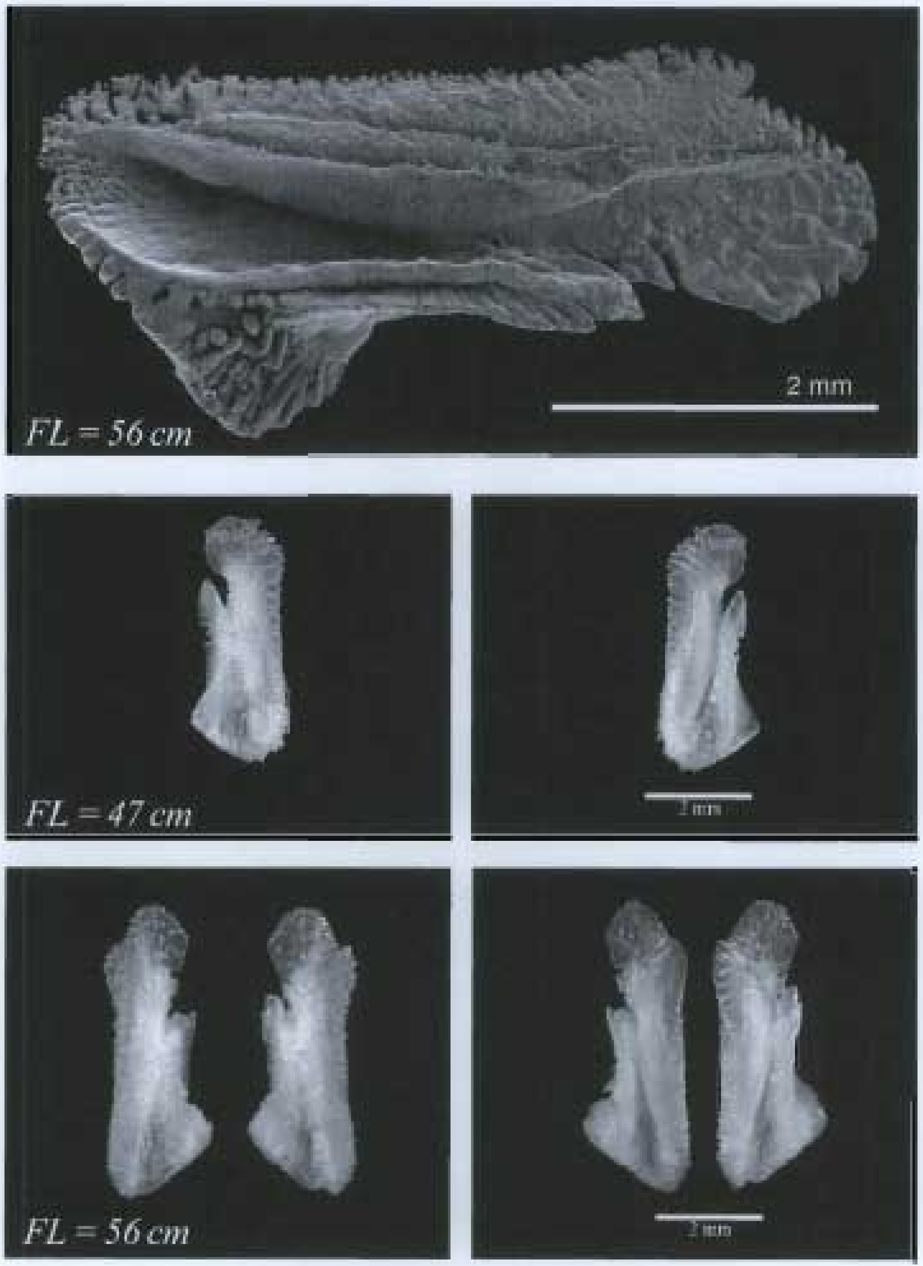


Scombridae: *Katsuwonus pelamis*



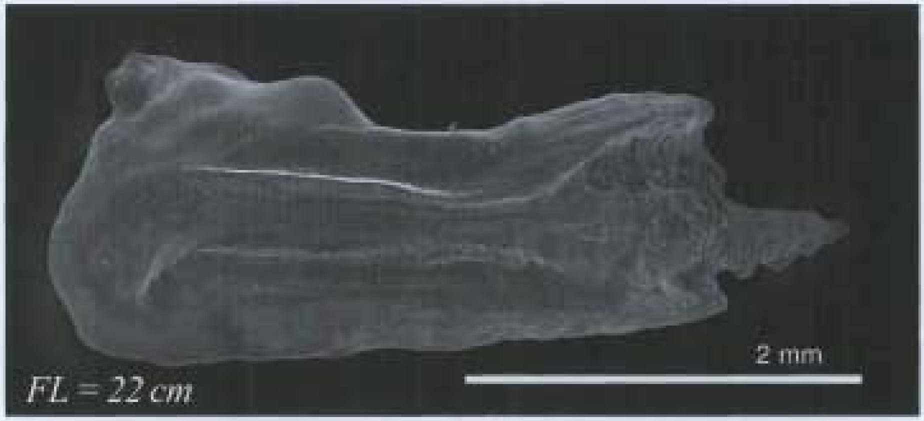
Perciformes

Scombridae: *Sarda sarda*



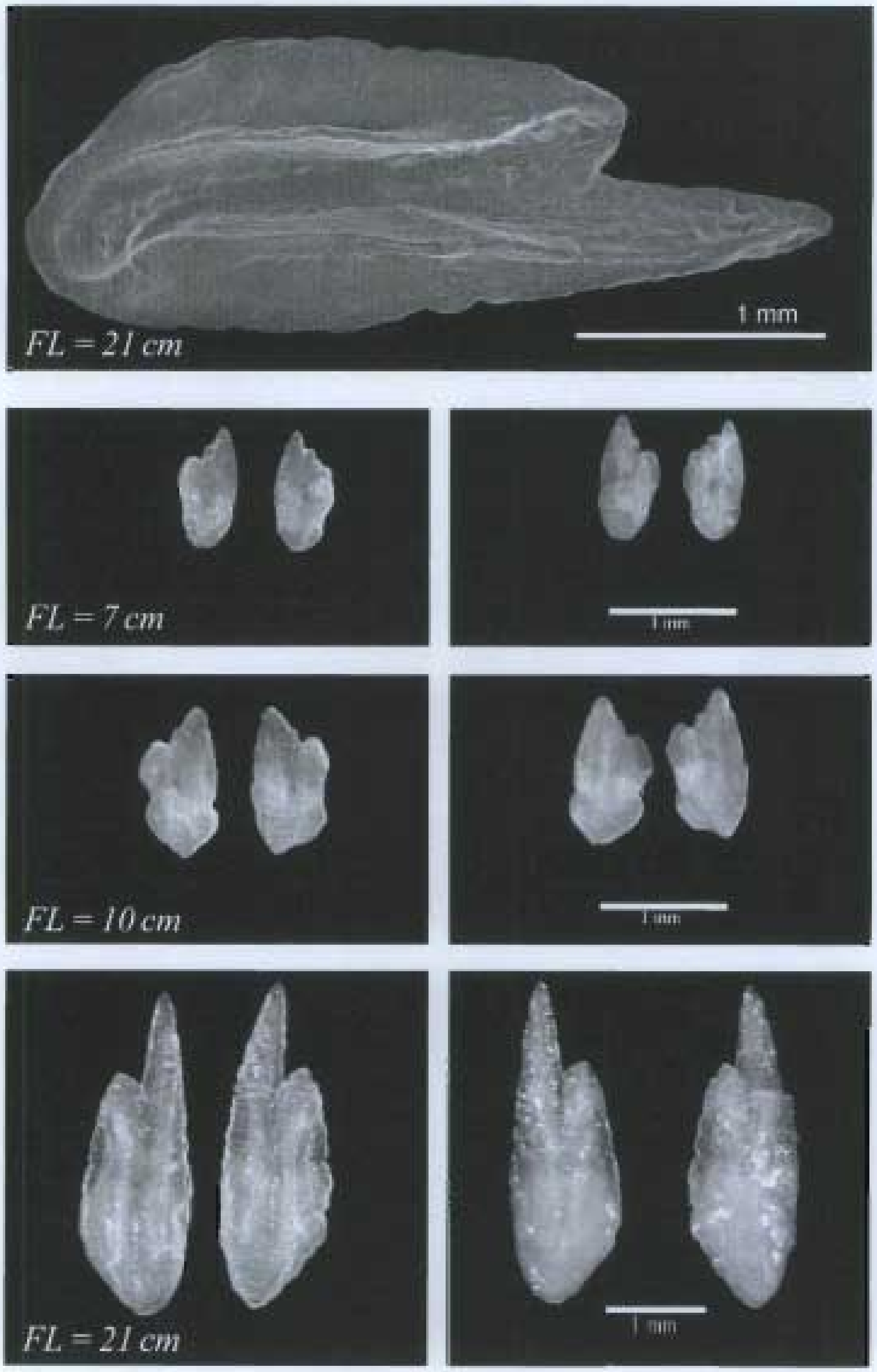
Perciformes

Scombridae: *Scomber japonicus*



Perciformes

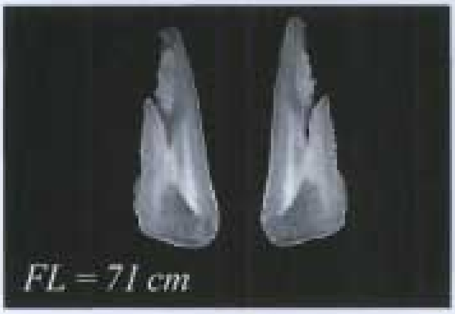
Scombridae: *Scomber scombrus*

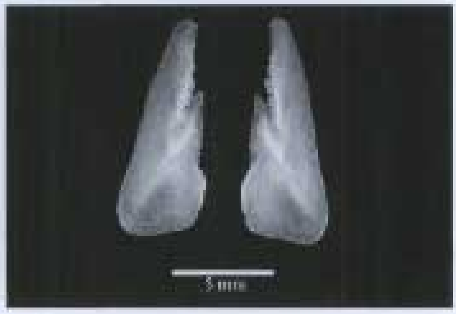


Perciformes

Scombridae: *Scomberomorus brasiliensis*

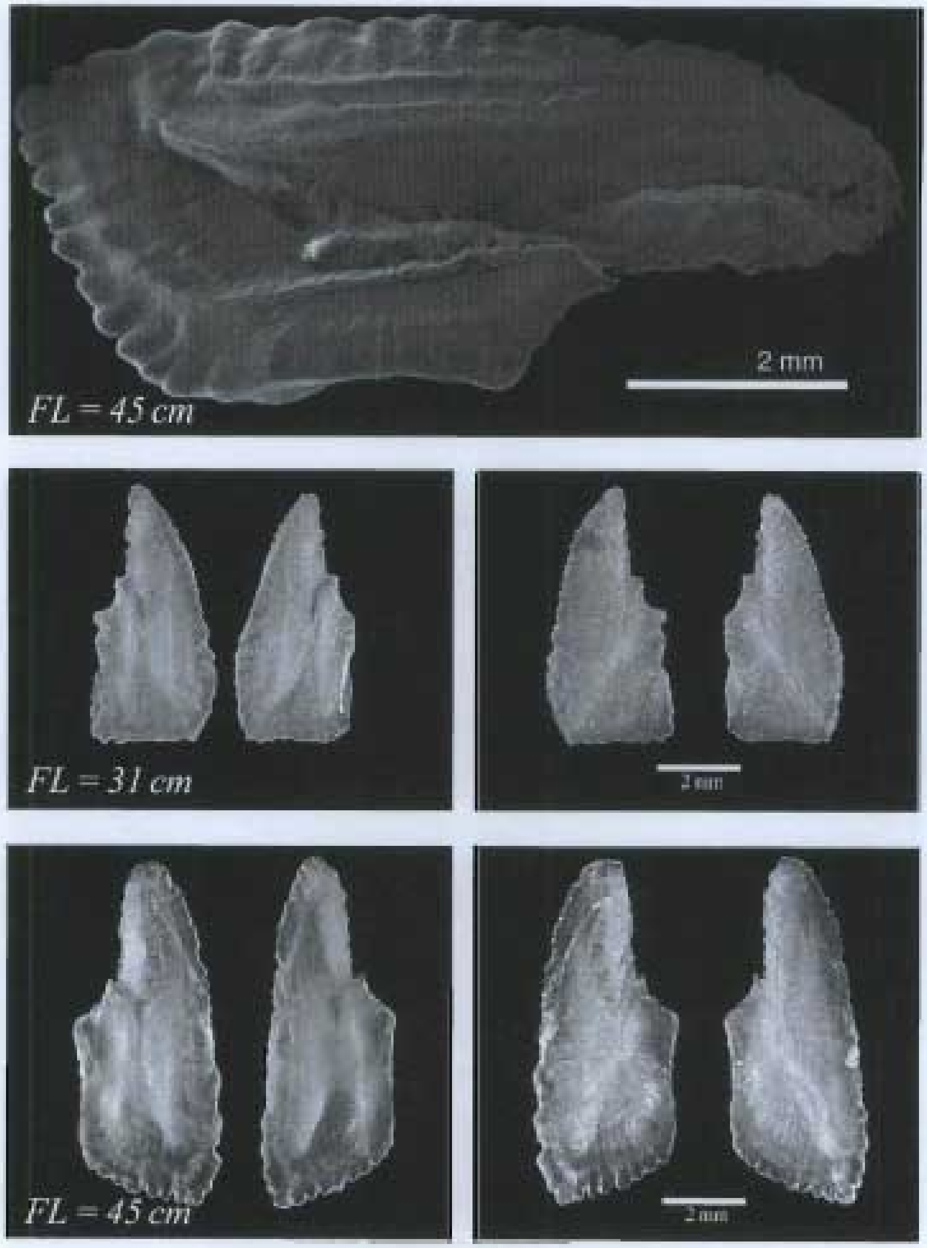
Scombridae: *Scomberomorus cavalla*





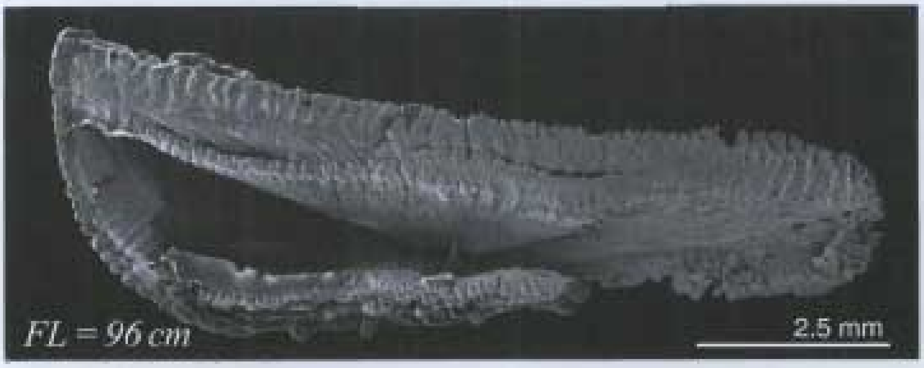
Perciformes

Scombridae: *Scomberomorus maculatus*



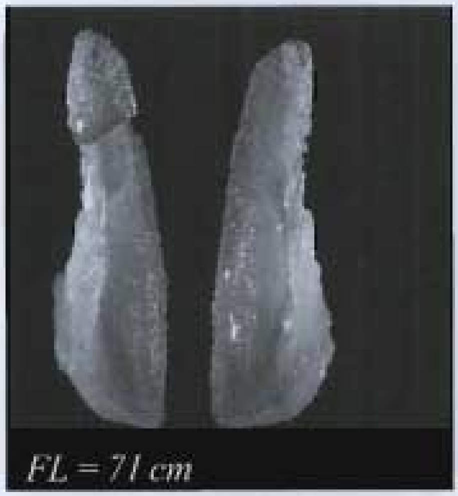
Perciformes

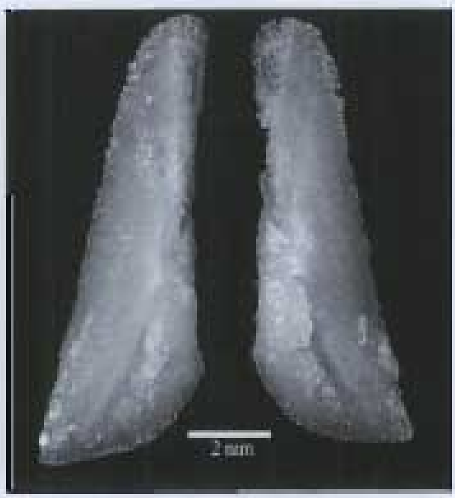
Scombridae: *Thunnus alalunga*



Asteriscii

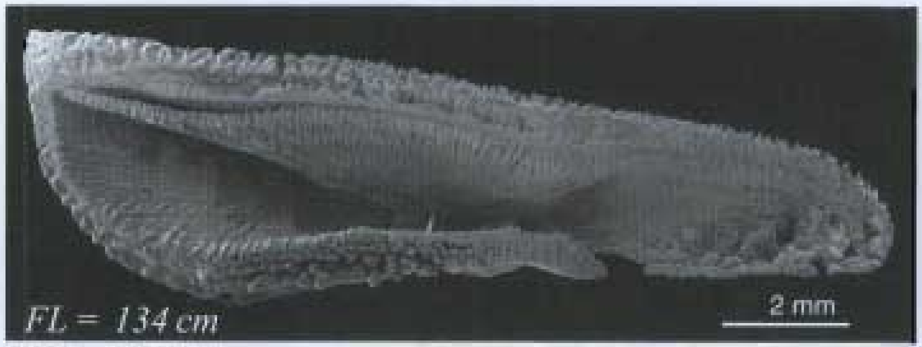
Lapilli





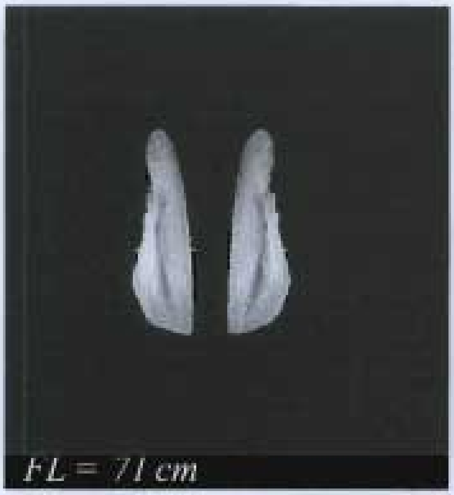
Perciformes

Scombridae: *Thunnus albacares*



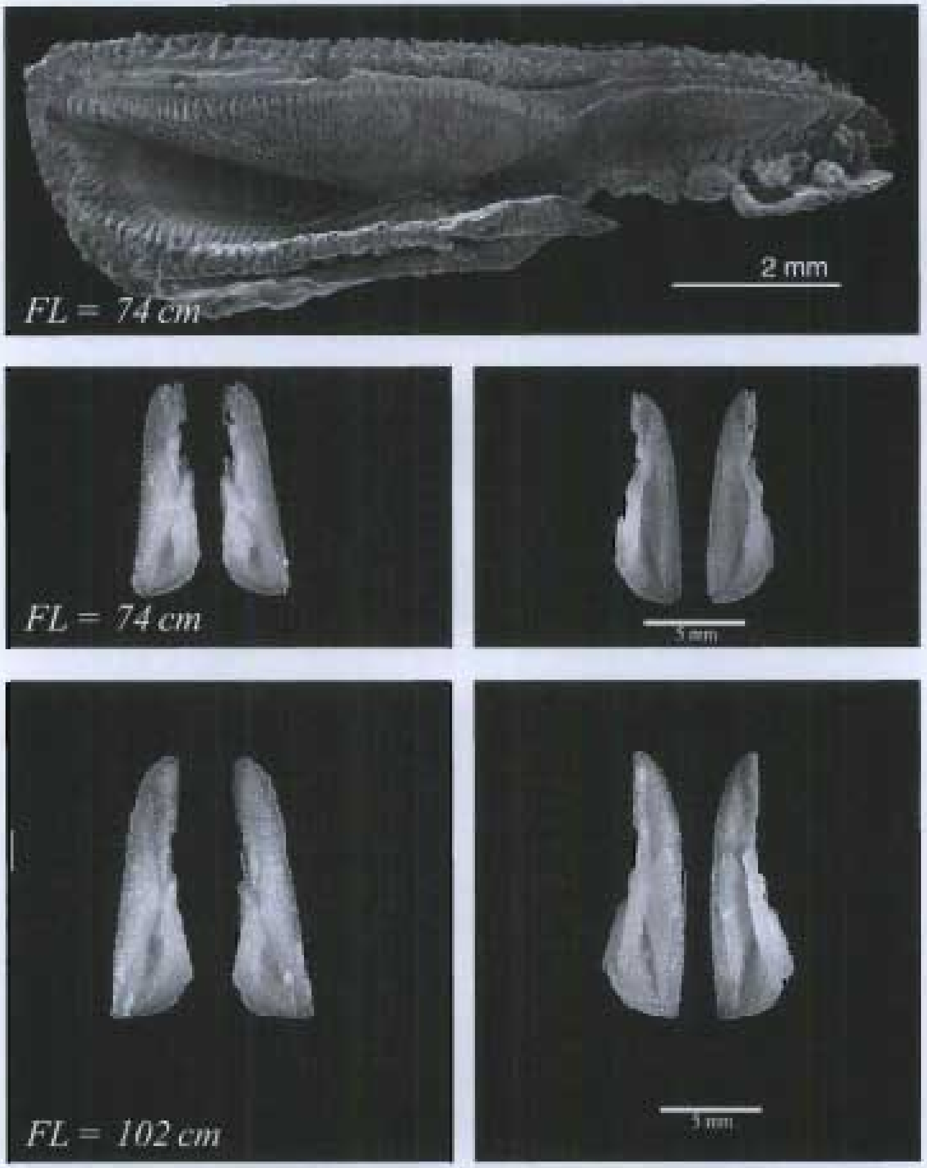
Asteriscii

Lapilli



Perciformes

Scombridae: *Thunnus obesus*

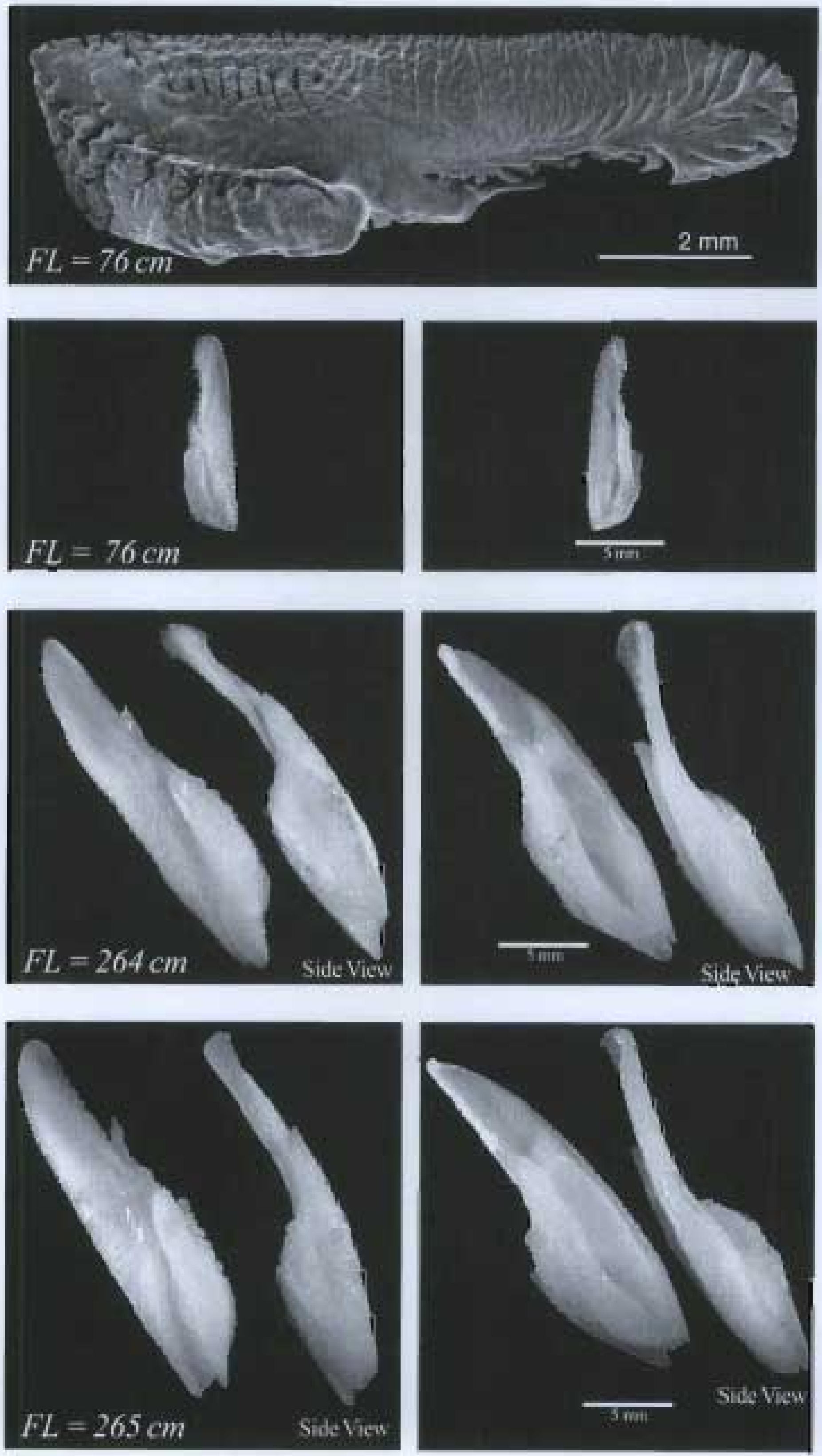


Asteriscii

Lapilli

Perciformes

Scombridae: *Thunnus thynnus*



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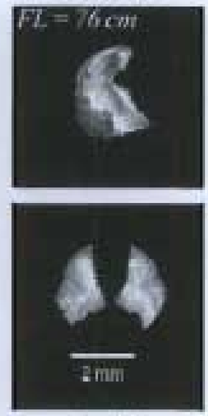
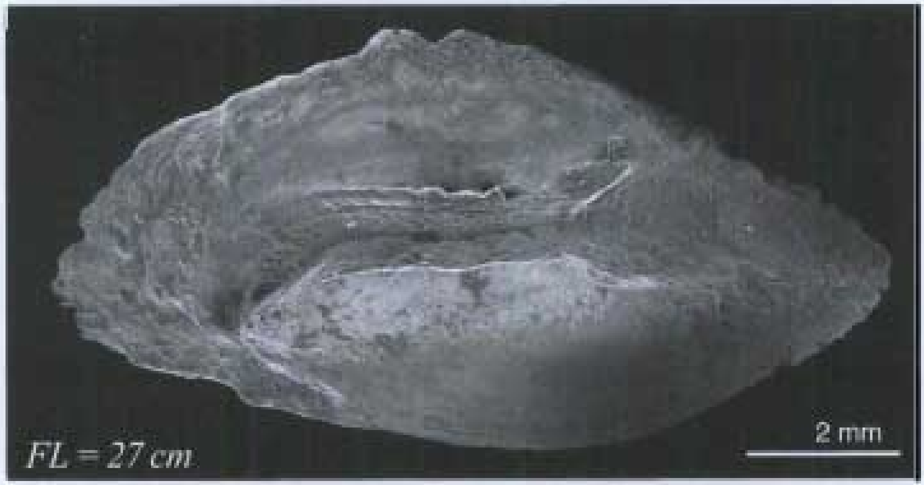


Lapilli

Perciformes

Serranidae: *Centropristis striata*

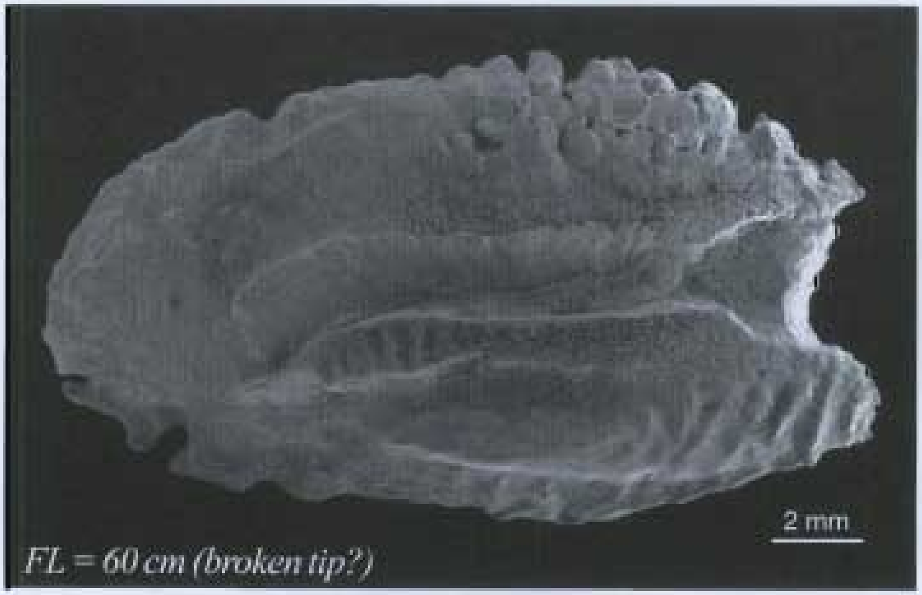


Perciformes

Serranidae: *Epinephelus niveatus*

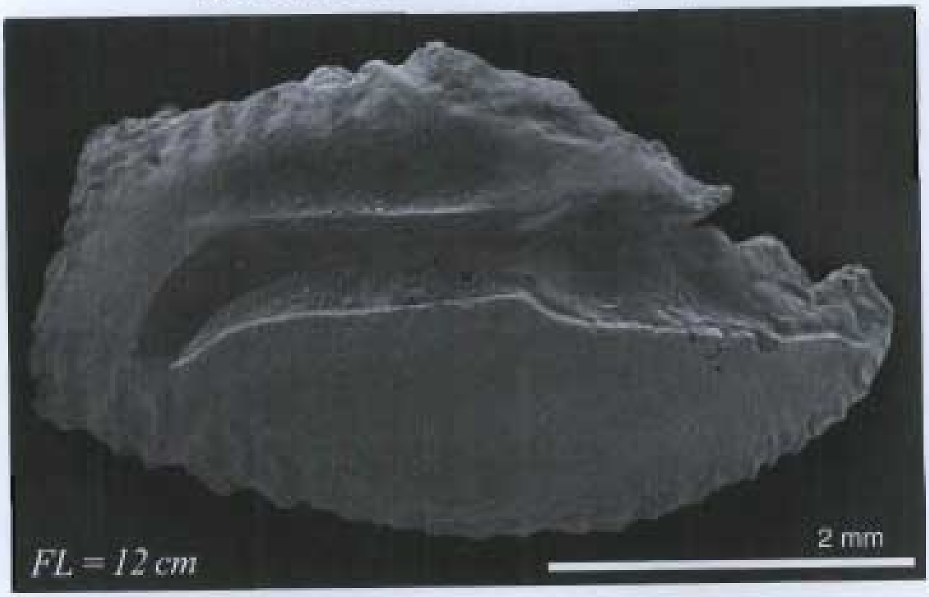
Asteriscii

Lapilli

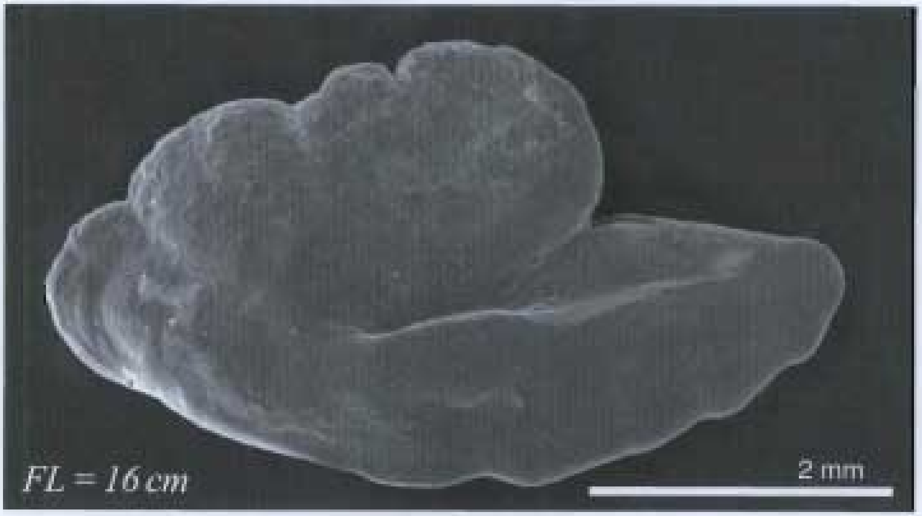


Perciformes

Sparidae: *Stenotomus chrysops*

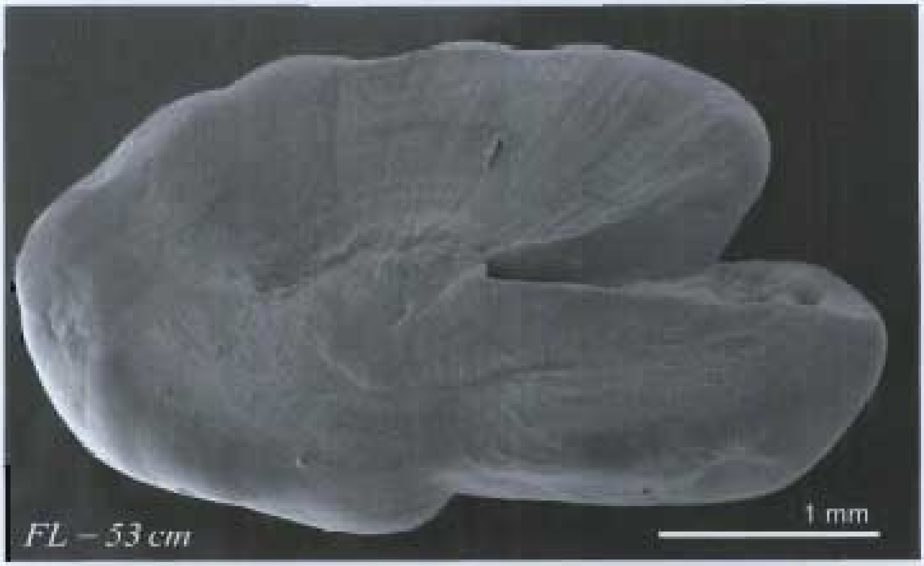


Stichaeidae: *Eumesogrammus praecisus*



Perciformes

Stichaeidae: *Lumpenus lumpretaeformis*



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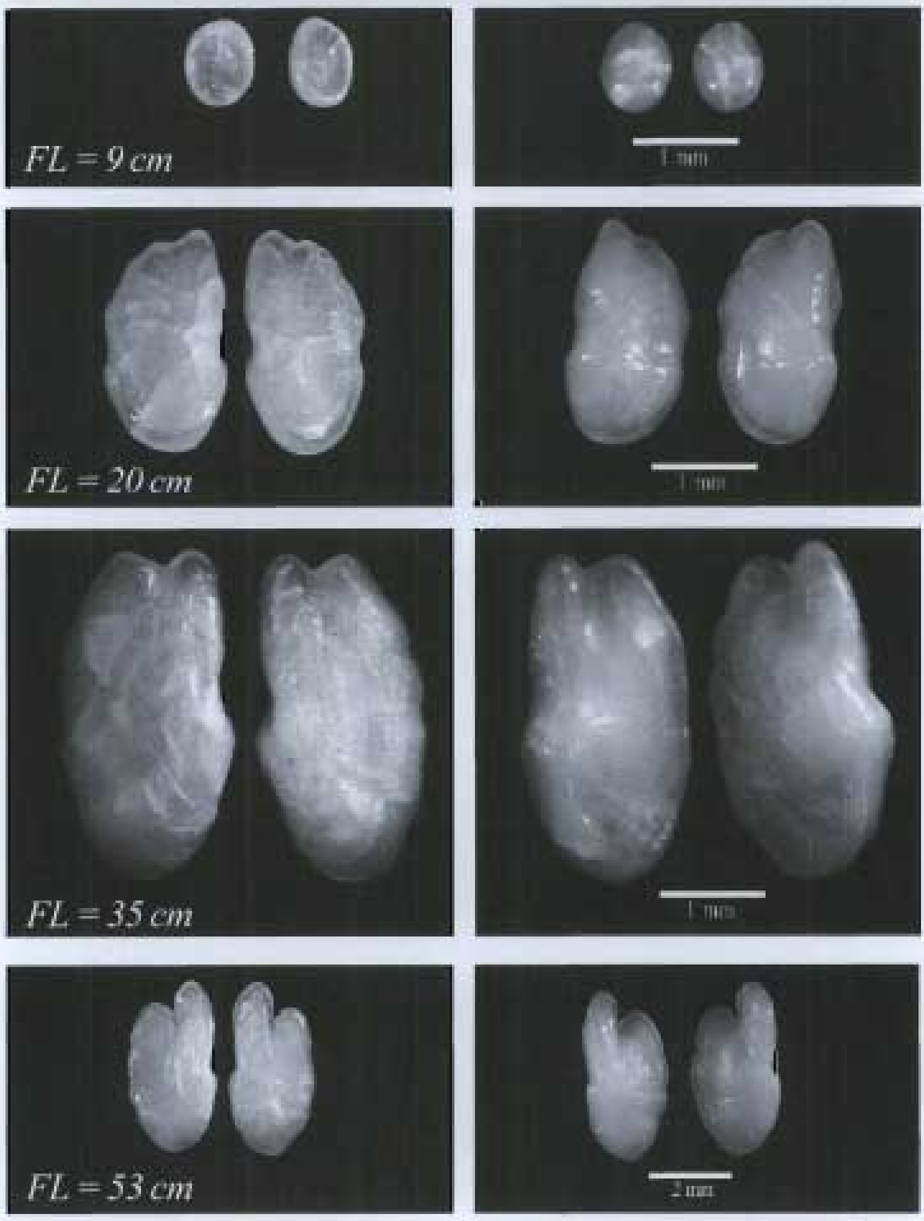
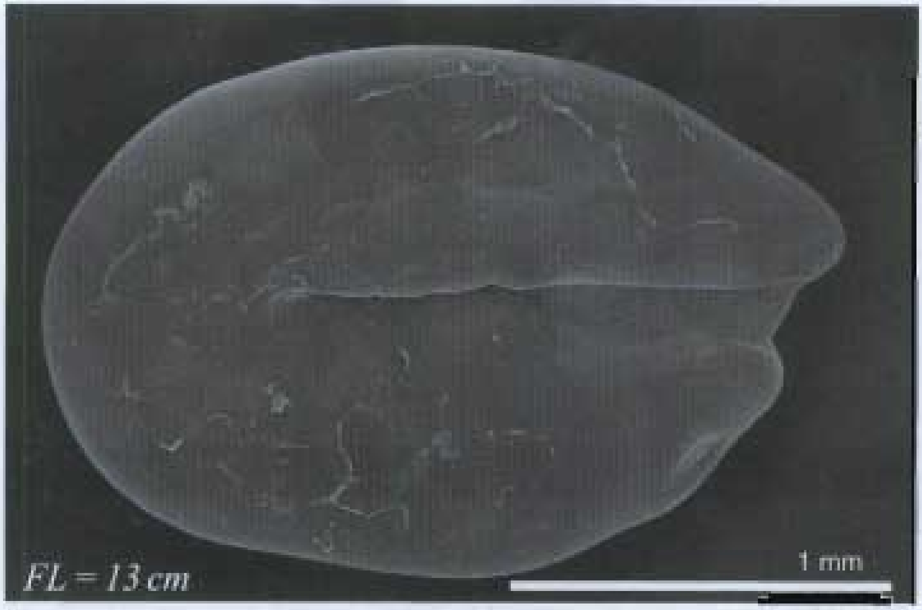
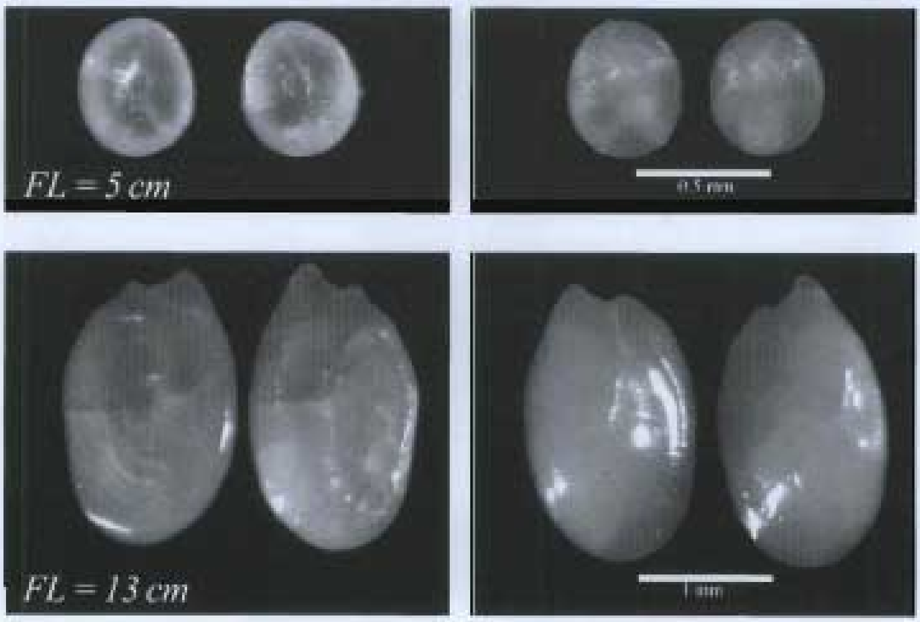
Lapilli



Perciformes

Stichaeidae: *Lumpenus maculatus*

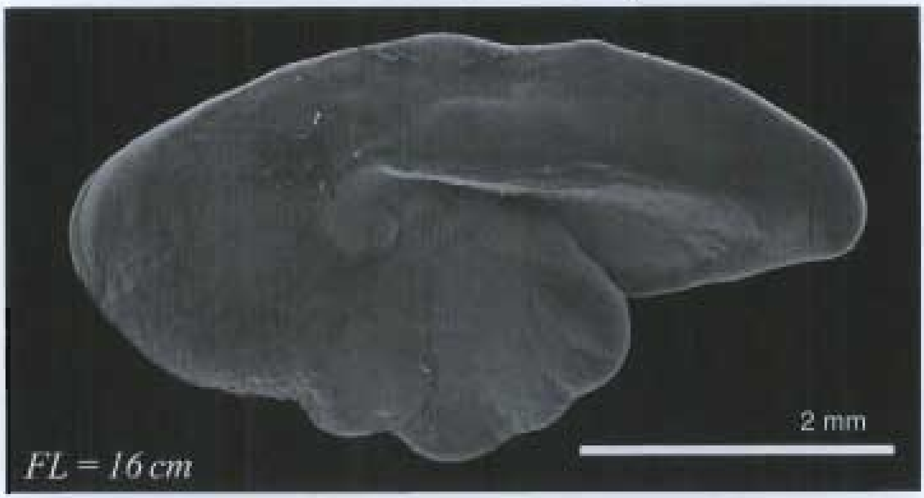




Stichaeidae: *Stichaeus punctatus*

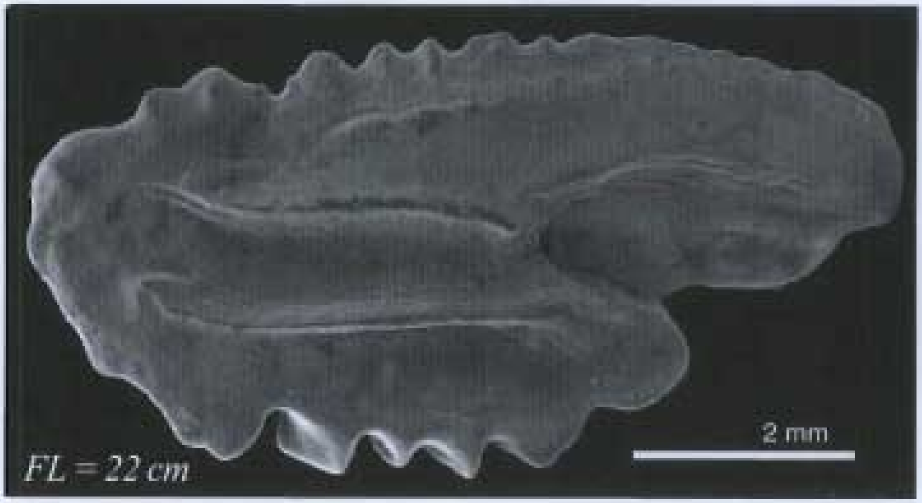
Perciformes

Stichaeidae: *Ulvaria subbifurcata*

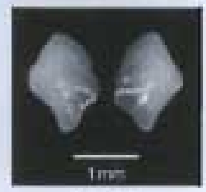


Perciformes

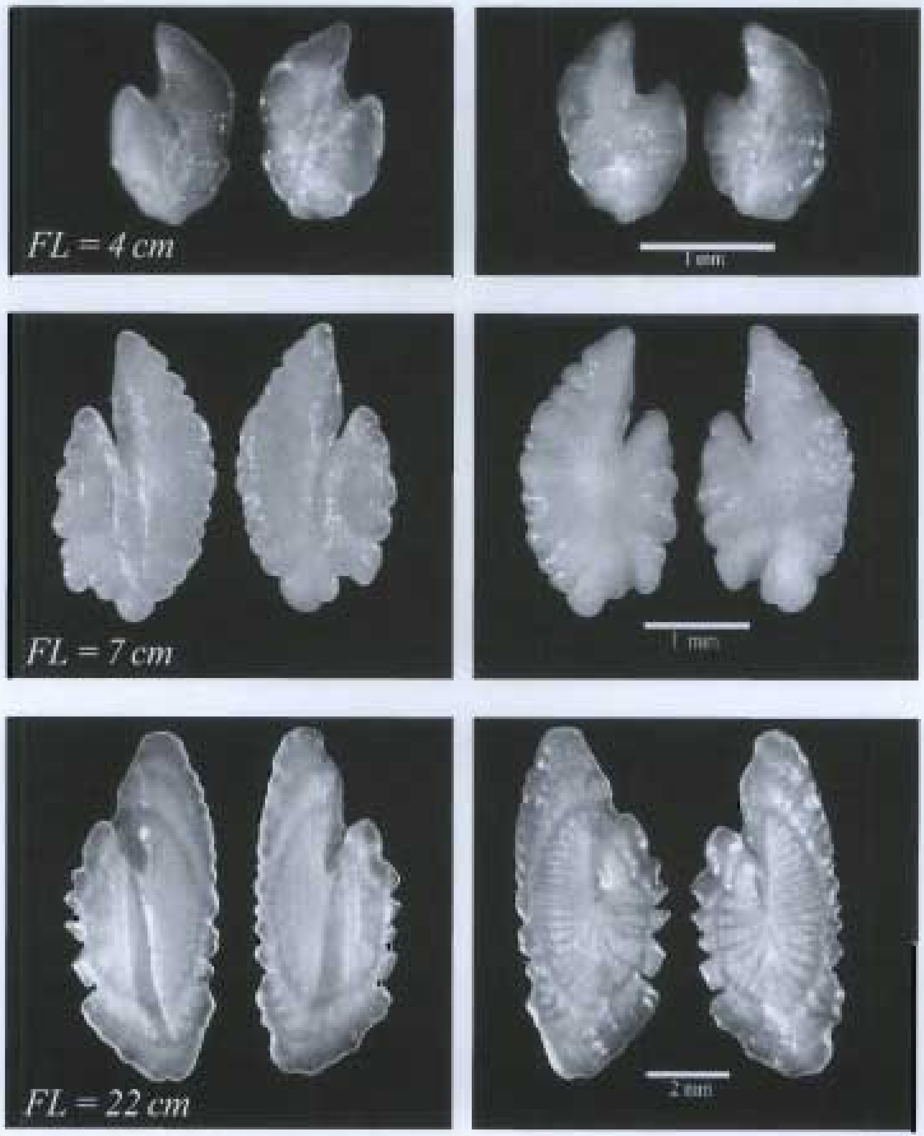
Stromateidae: *Peprilus tricanthus*



Asteriscii

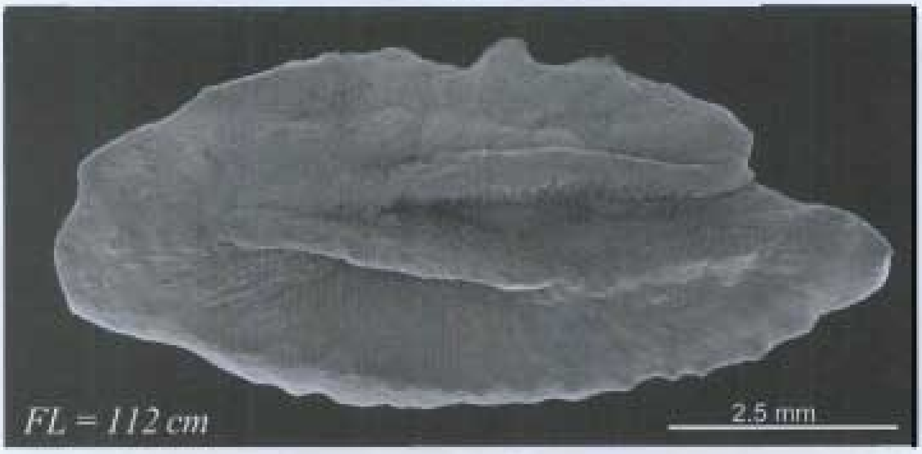


Lapilli



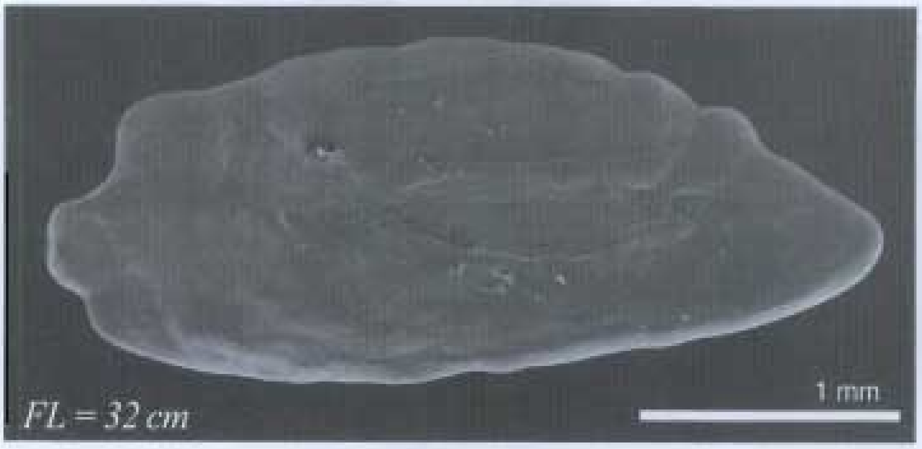
Perciformes

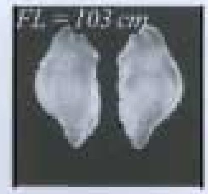
Trichiuridae: *Aphanopus carbo*



Asteriscii
& Lapilli

Trichiuridae: *Benthodesmus elongatus*

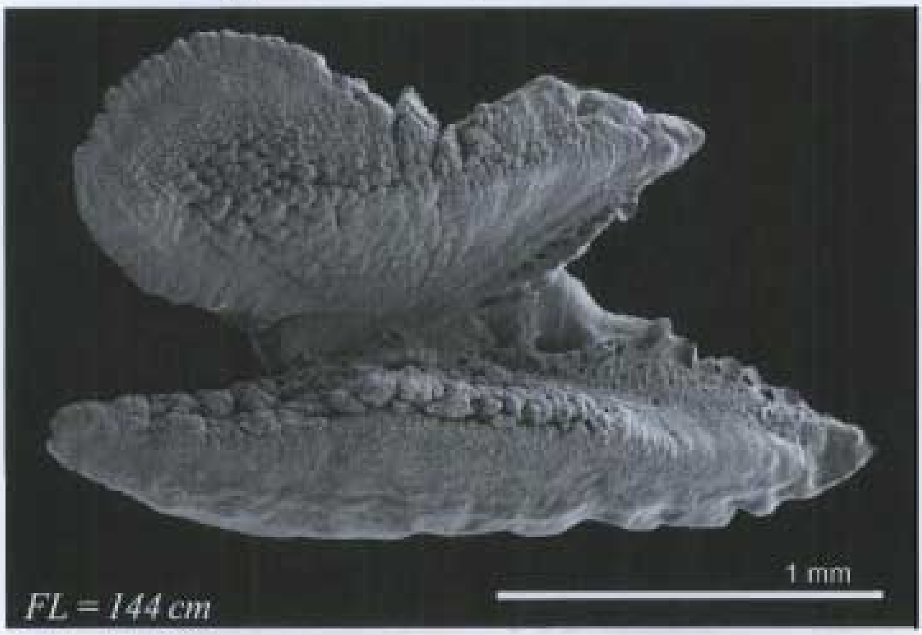




Asteriscii
& Lapilli

Perciformes

Xiphiidae: *Tetrapturus albidus*



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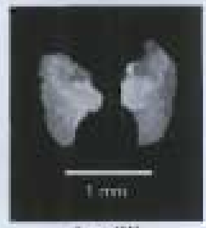
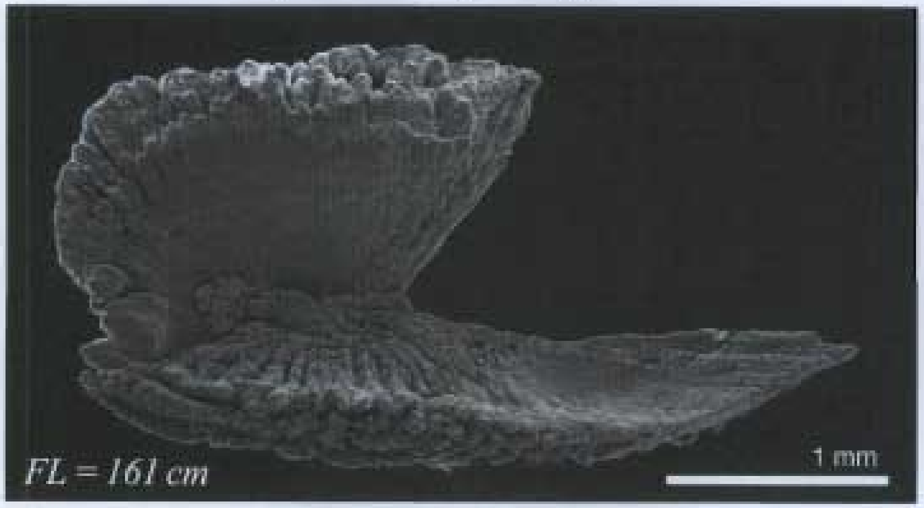


Lapilli

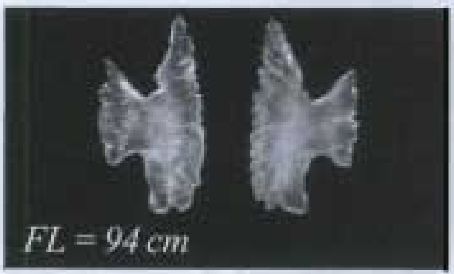
Perciformes

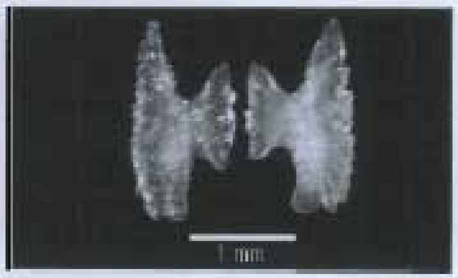
Xiphiidae: *Xiphias gladius*

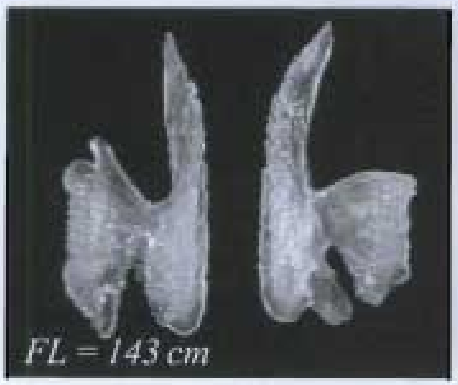


Asteriscii

Lapilli

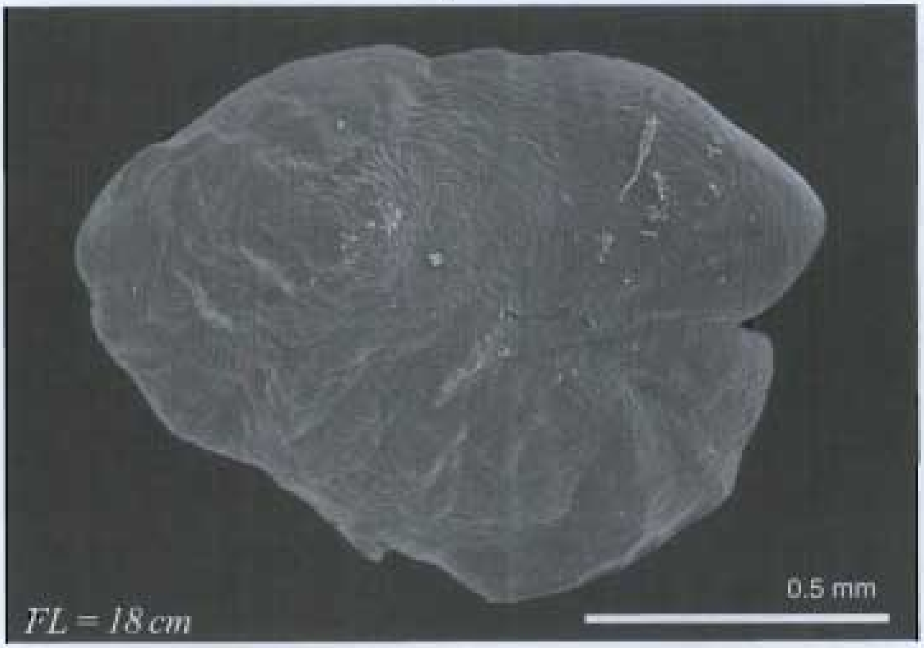


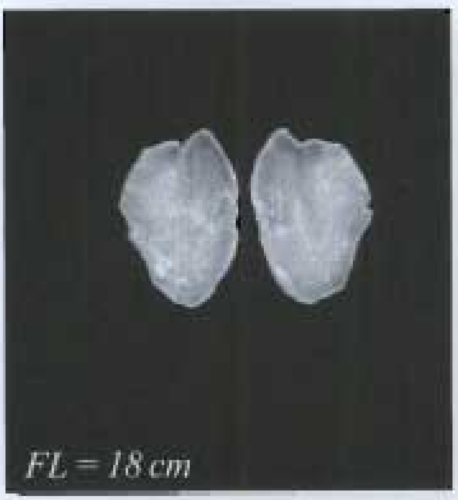


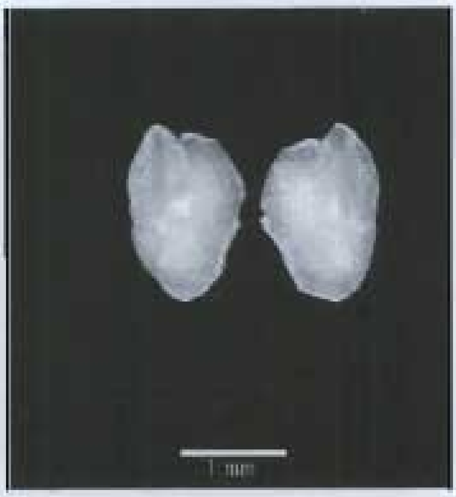


Perciformes

Zoarcidae: *Gymnelus viridis*

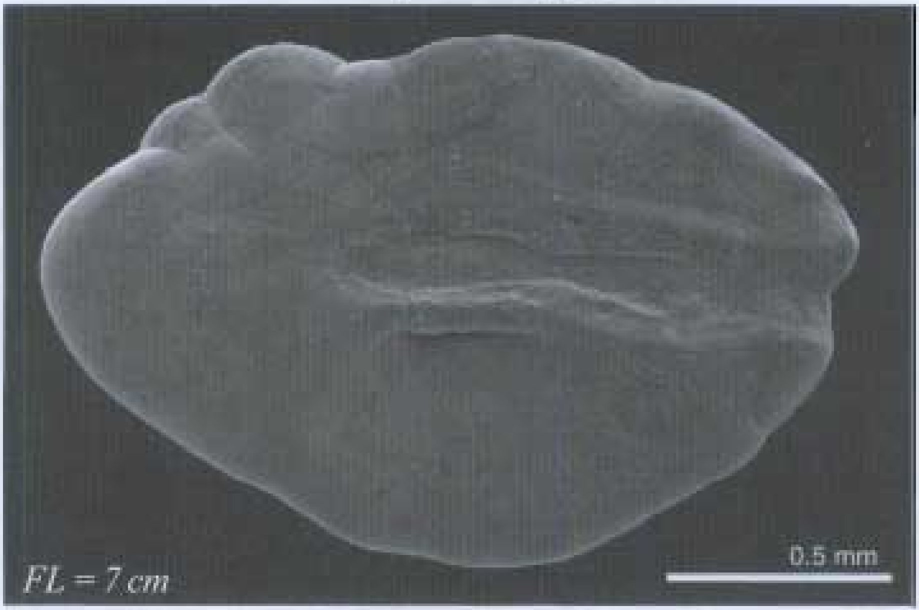






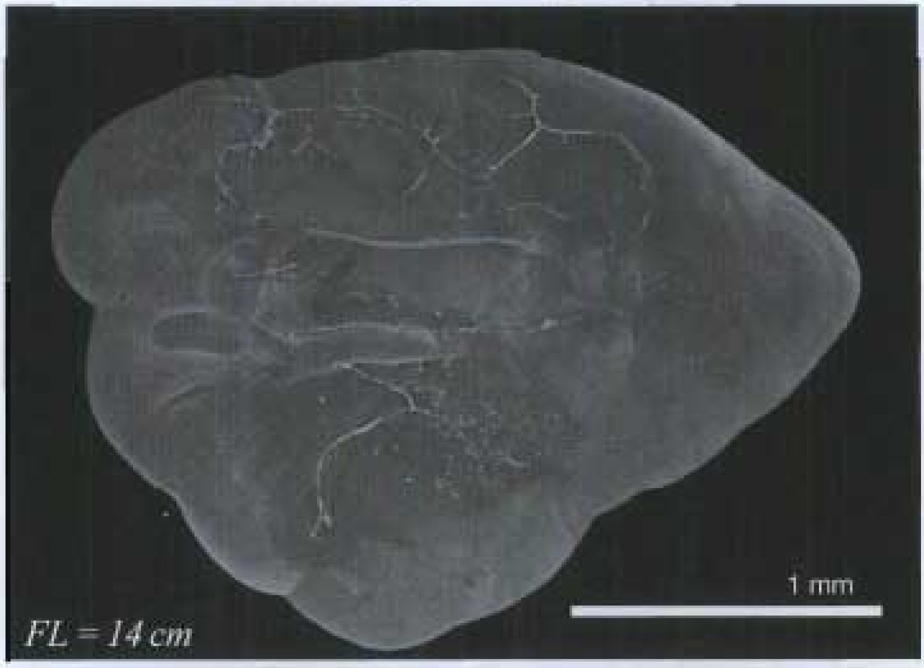
Perciformes

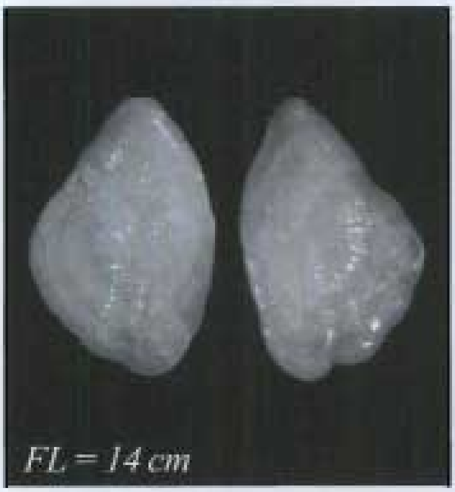
Zoarcidae: *Lycenchelys paxillus*

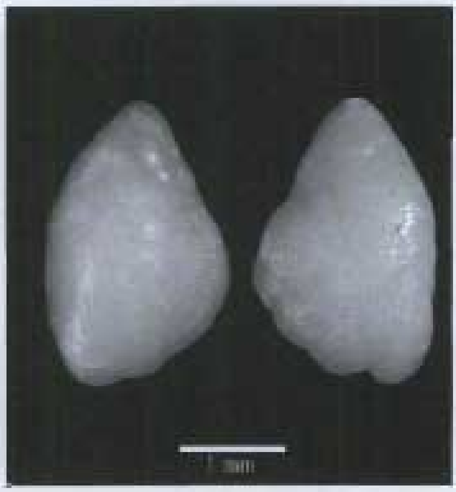


Perciformes

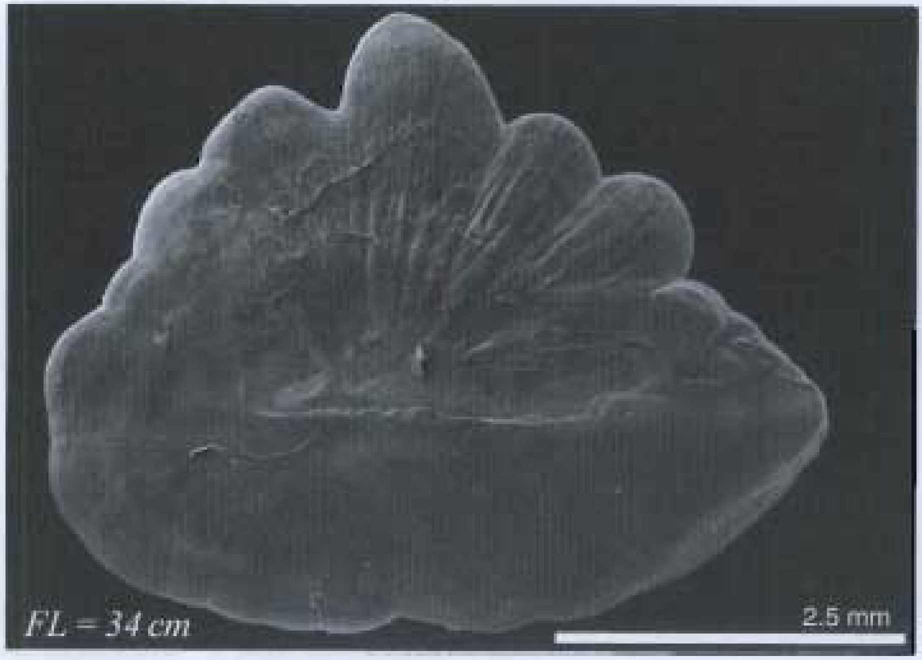
Zoarcidae: *Lycenchelys verrilli*



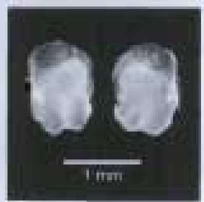




Zoarcidae: *Lycodes esmarki*



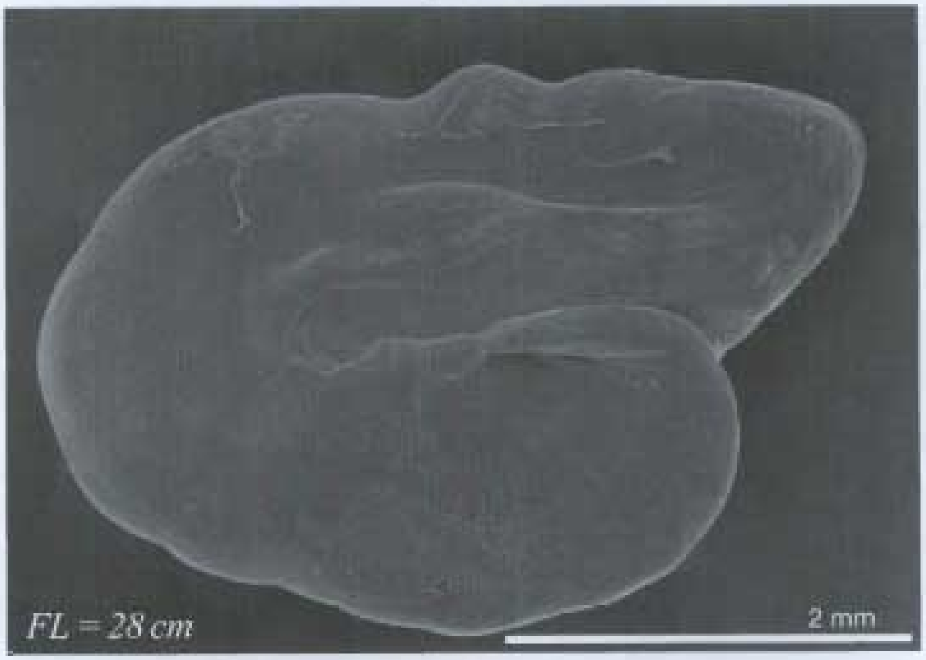
Asteriscii

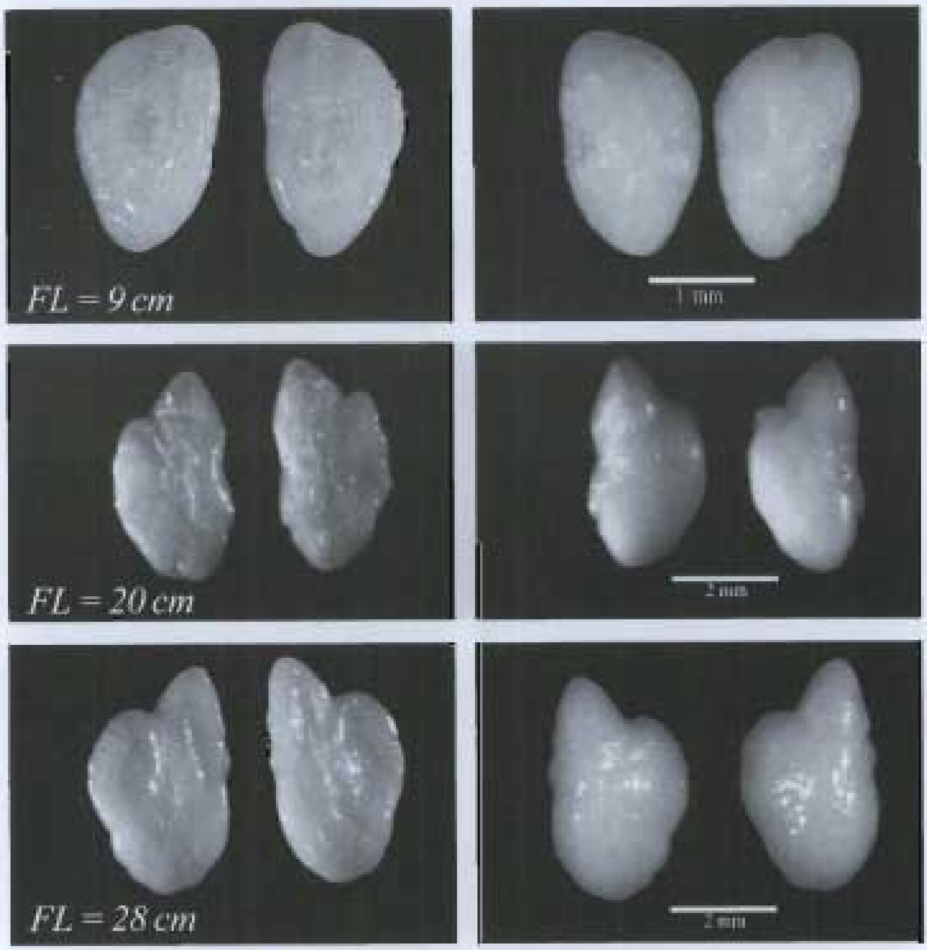


Lapilli

Perciformes

Zoarcidae: *Lycodes lavalaei*





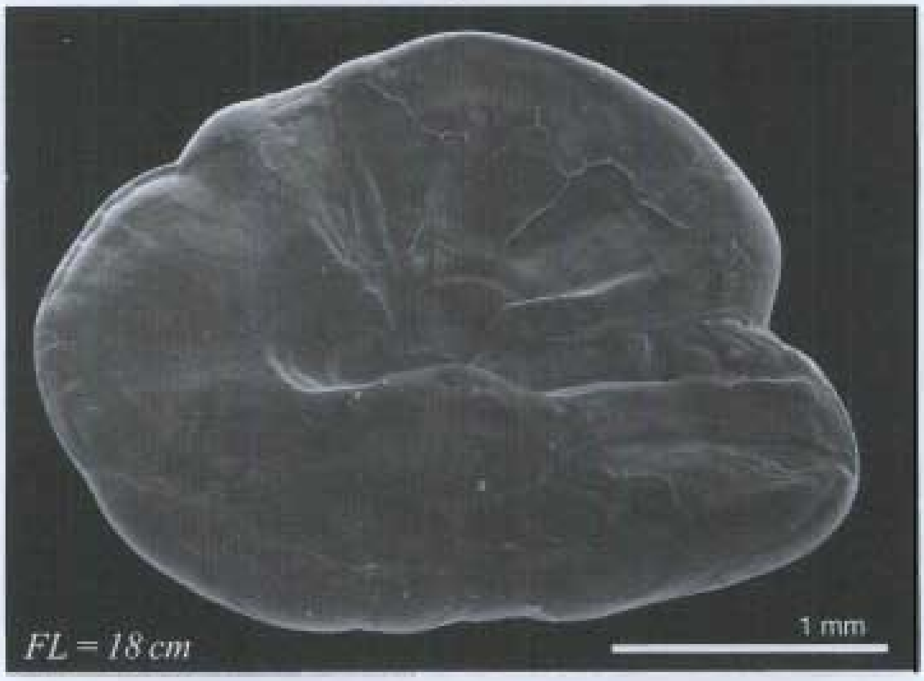
Perciformes

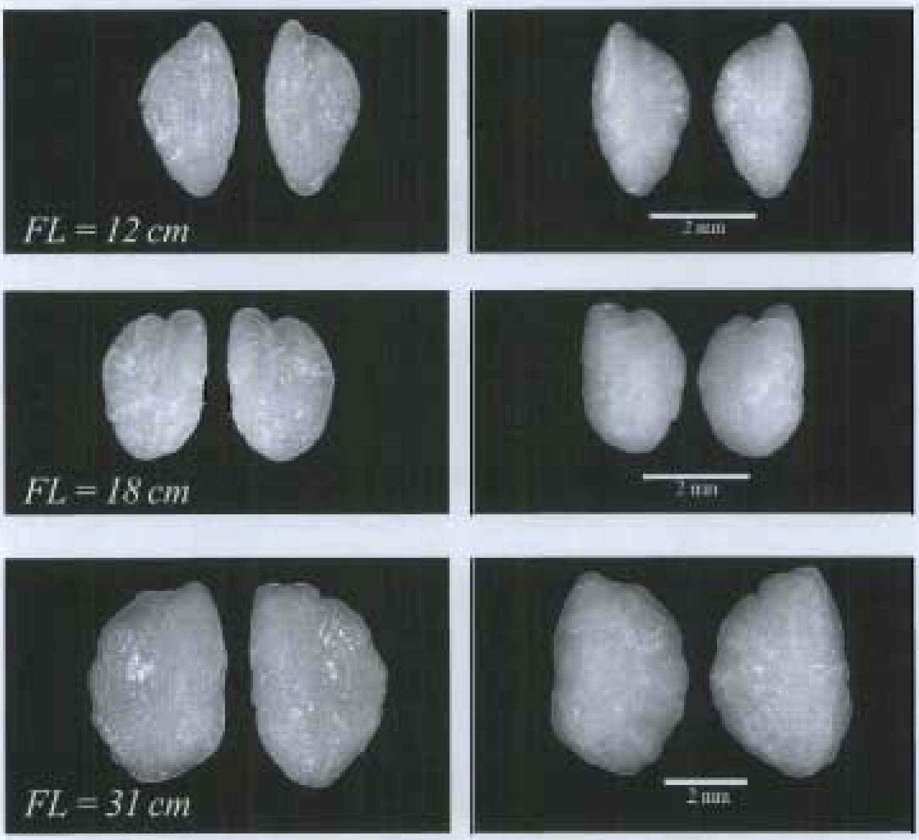
Zoarcidae: *Lycodes pallidus*

Zoarcidae: *Lycodes reticulatus*

Perciformes

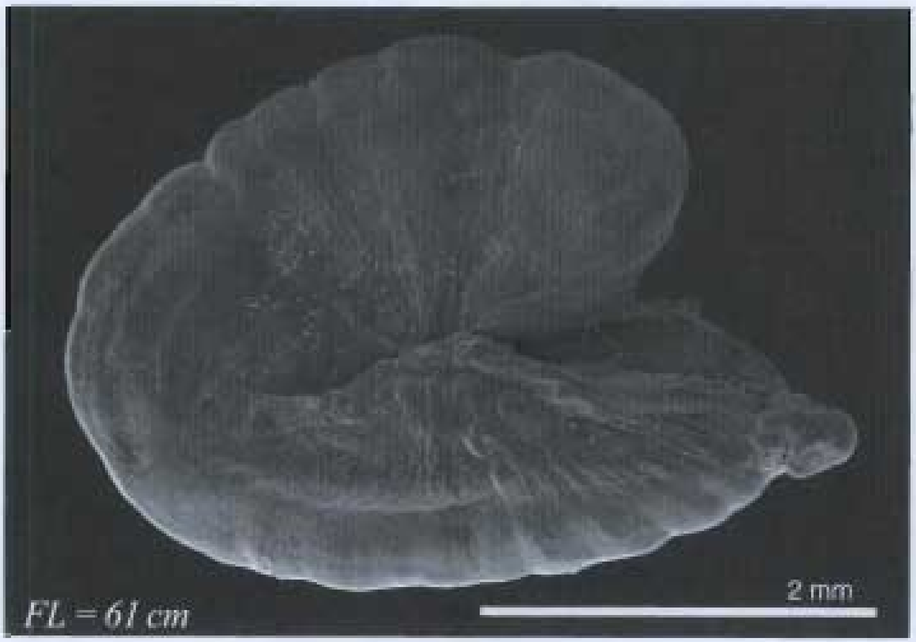
Zoarcidae: *Lycodes vahlii*

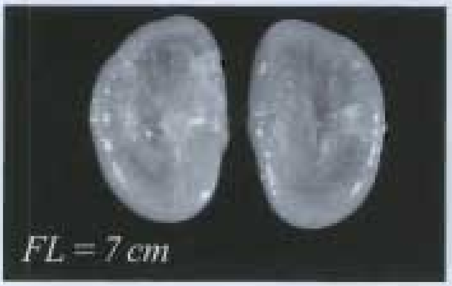




Perciformes

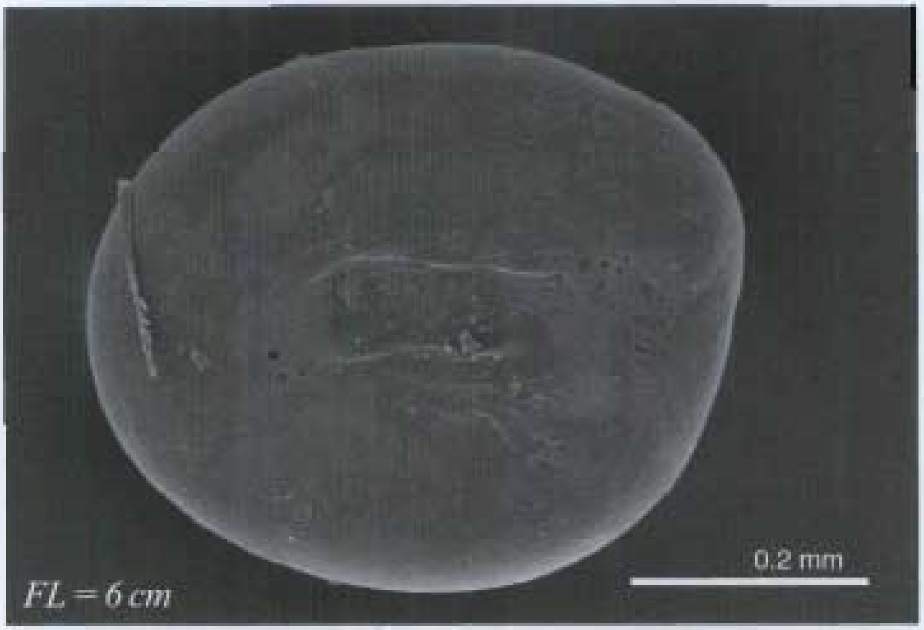
Zoarcidae: *Macrozoarces americanus*



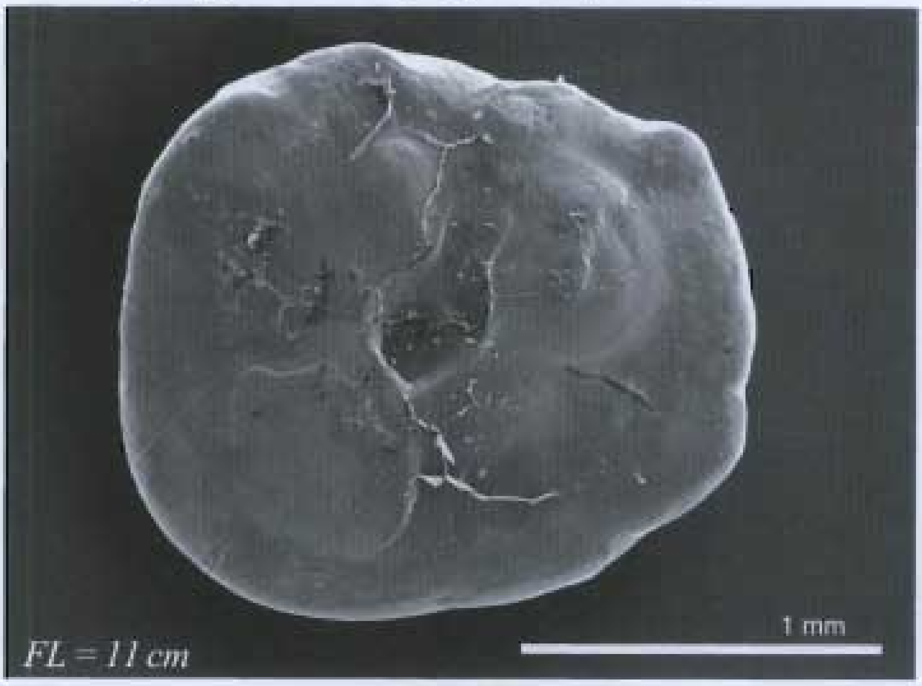


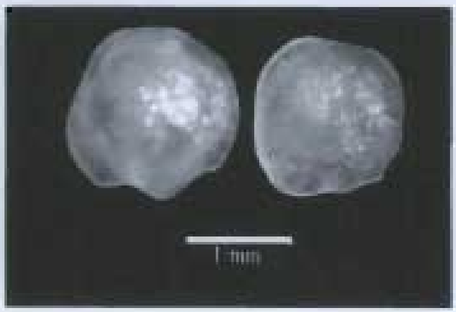
Perciformes

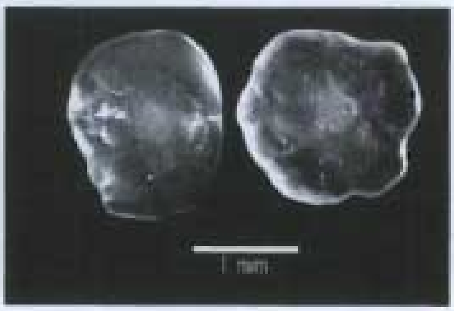
Zoarcidae: *Melanostigma atlanticum*



Cynoglossidae: *Symphurus pterospilotus*

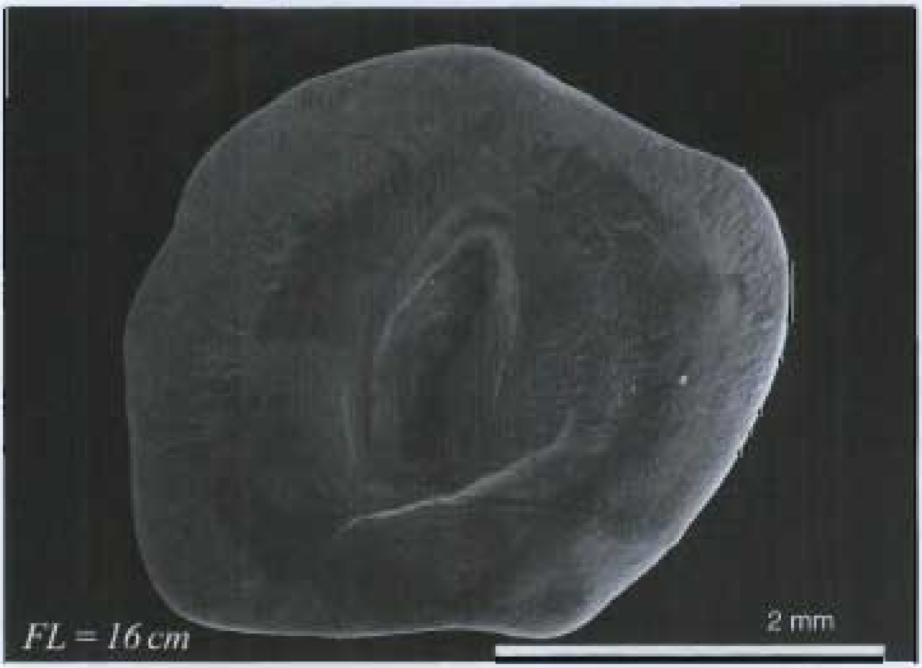






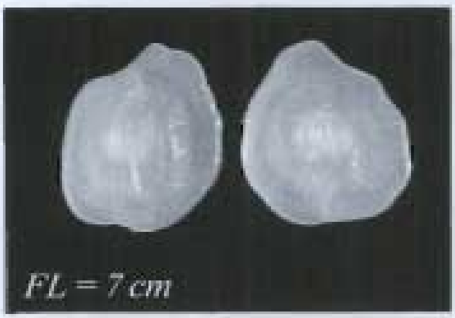
Pleuronectiformes

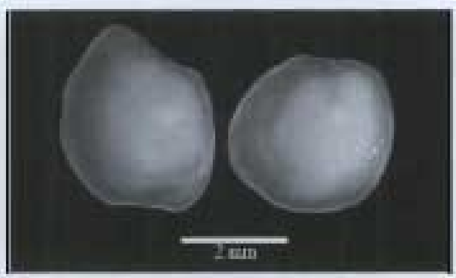
Paralichthyidae: *Citharichthys arctifrons*



Asteriscii

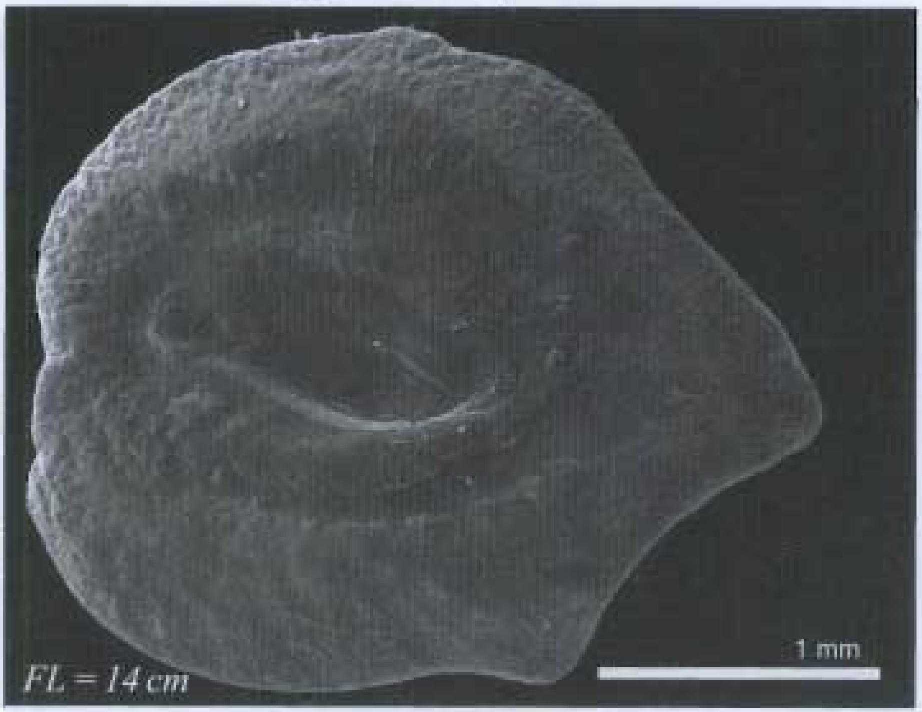
Lapilli

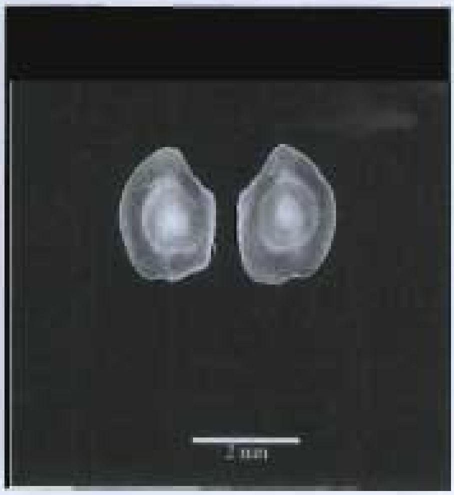


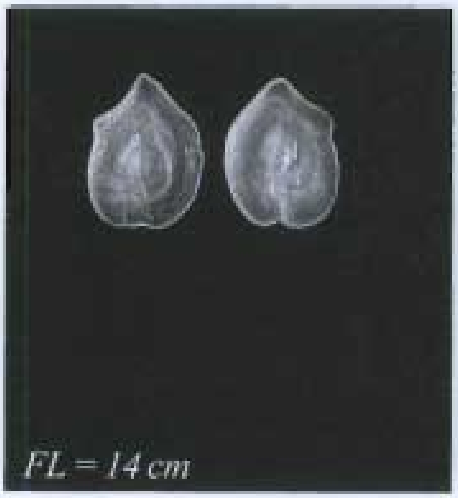


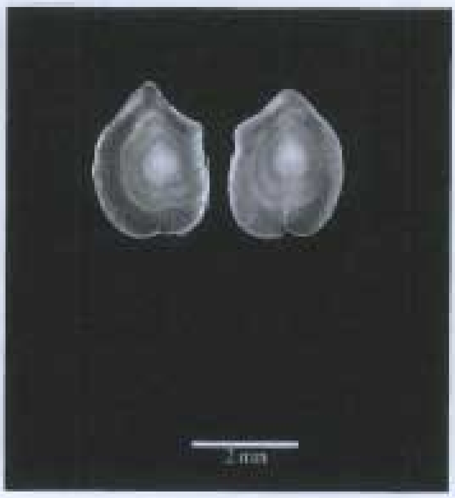
Pleuronectiformes

Paralichthyidae: *Etropus microstomus*



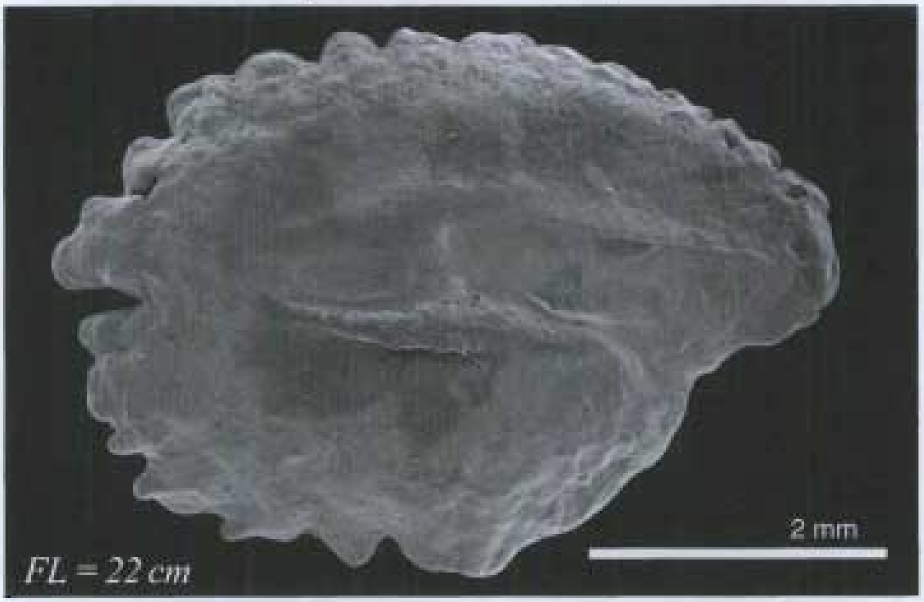






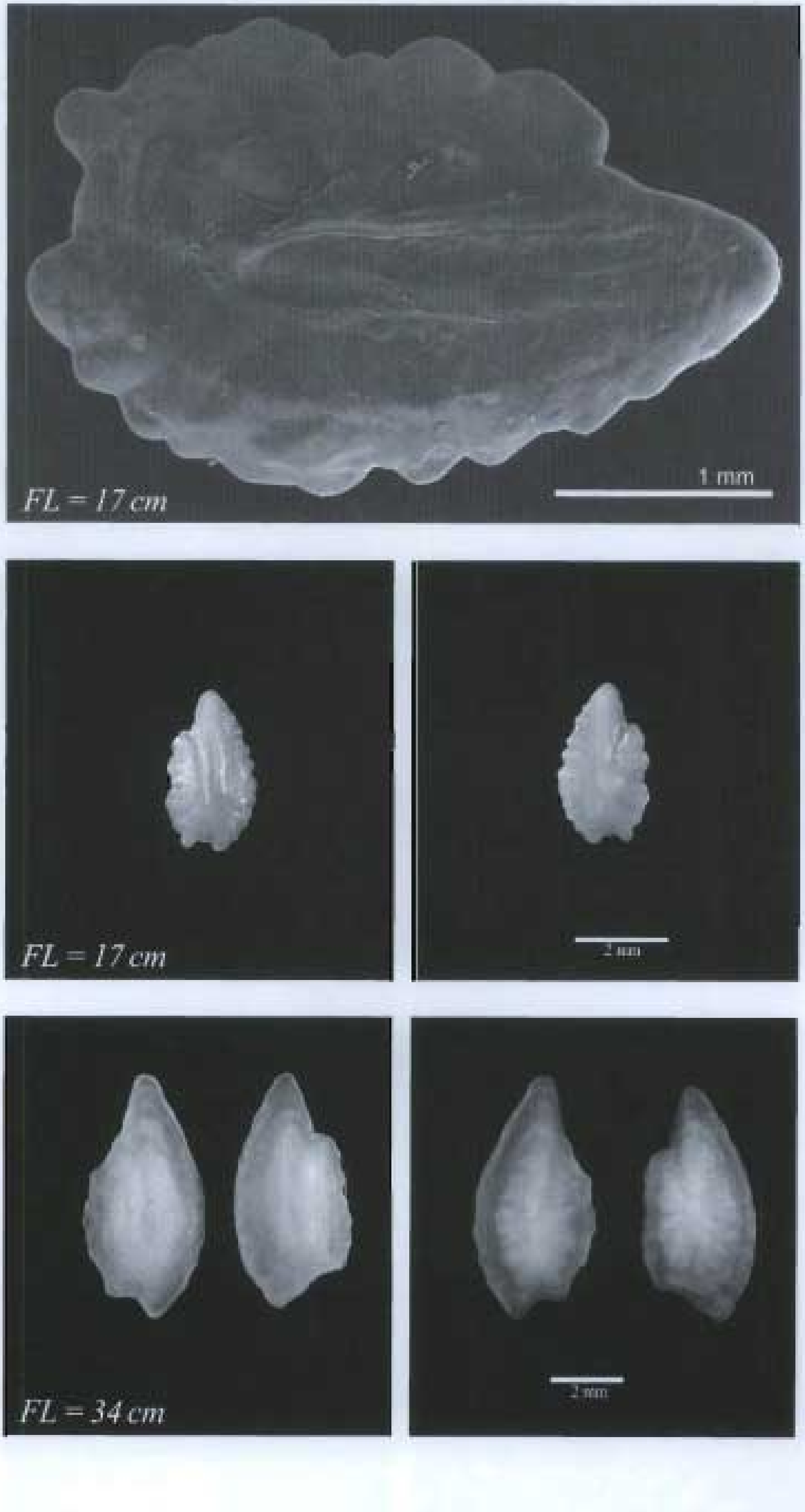
Pleuronectiformes

Paralichthyidae: *Paralichthys dentatus*



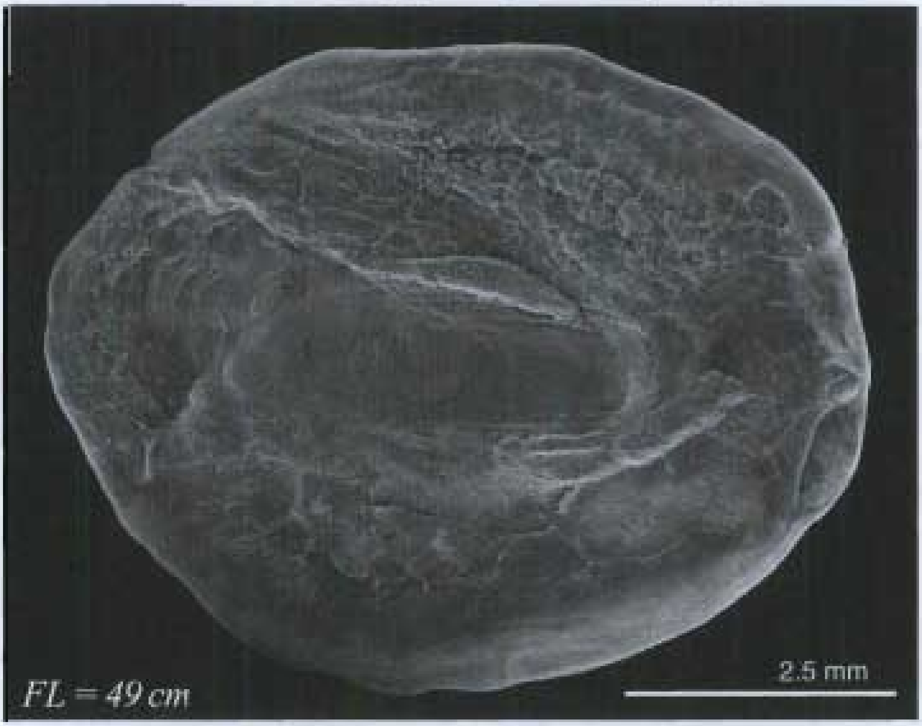
Pleuronectiformes

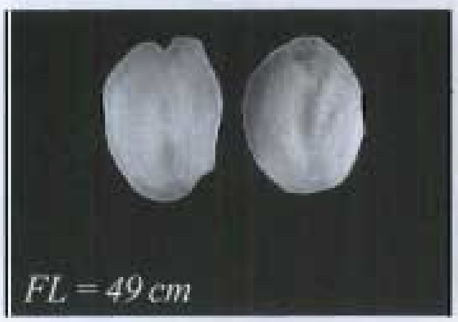
Paralichthyidae: *Paralichthys oblongus*



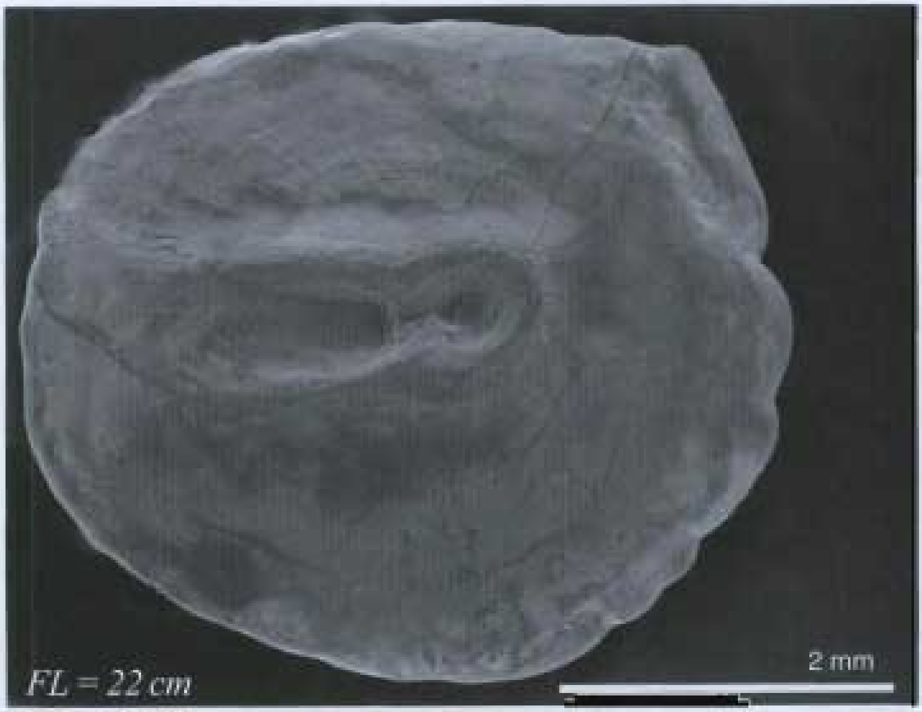
Pleuronectiformes

Pleuronectidae: *Glyptocephalus cynoglossus*



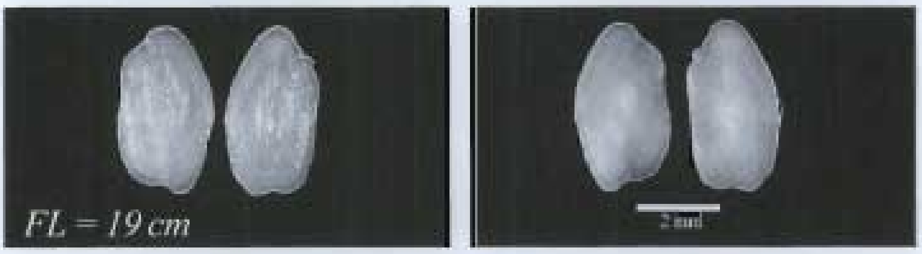


Pleuronectidae: *Hippoglossoides platessoides*

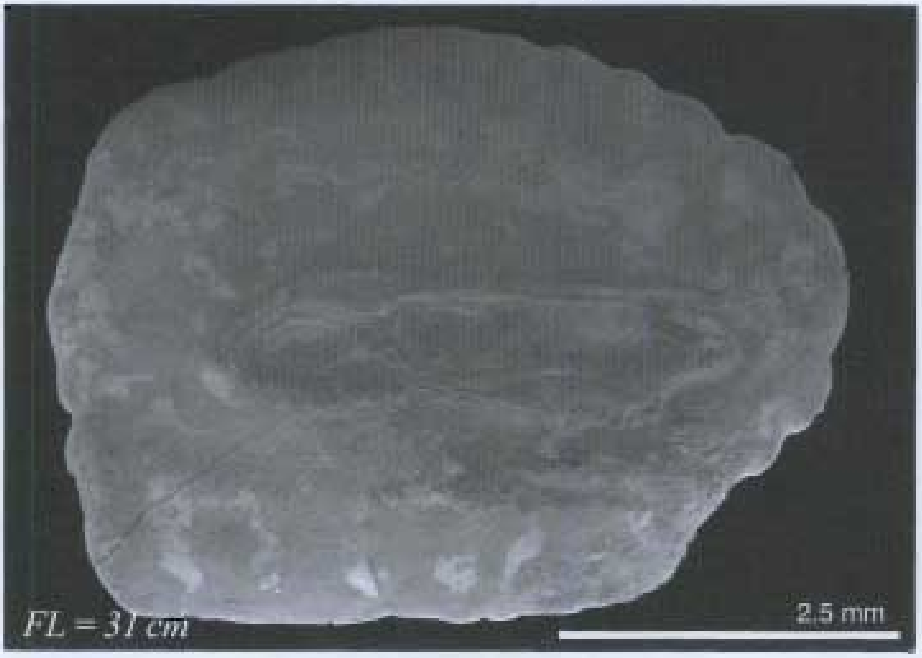


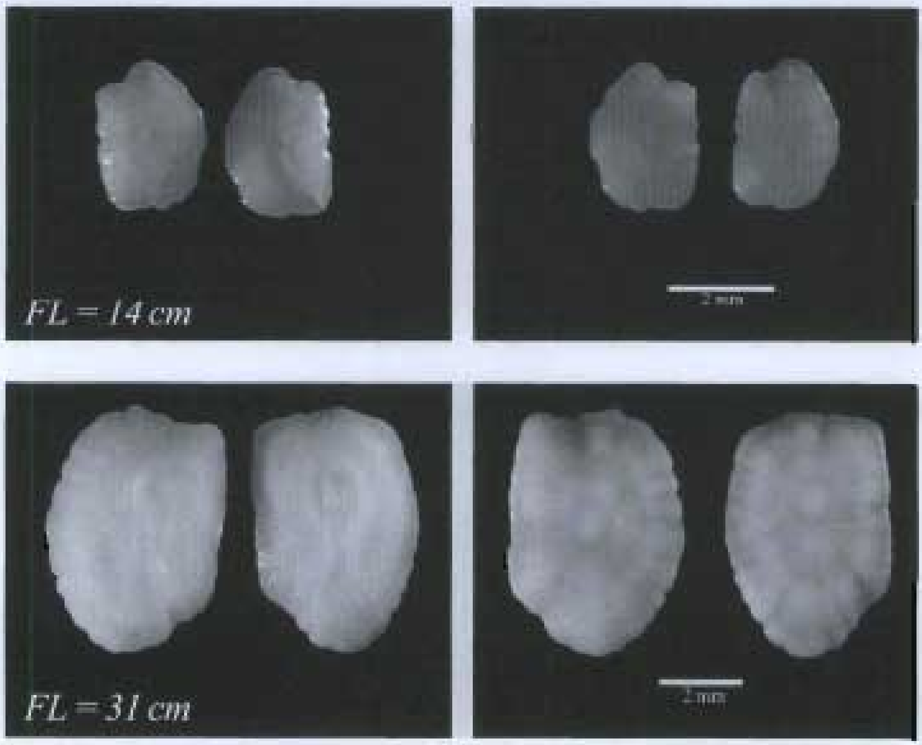
Pleuronectiformes

Pleuronectidae: *Hippoglossus hippoglossus*



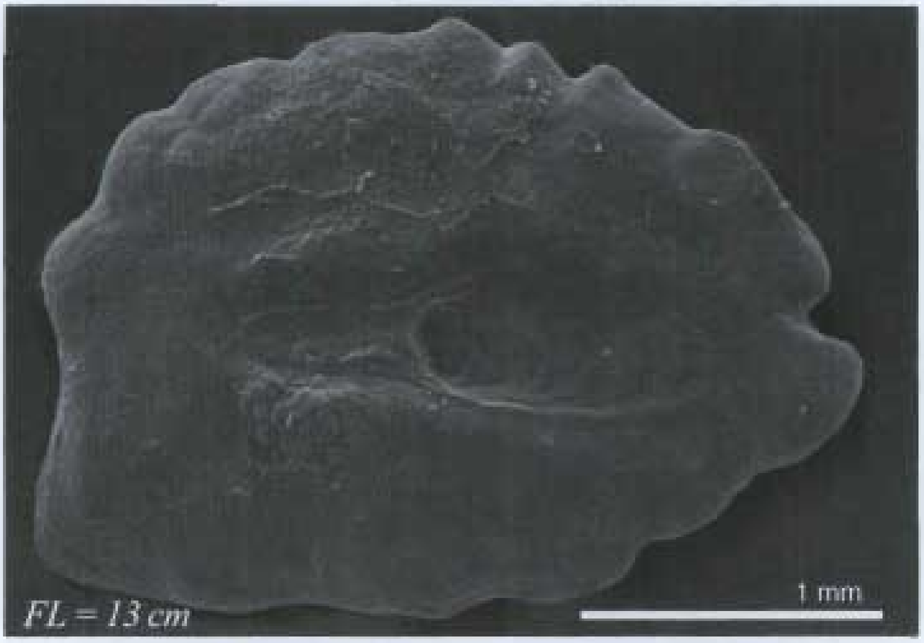
Pleuronectidae: *Limanda ferruginea*





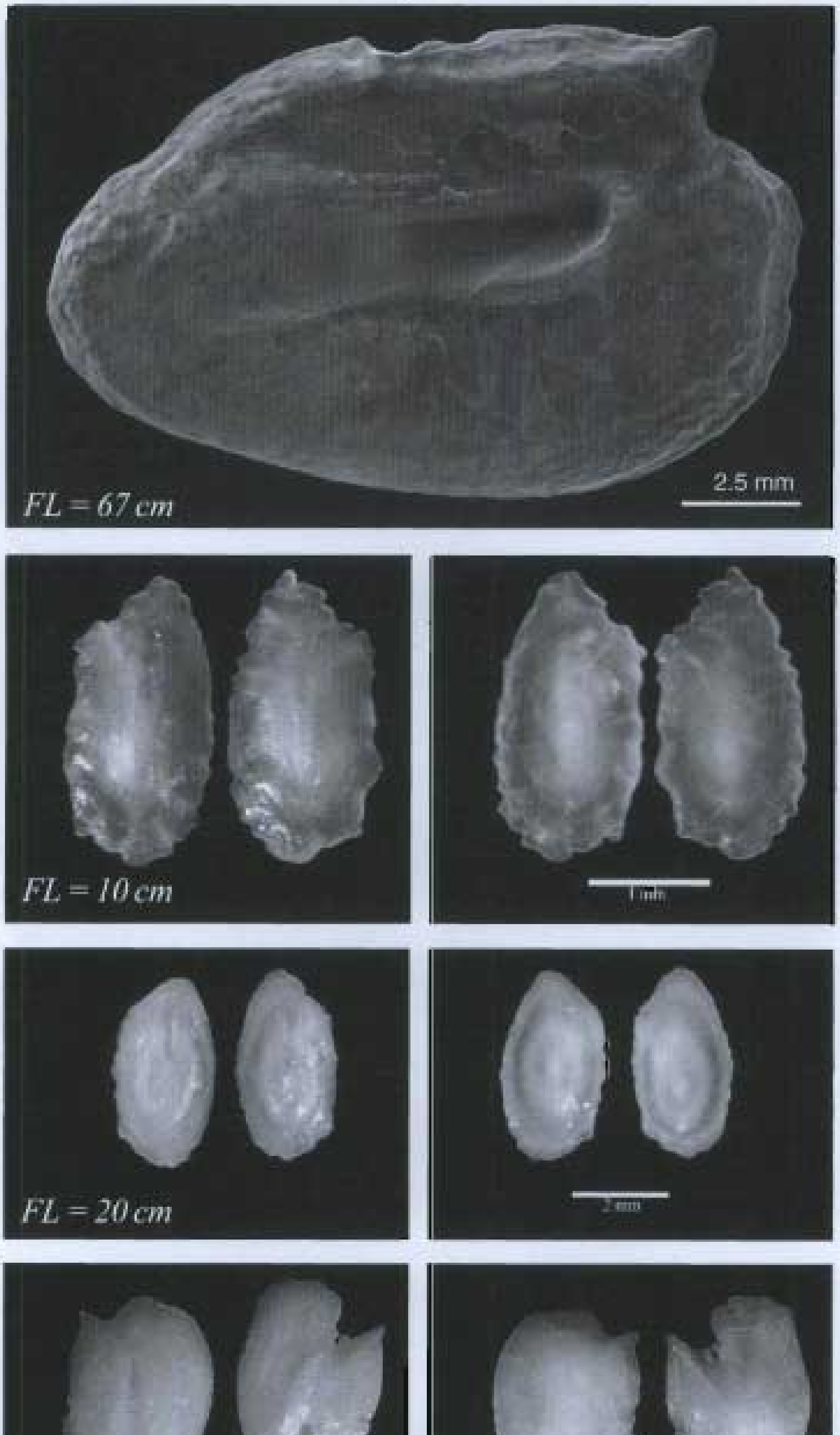
Pleuronectiformes

Pleuronectidae: *Liopsetta putnami*



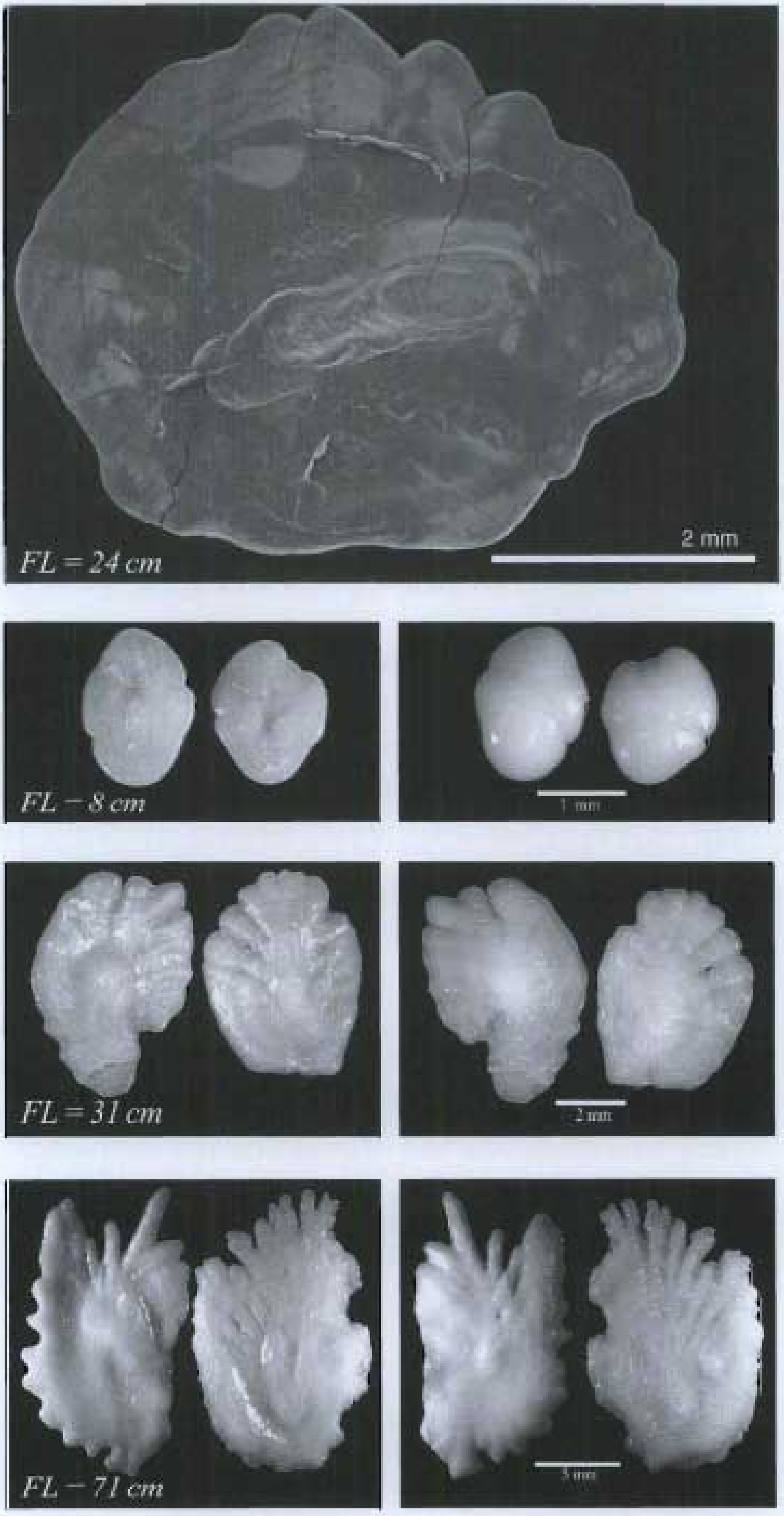
Pleuronectiformes

Pleuronectidae: *Pseudopleuronectes americanus*



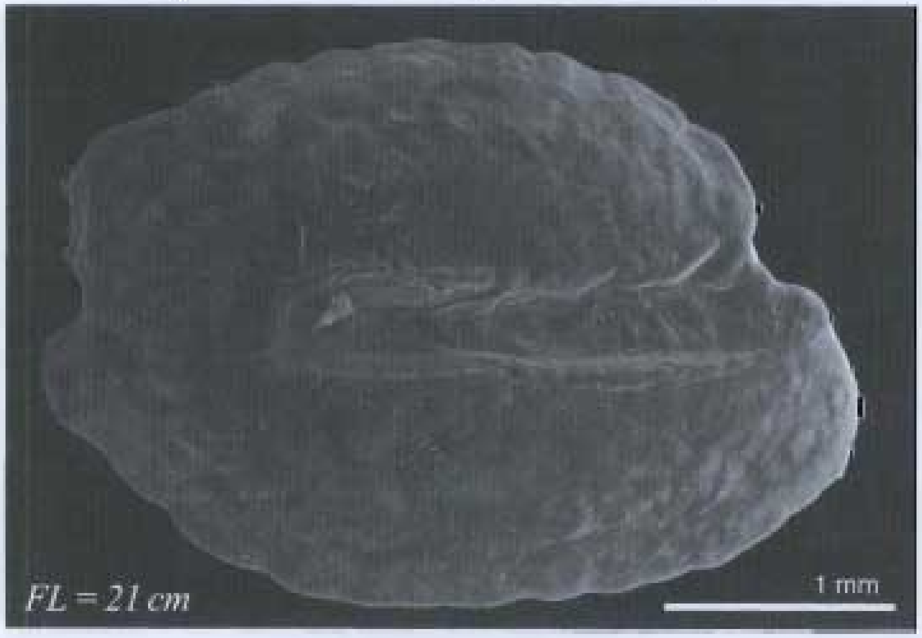
Pleuronectiformes

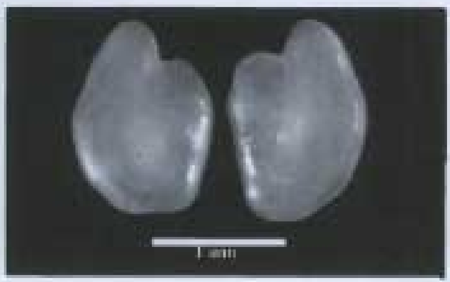
Pleuronectidae: *Reinhardtius hippoglossoides*

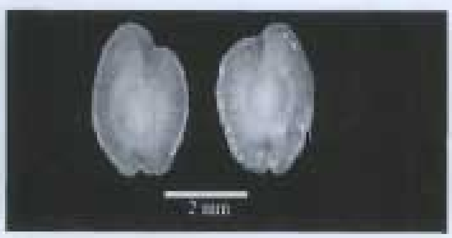


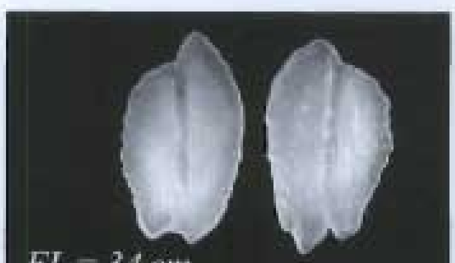
Pleuronectiformes

Scophthalmidae: *Scophthalmus aquosus*



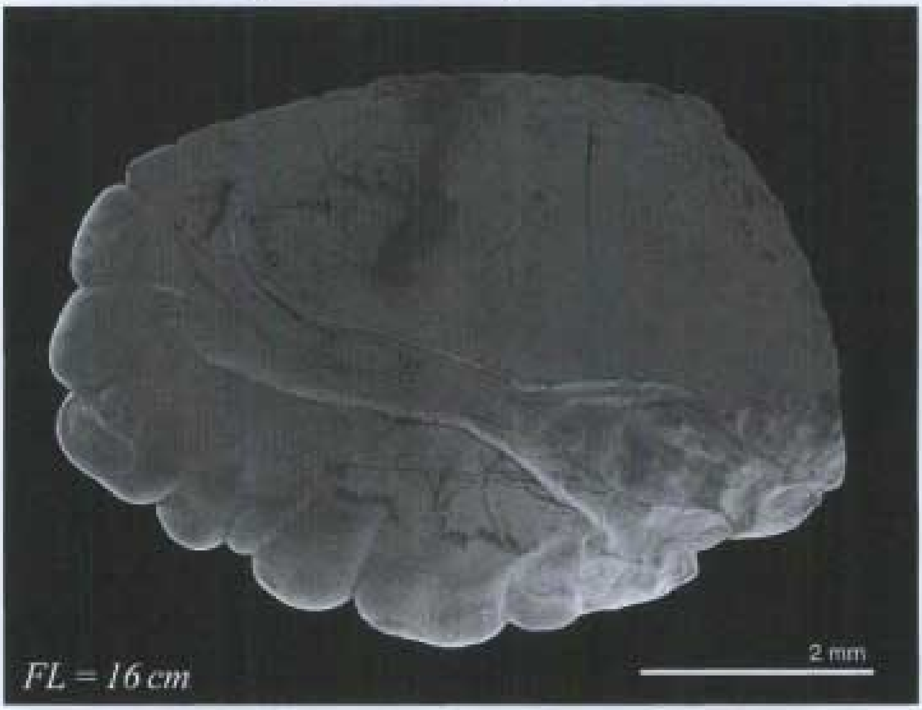






Polymixiiformes

Polymixiidae: *Polymixia lowei*

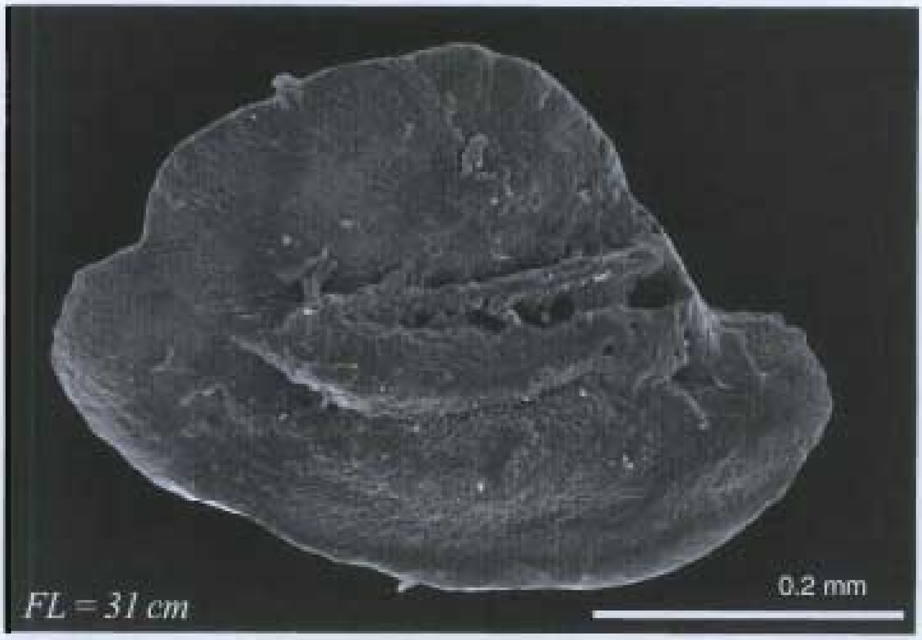


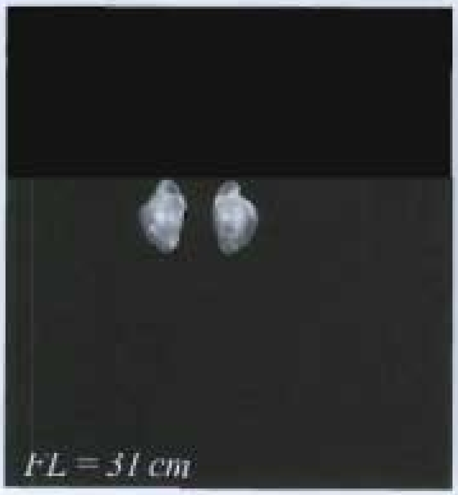
Asteriscii

Lapilli

Saccopharyngiformes

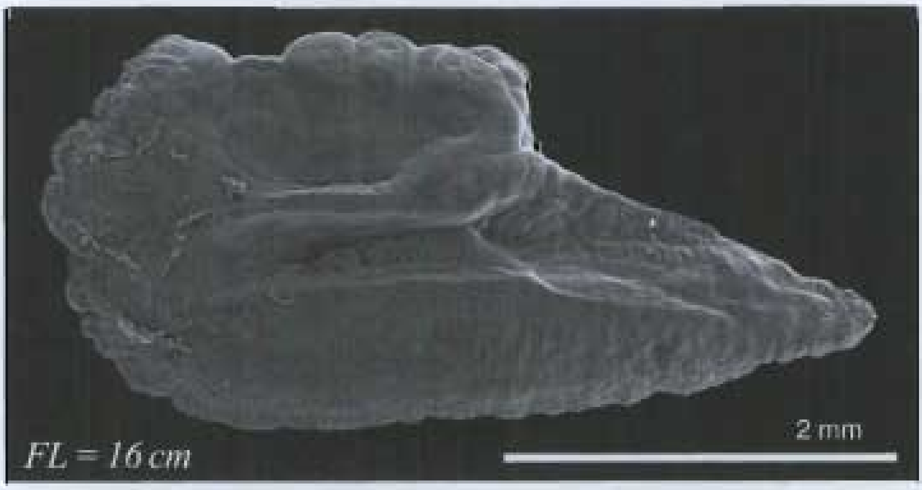
Eurypharyngidae: *Eurypharynx pelecanoides*

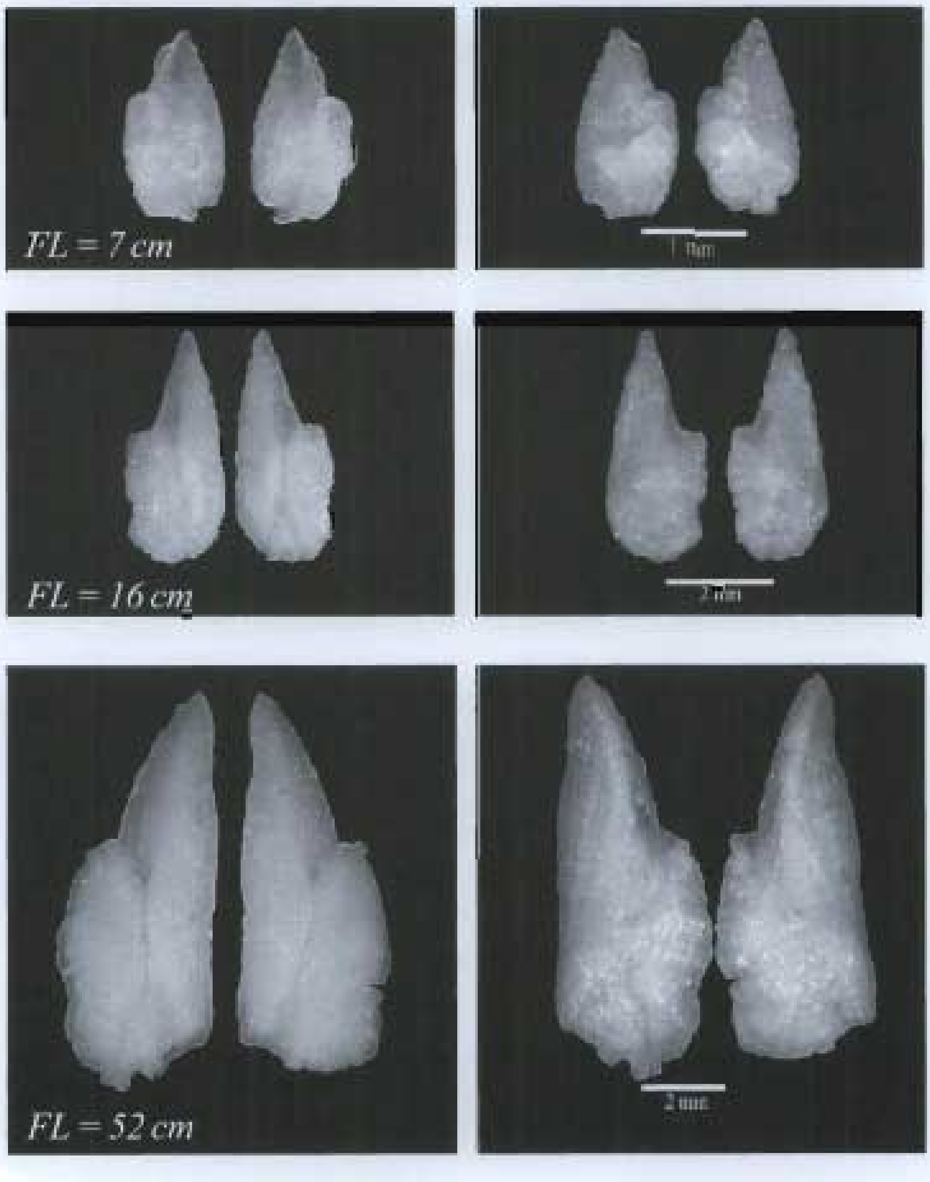




Salmoniformes

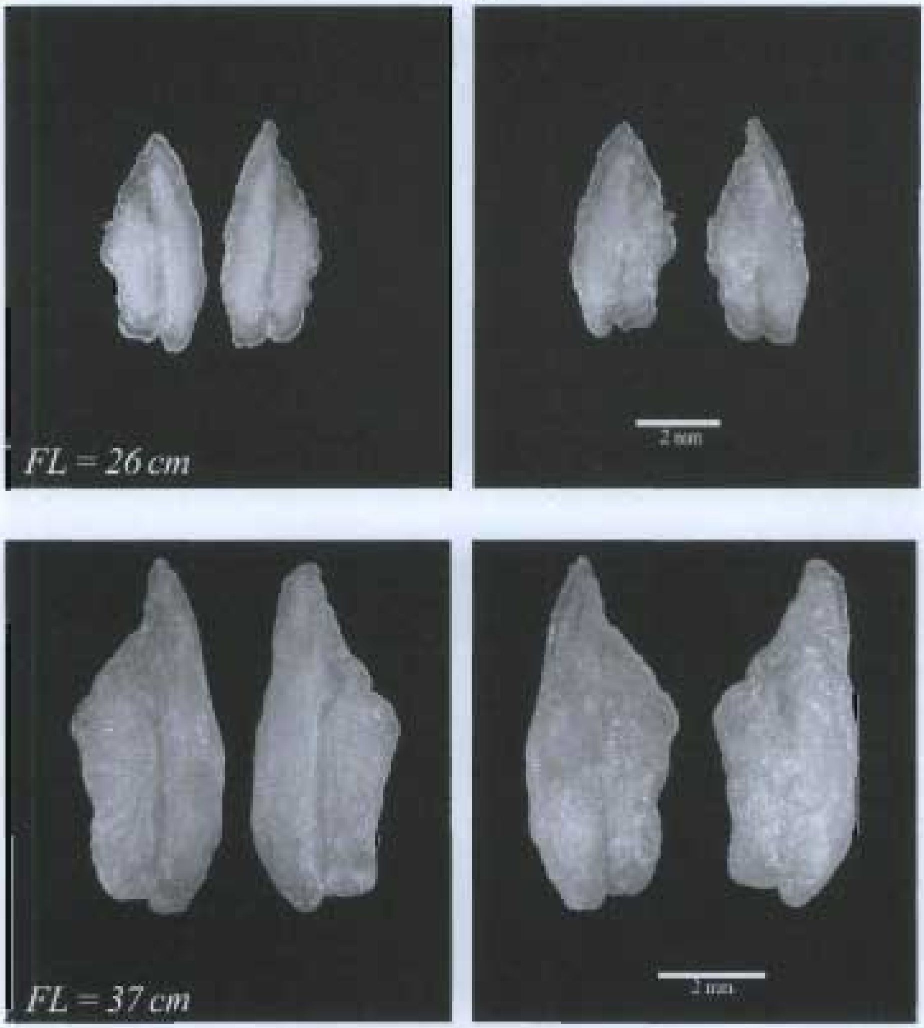
Salmonidae: *Coregonus clupeaformis*





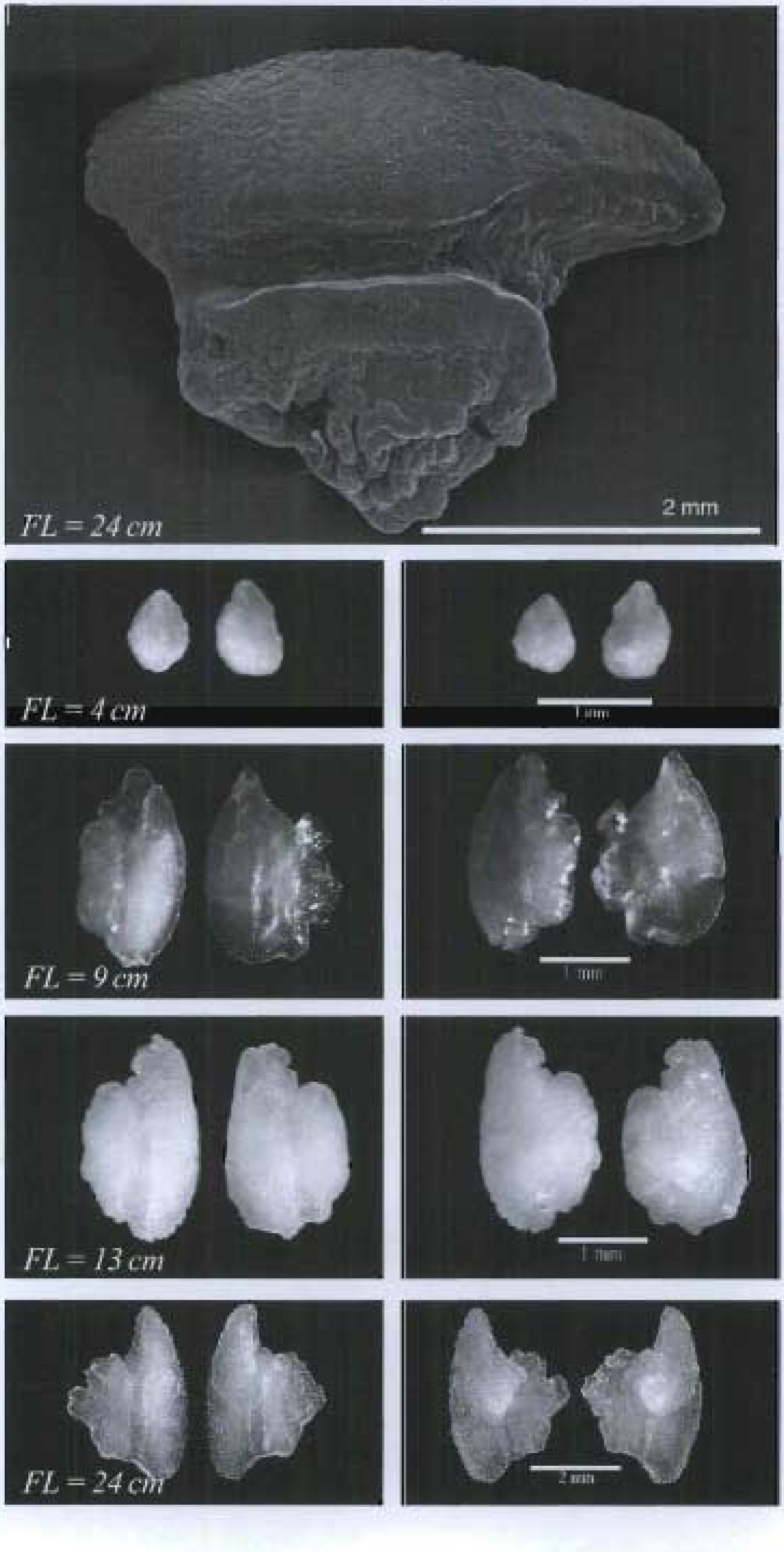
Salmoniformes

Salmonidae: *Coregonus huntsmani*



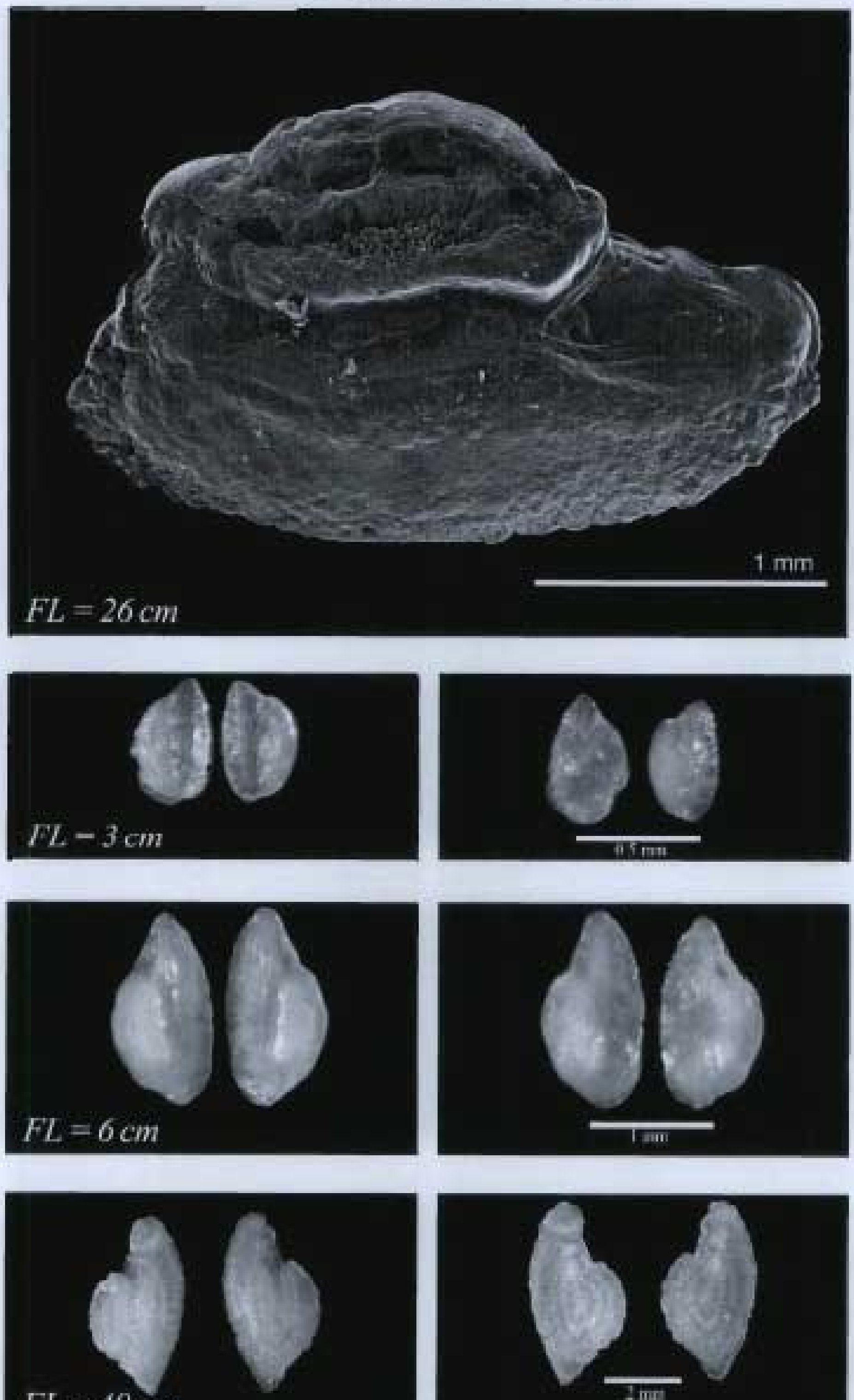
Salmoniformes

Salmonidae: *Oncorhynchus mykiss*



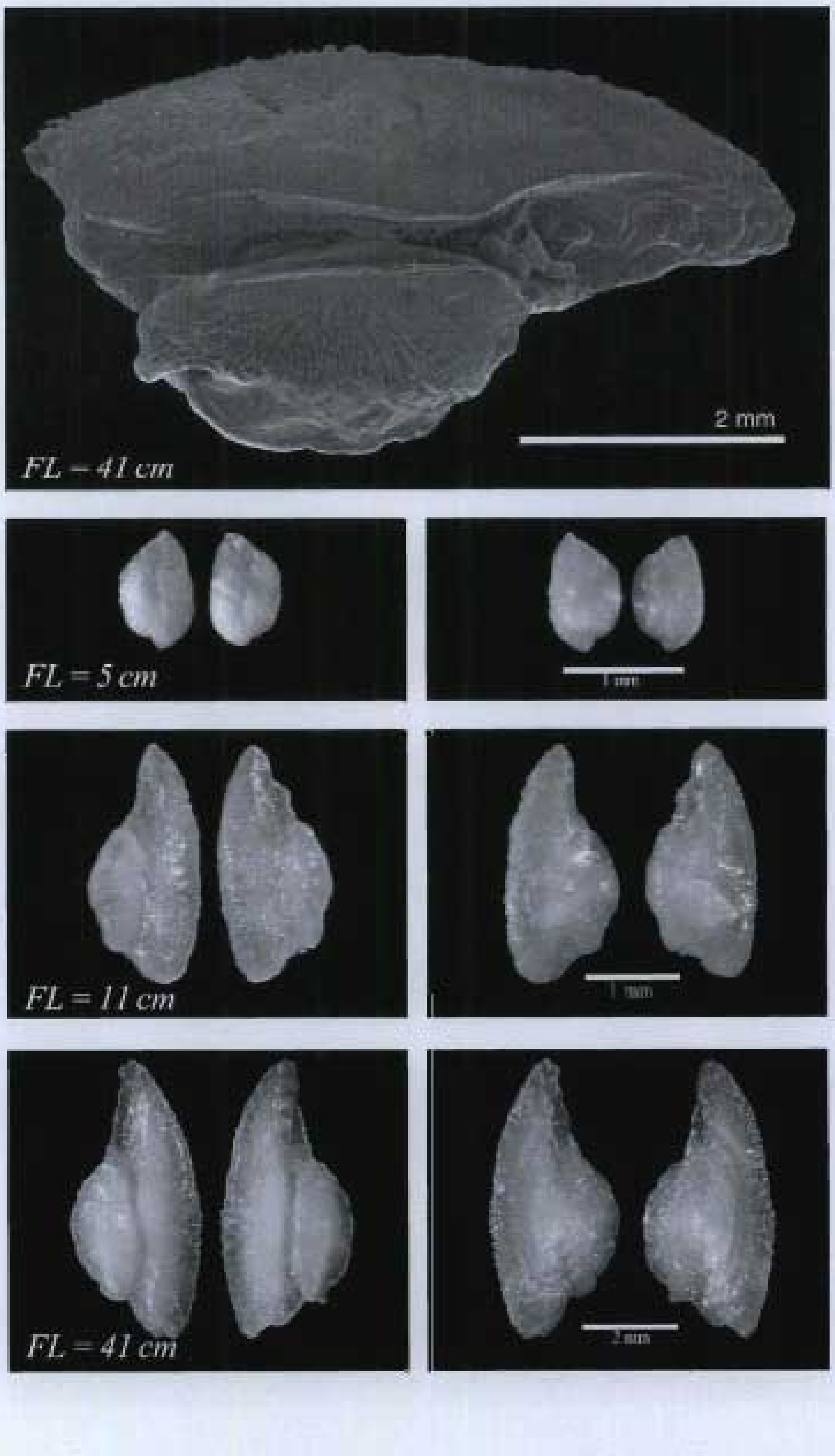
Salmoniformes

Salmonidae: *Salmo salar*

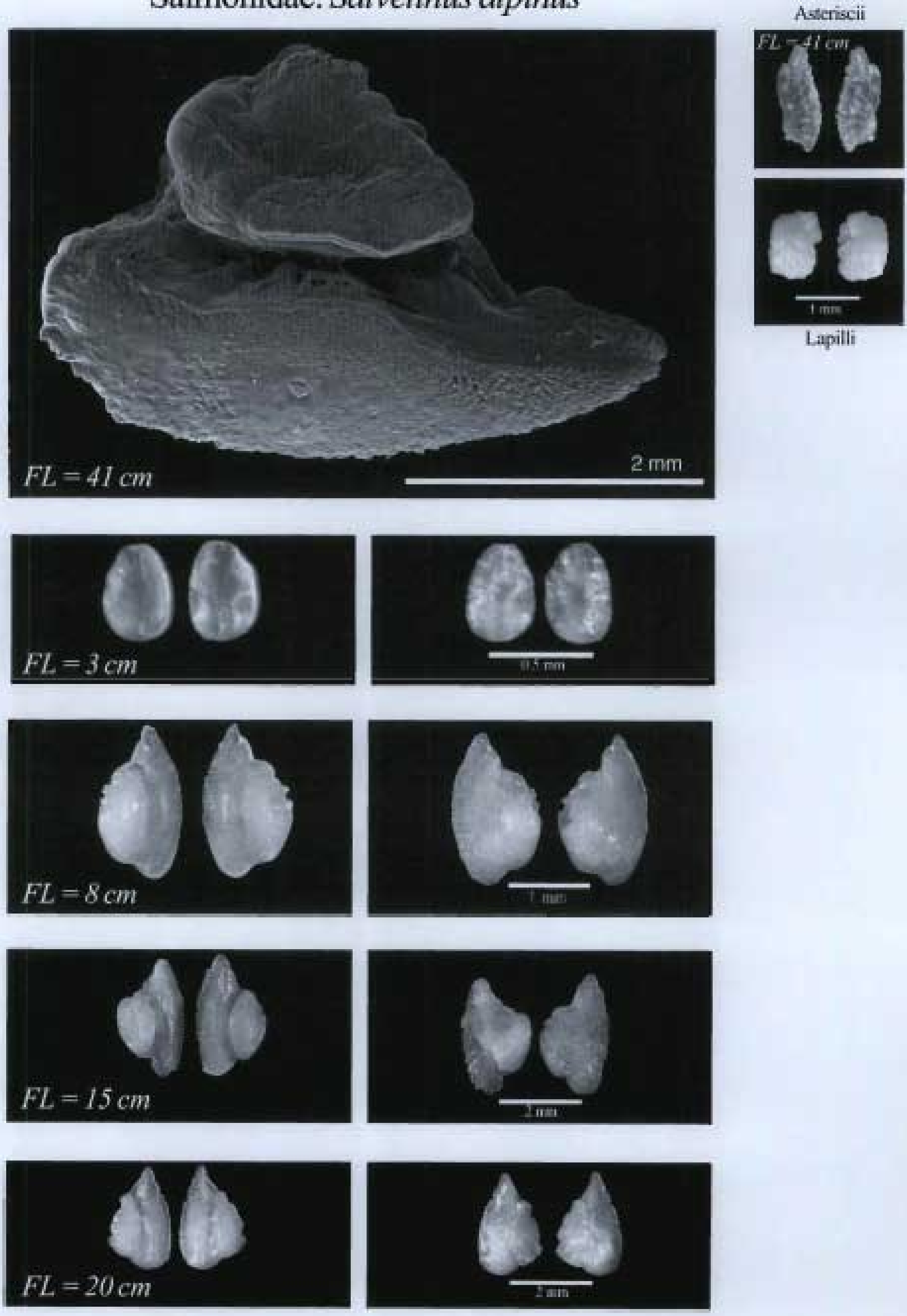


Salmoniformes

Salmonidae: *Salmo trutta*

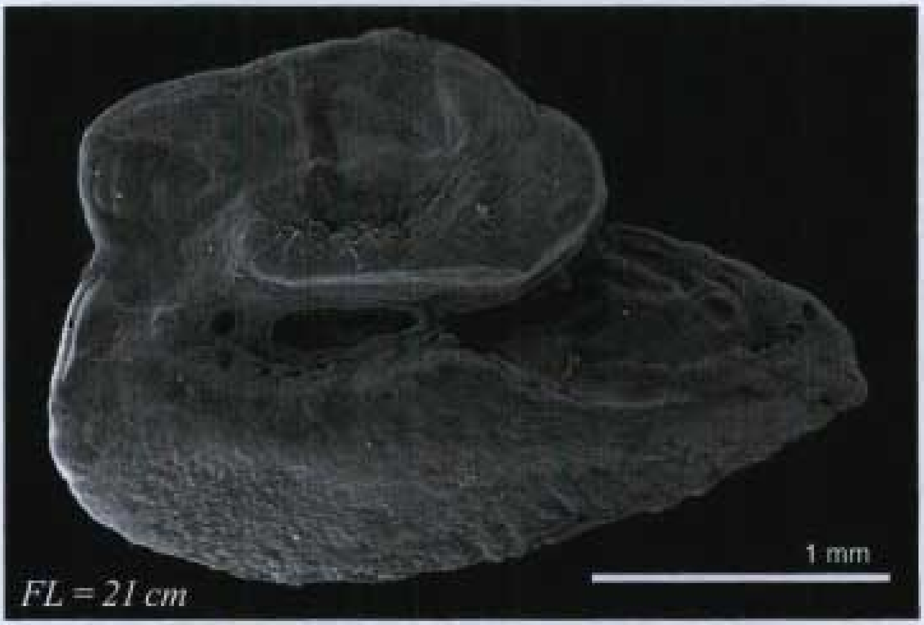


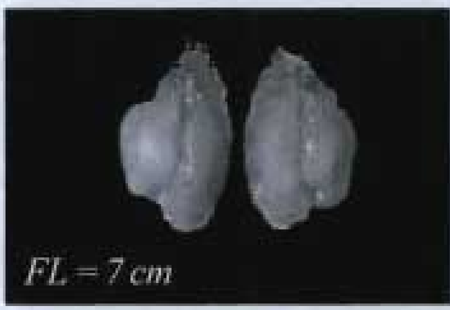
Salmonidae: *Salvelinus alpinus*



Salmoniformes

Salmonidae: *Salvelinus fontinalis*

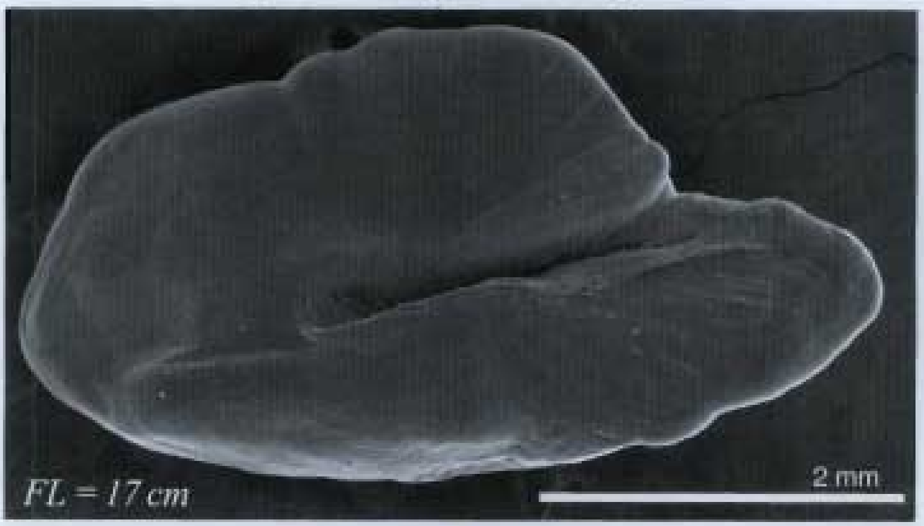


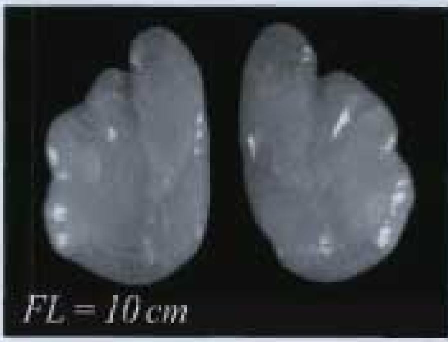


Agonidae: *Agonus decagonus*

Asteriscii

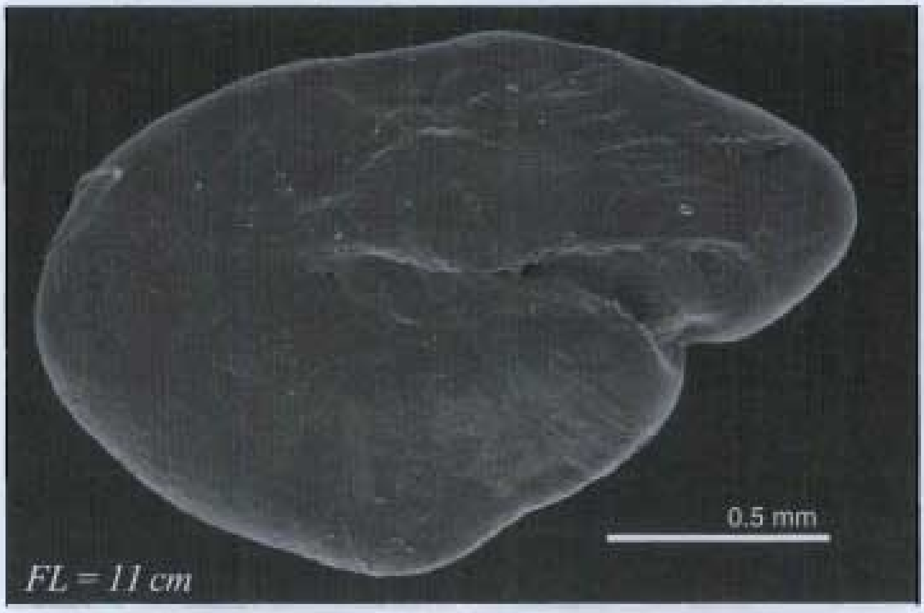
Lapilli





Scorpaeniformes

Agonidae: *Aspidophoroides monopterygius*

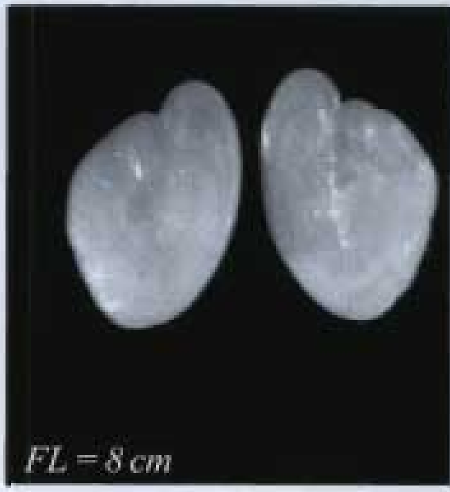


Asteriscii

Lapilli

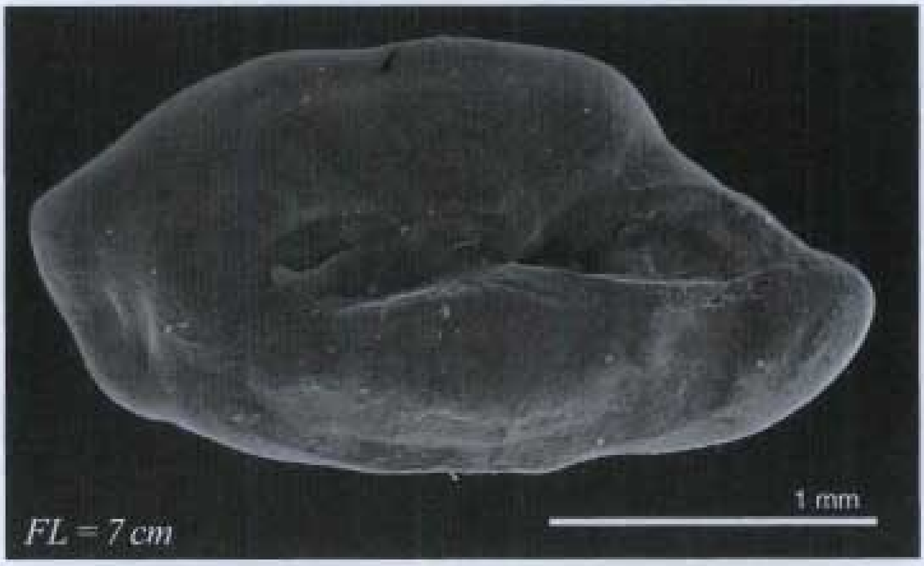
Scorpaeniformes

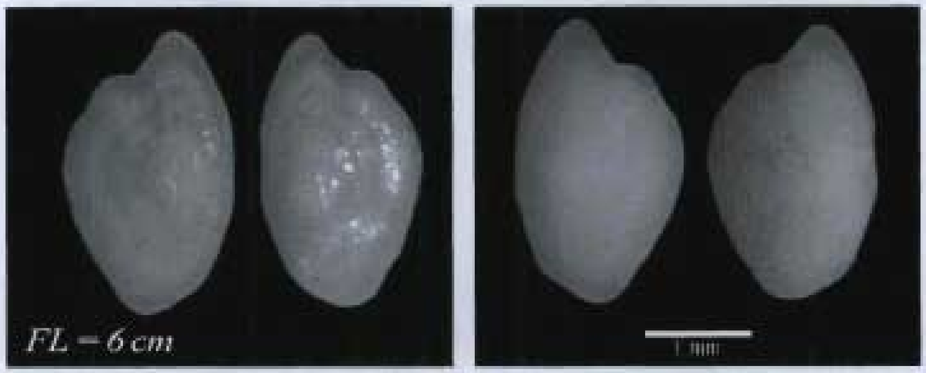
Agonidae: *Aspidophoroides olriki*

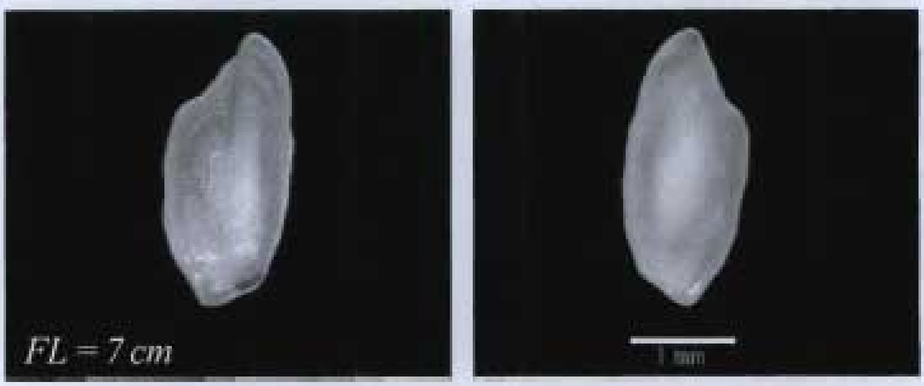


Scorpaeniformes

Cottidae: *Artediellus atlanticus*

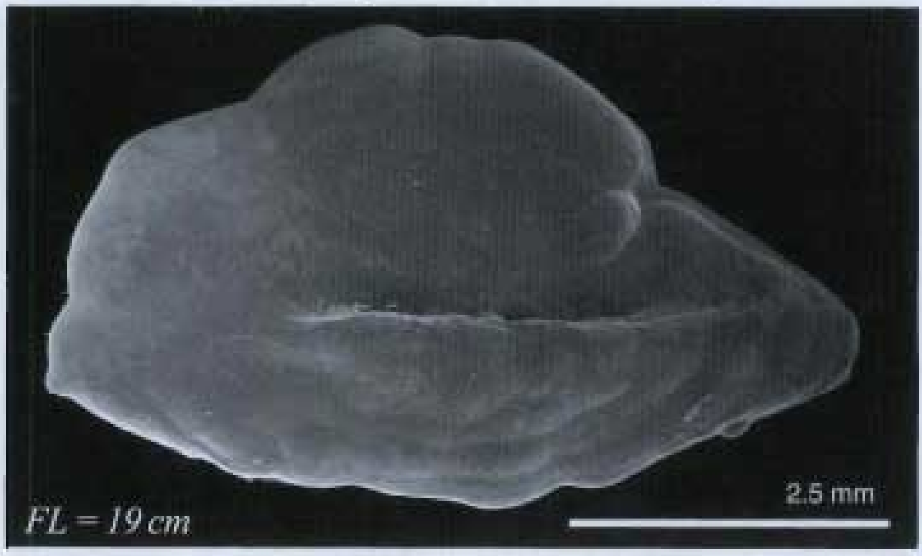


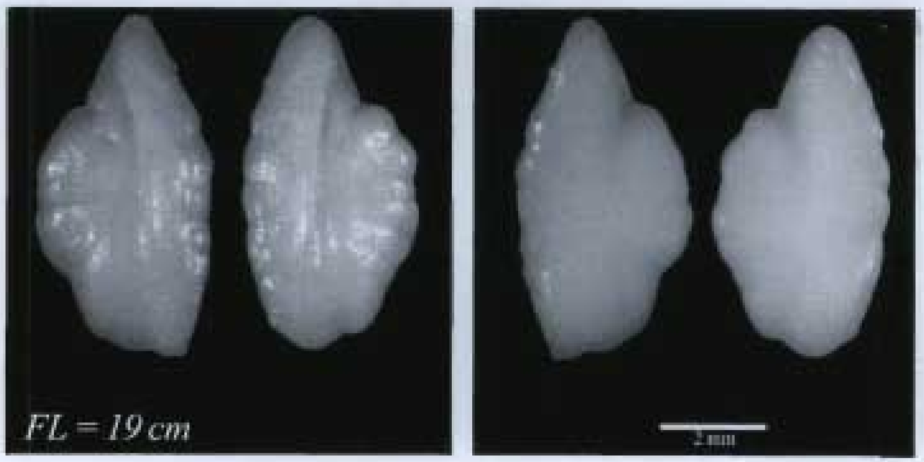




Scorpaeniformes

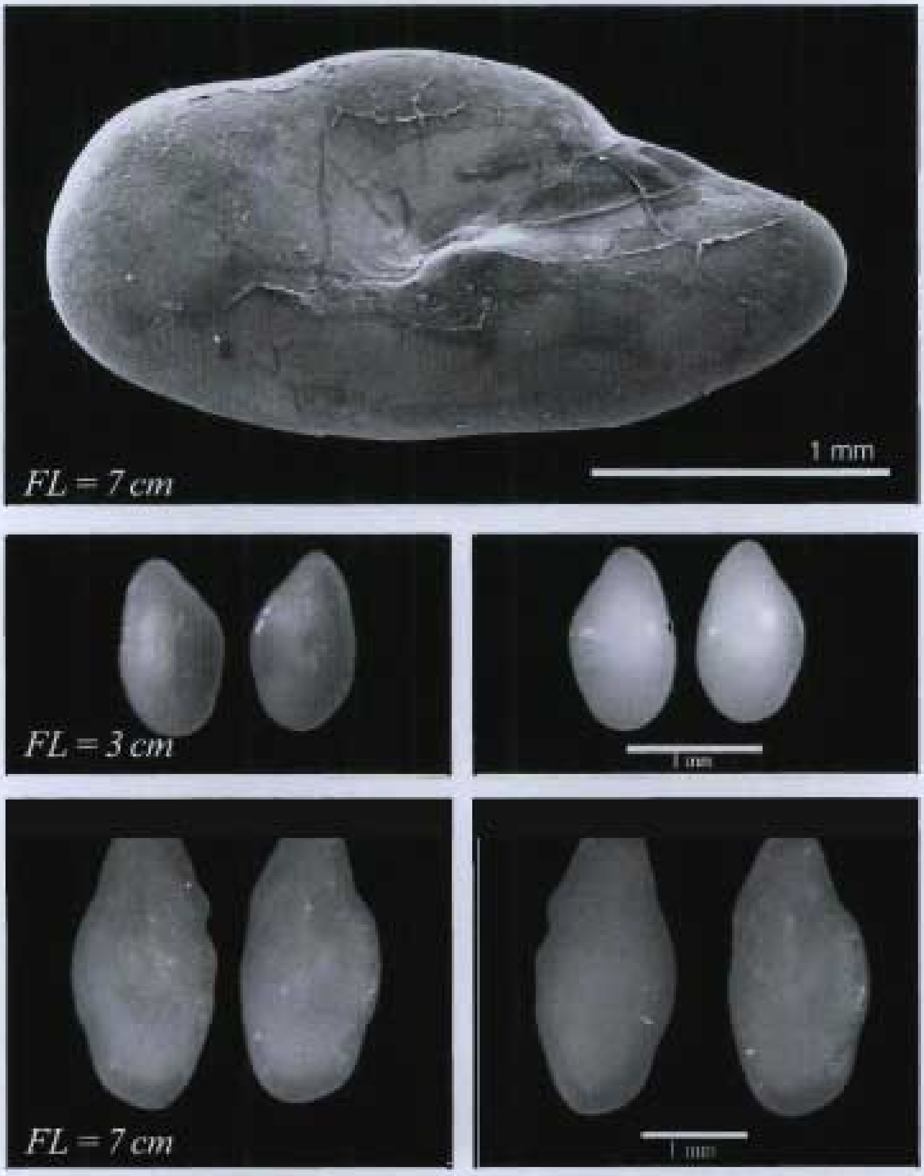
Cottidae: *Gymnocanthus tricuspis*





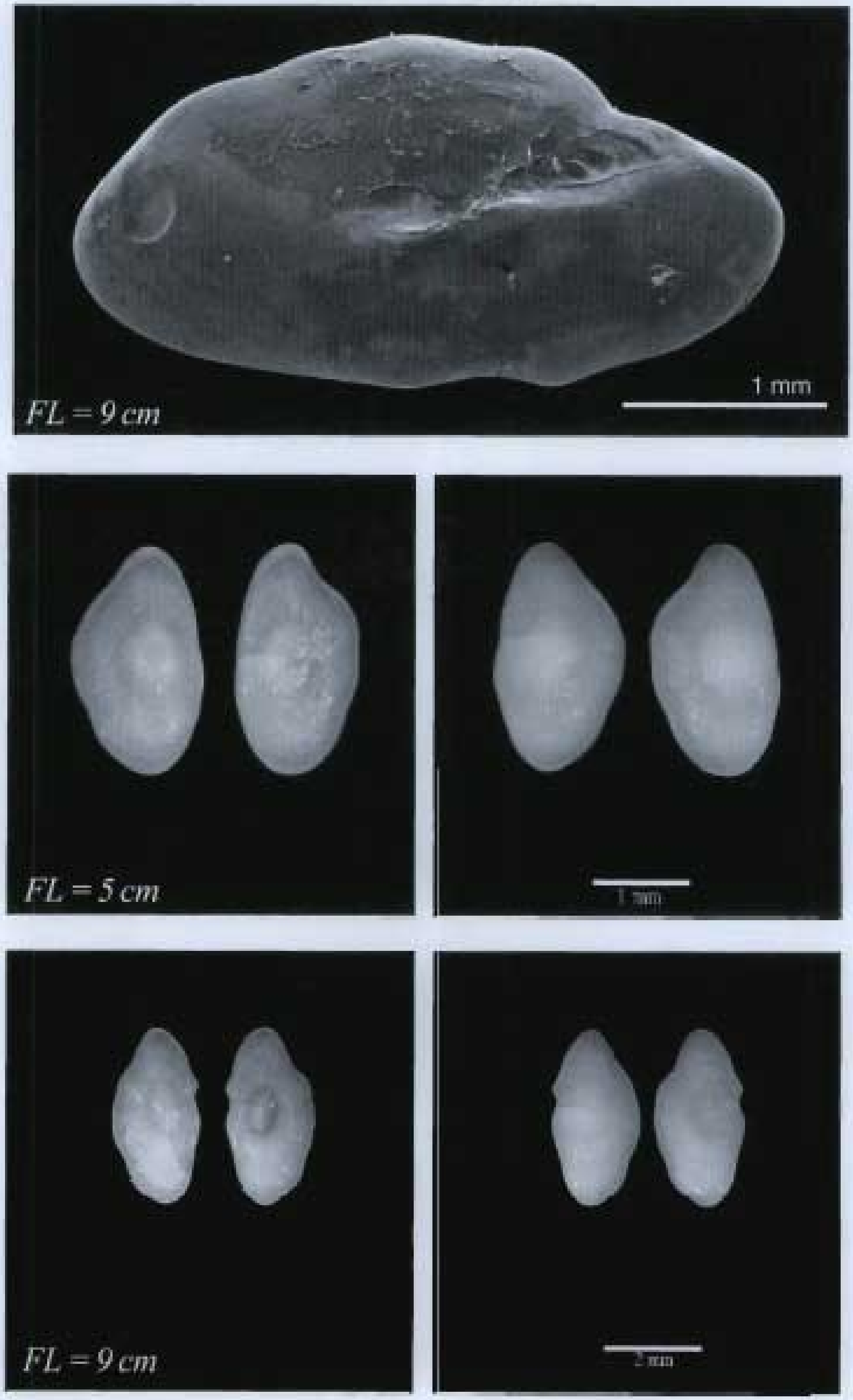
Scorpaeniformes

Cottidae: *Icelus bicornis*



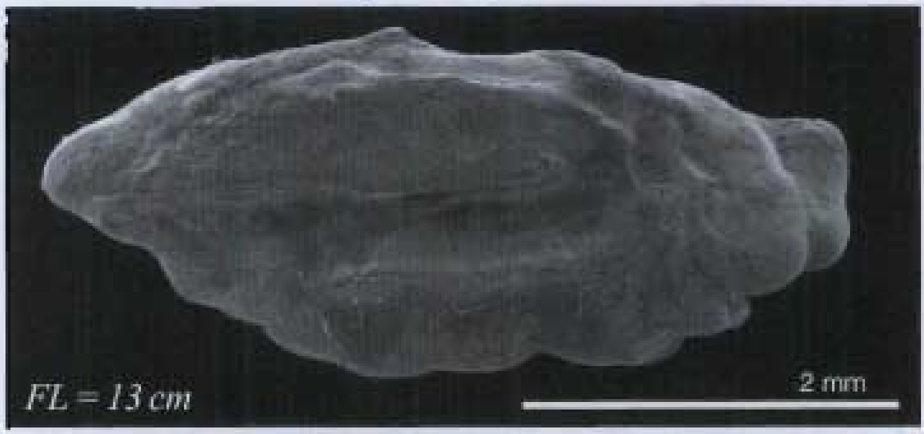
Scorpaeniformes

Cottidae: *Icelus spatula*



Scorpaeniformes

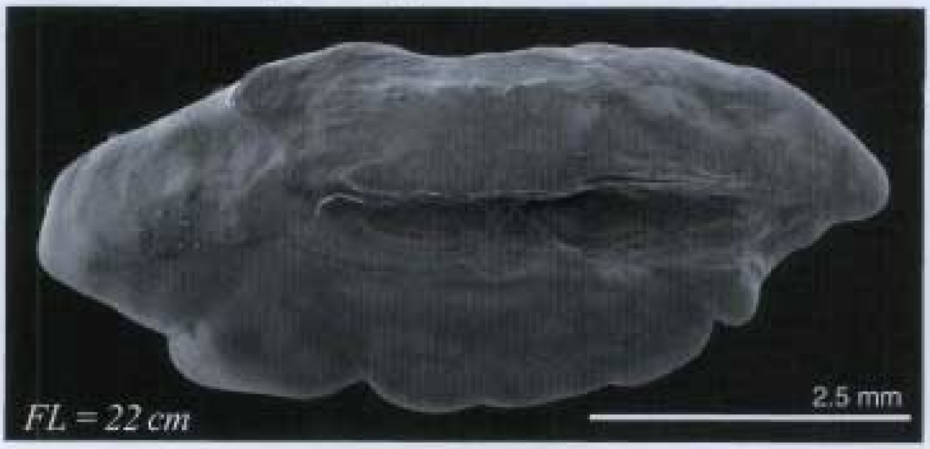
Cottidae: *Myoxocephalus aenaeus*

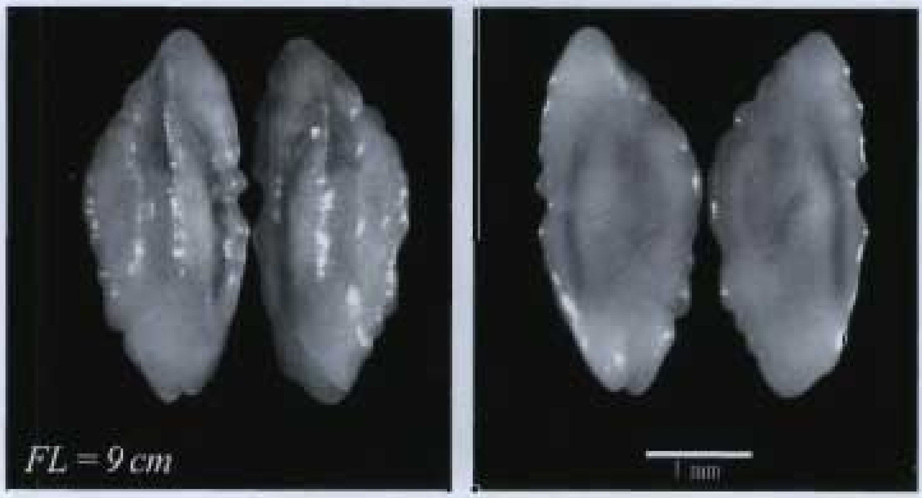


Asteriscii

Lapilli

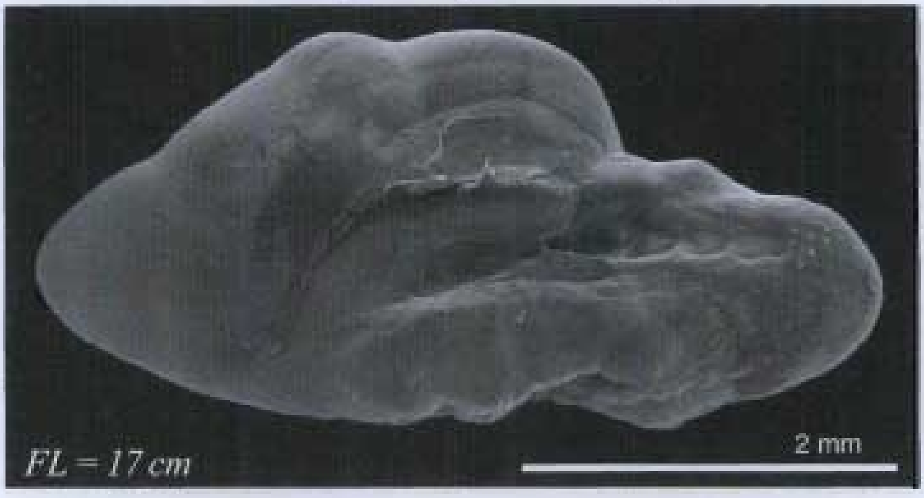
Cottidae: *Myoxocephalus octodecemspinosus*

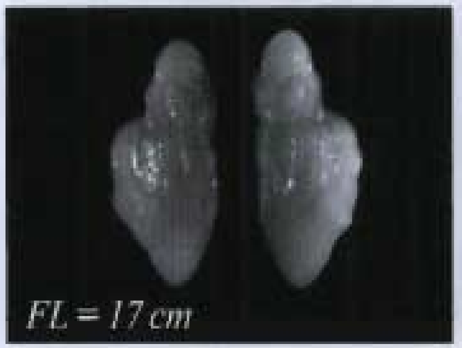




Scorpaeniformes

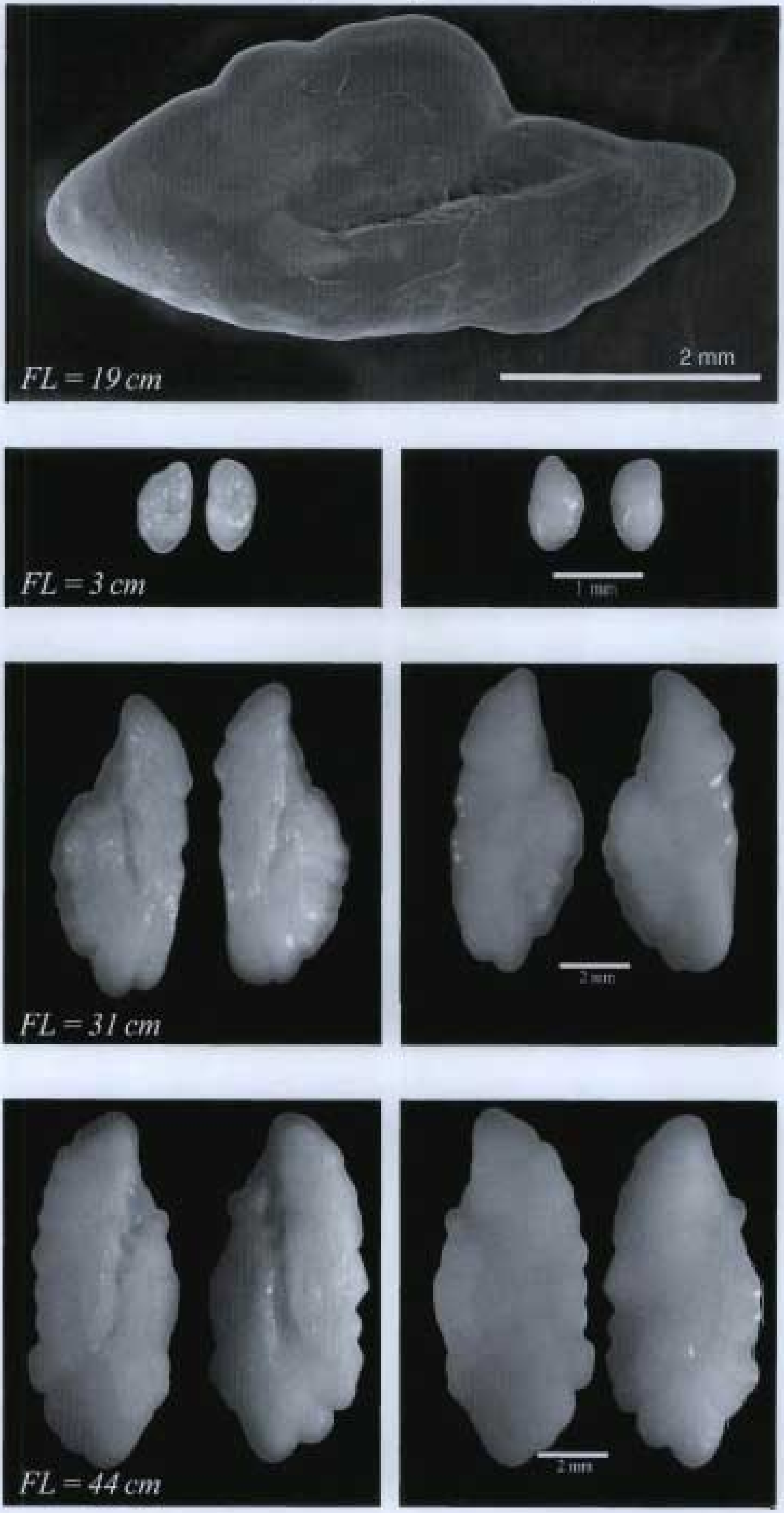
Cottidae: *Myoxocephalus scorpioides*





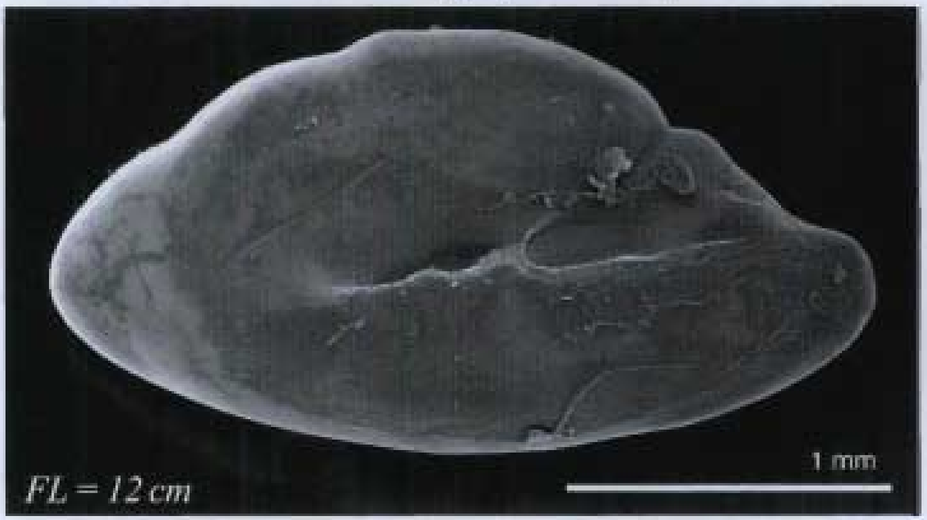
Scorpaeniformes

Cottidae: *Myoxocephalus scorpius*

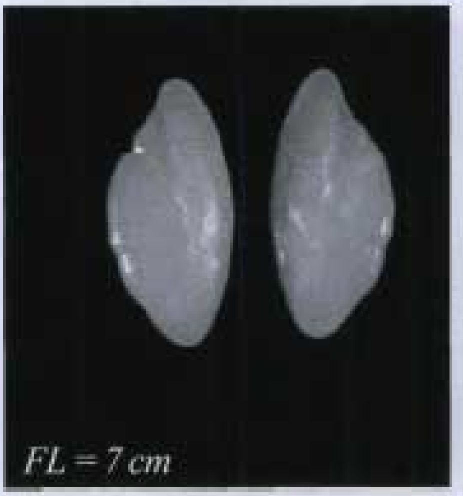


Scorpaeniformes

Cottidae: *Triglops murrayi*

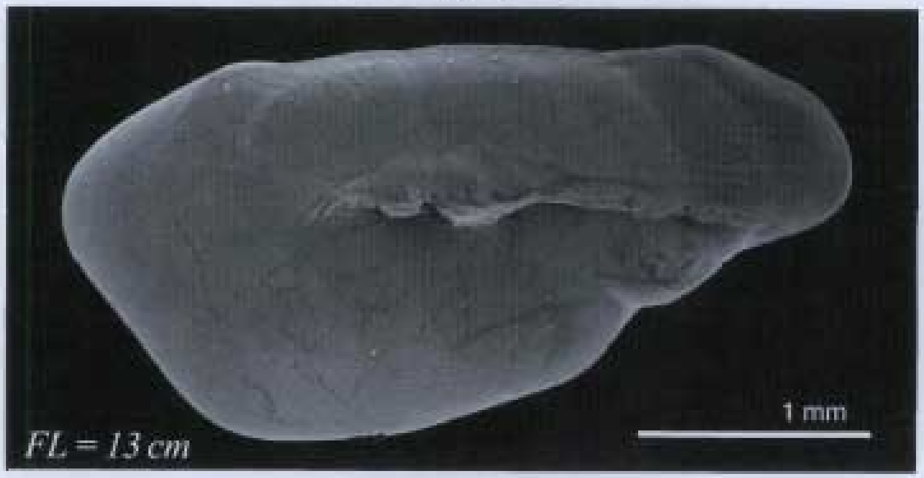


Lapilli
& Asteriscii



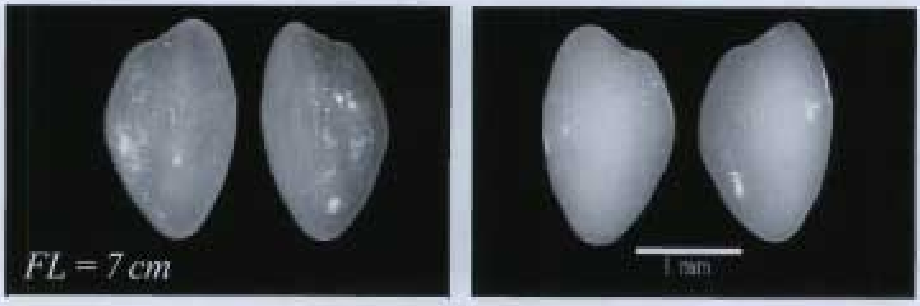
Scorpaeniformes

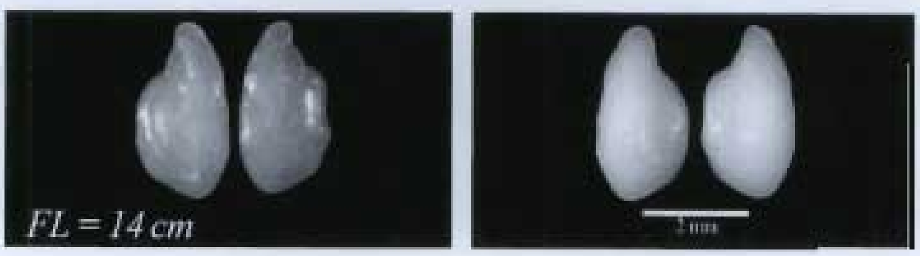
Cottidae: *Triglops nybelini*



Asterisci

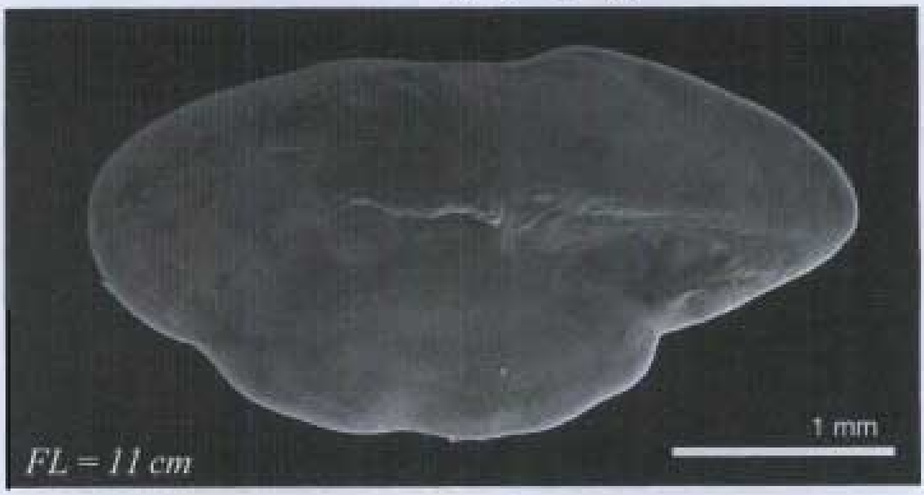
Lapilli





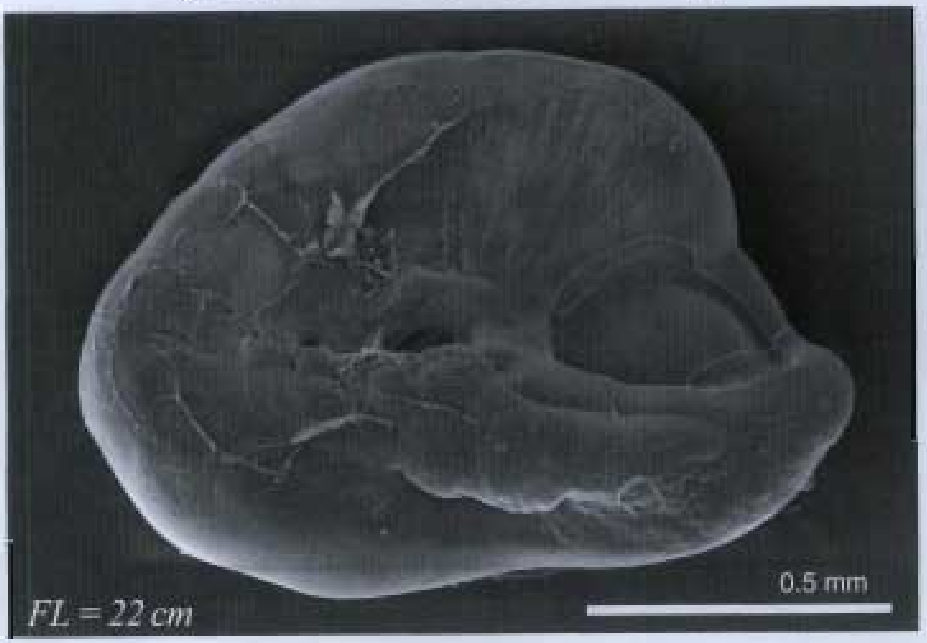
Scorpaeniformes

Cottidae: *Triglops pingeli*

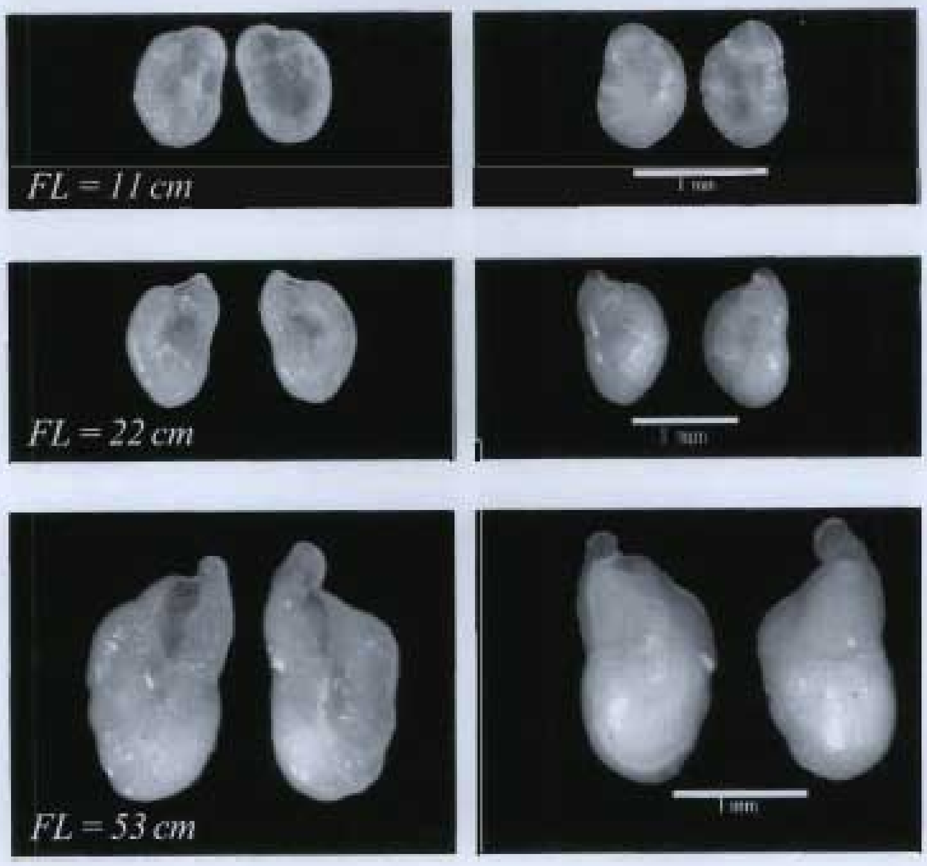


Scorpaeniformes

Cyclopteridae: *Cyclopterus lumpus*

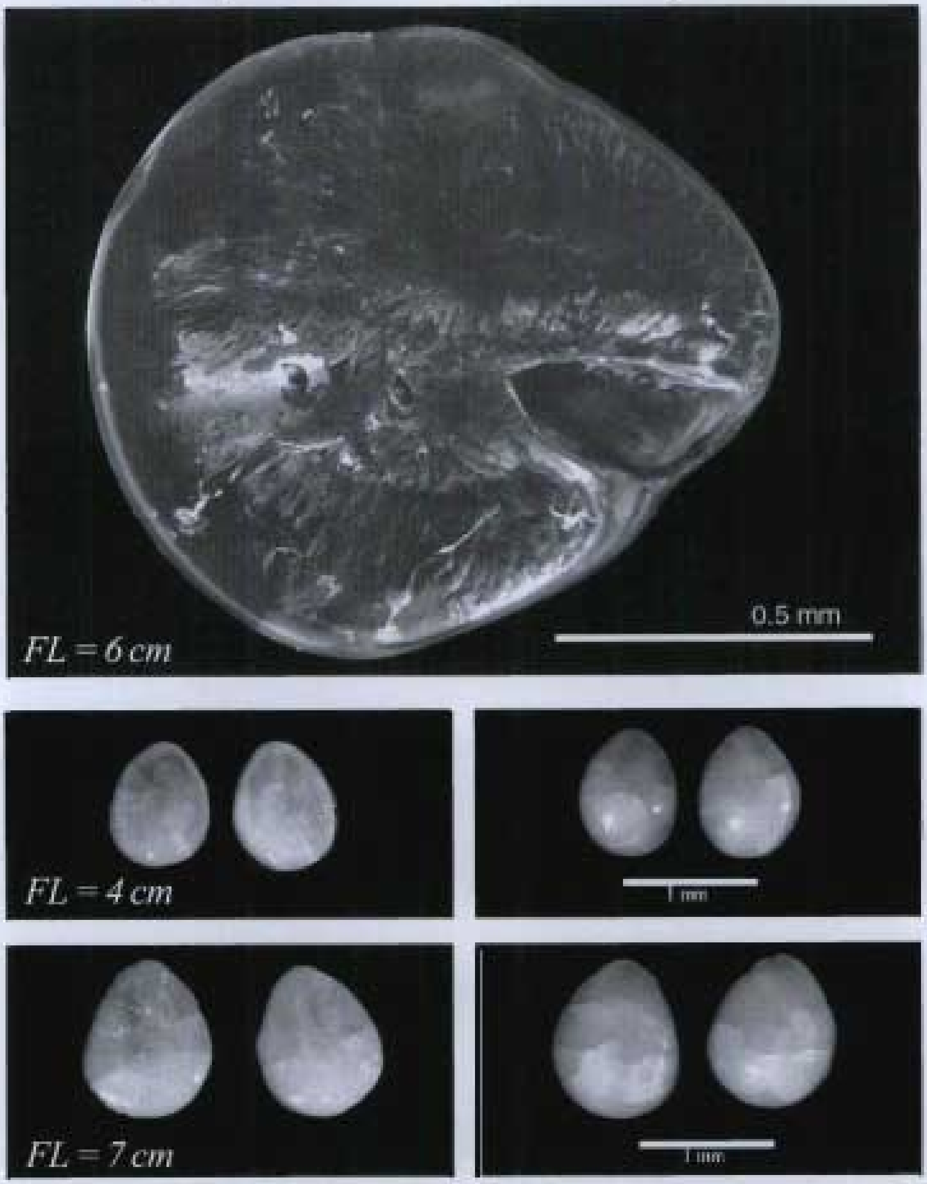


Asteriscii & Lapilli



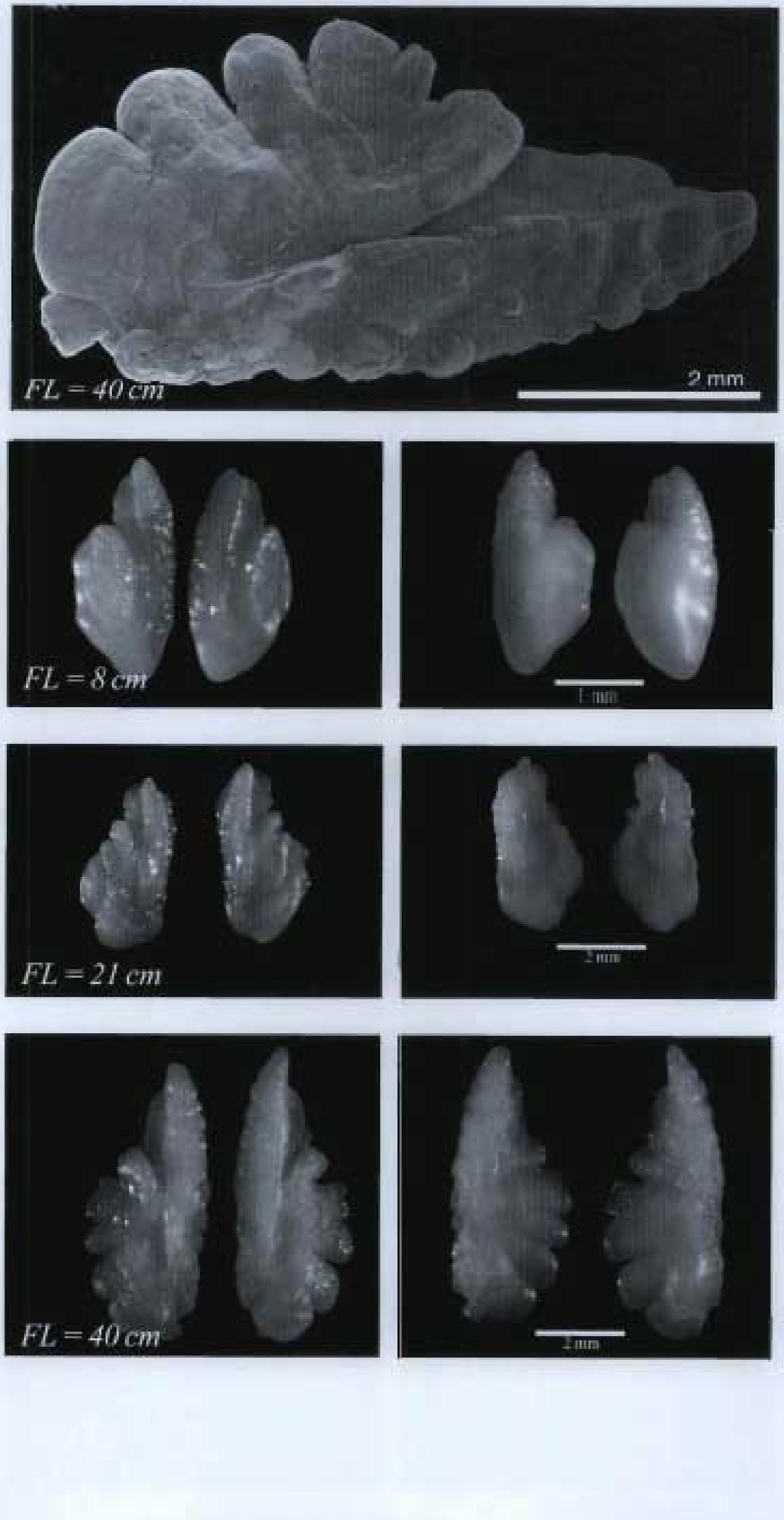
Scorpaeniformes

Cyclopteridae: *Eumicrotremus spinosus*



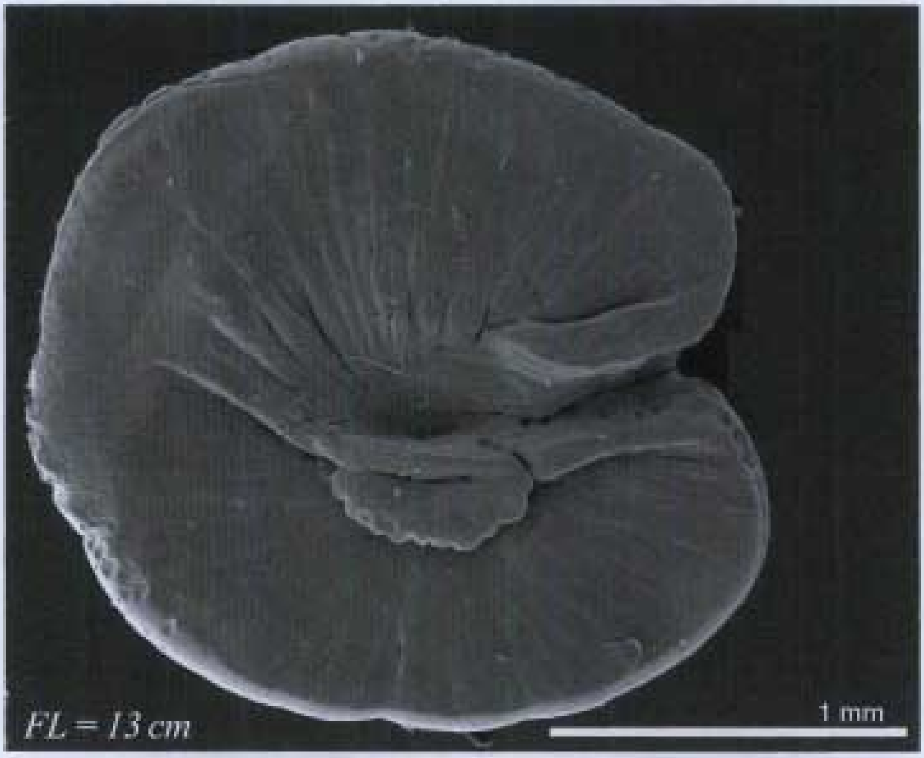
Scorpaeniformes

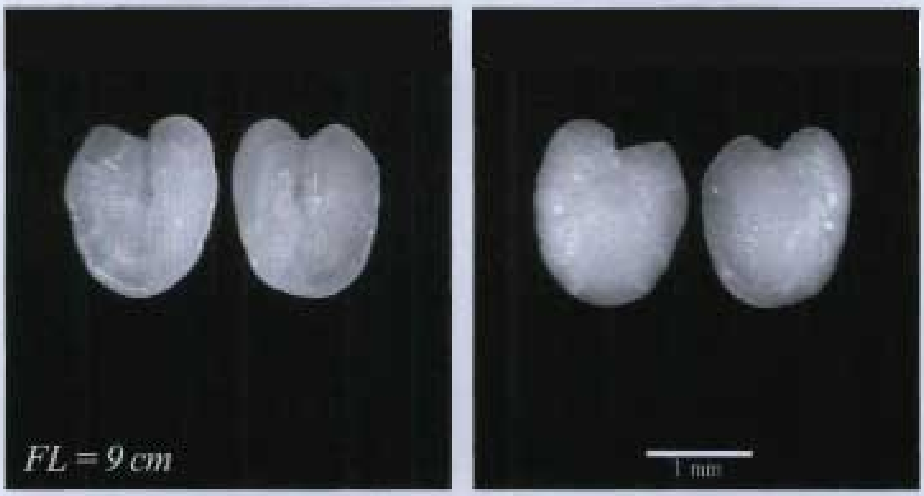
Hemitripteridae: *Hemitripterus americanus*

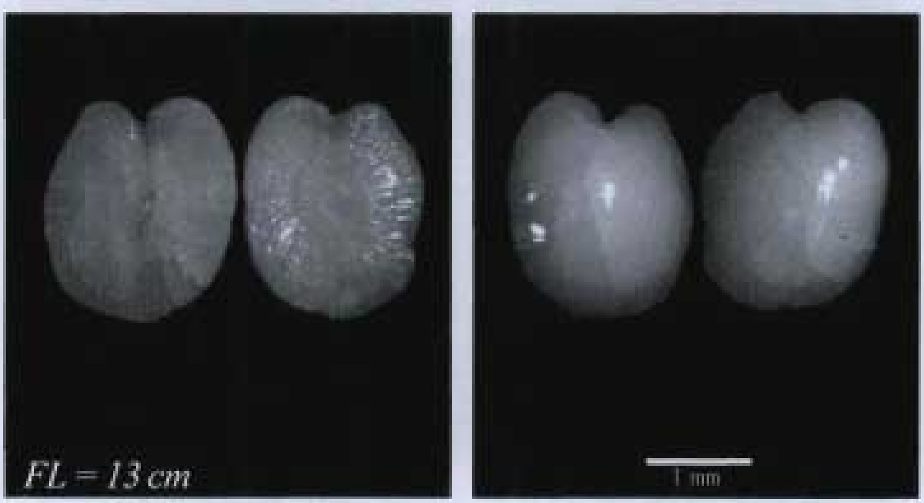


Scorpaeniformes

Liparidae: *Careproctus reinhardti*

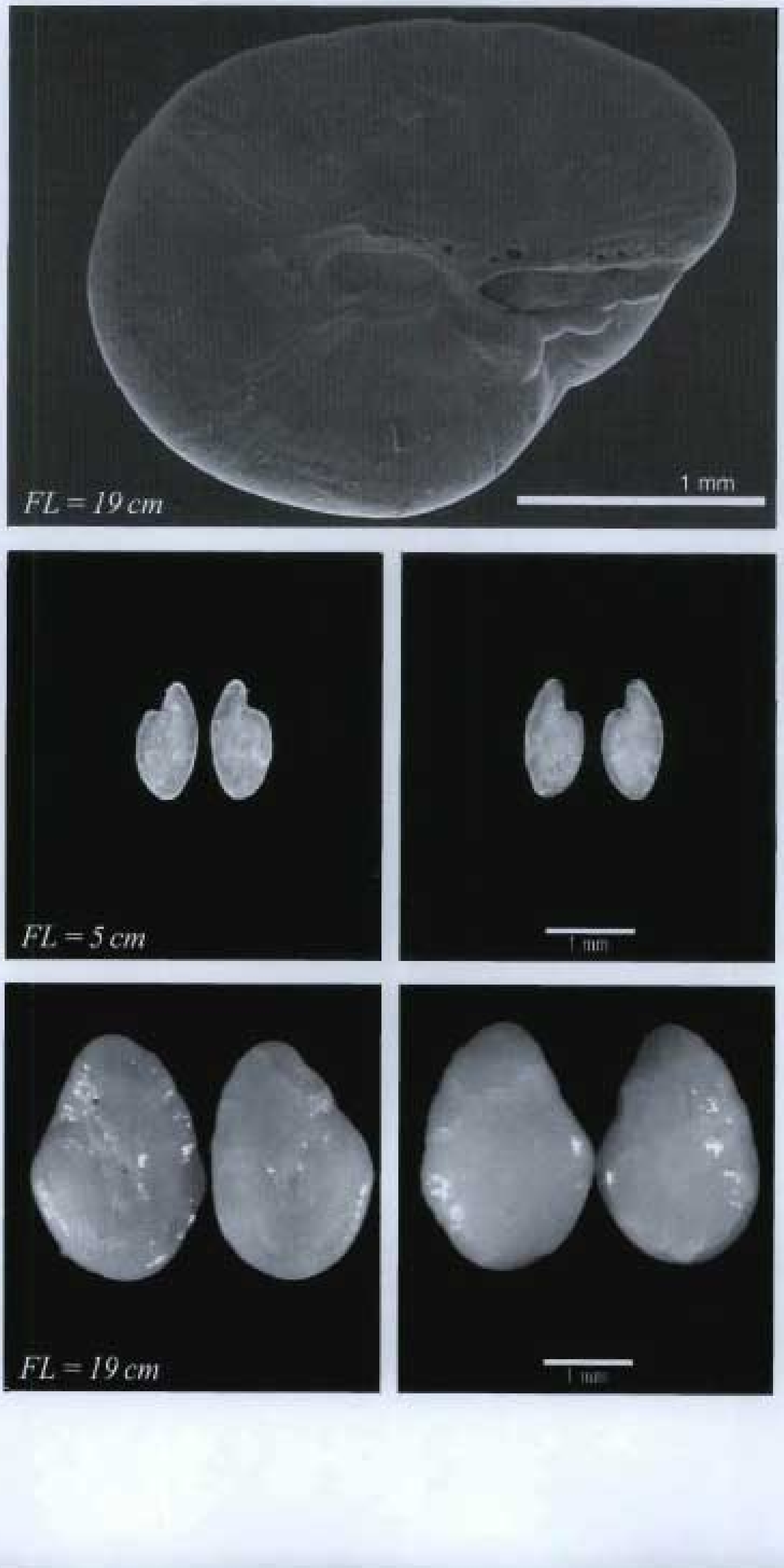






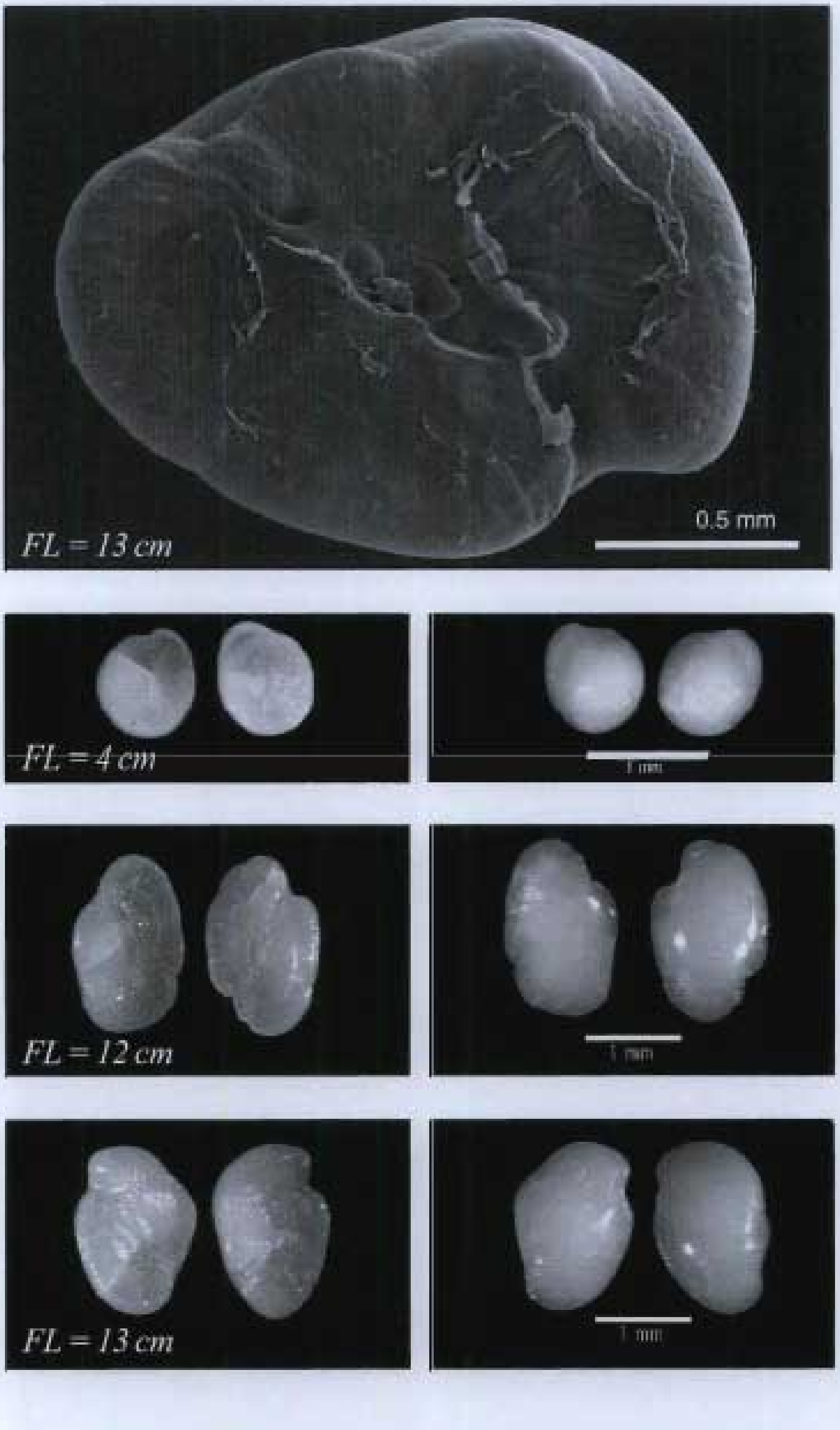
Scorpaeniformes

Liparidae: *Liparis atlanticus*



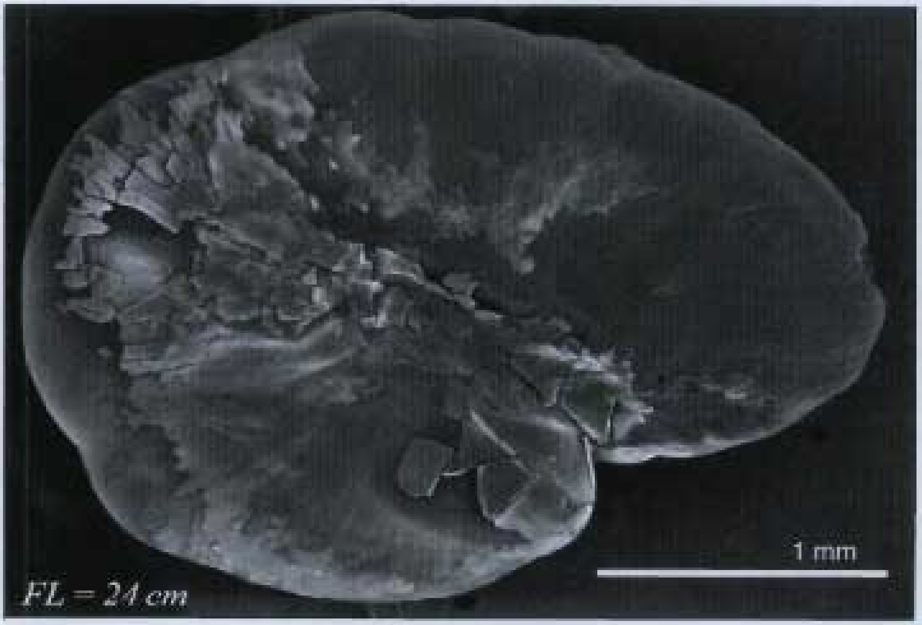
Scorpaeniformes

Liparidae: *Liparis fabricii*

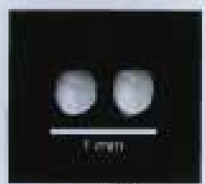


Scorpaeniformes

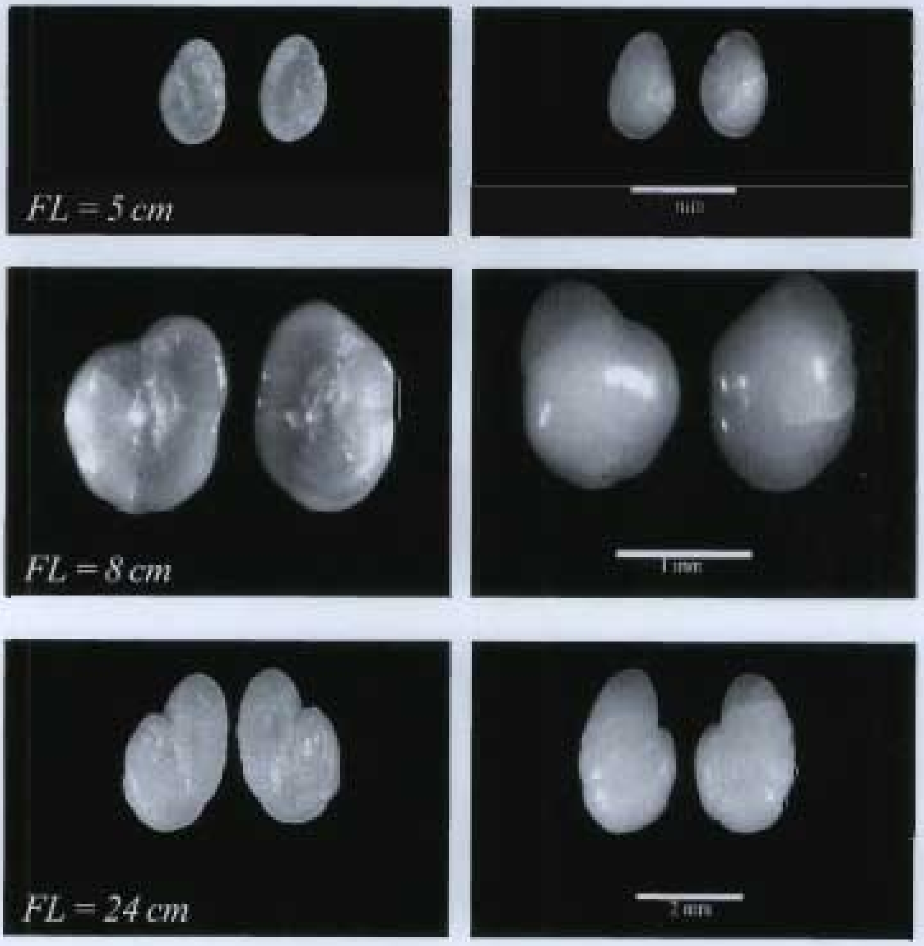
Liparidae: *Liparis gibbus*



Asterisci

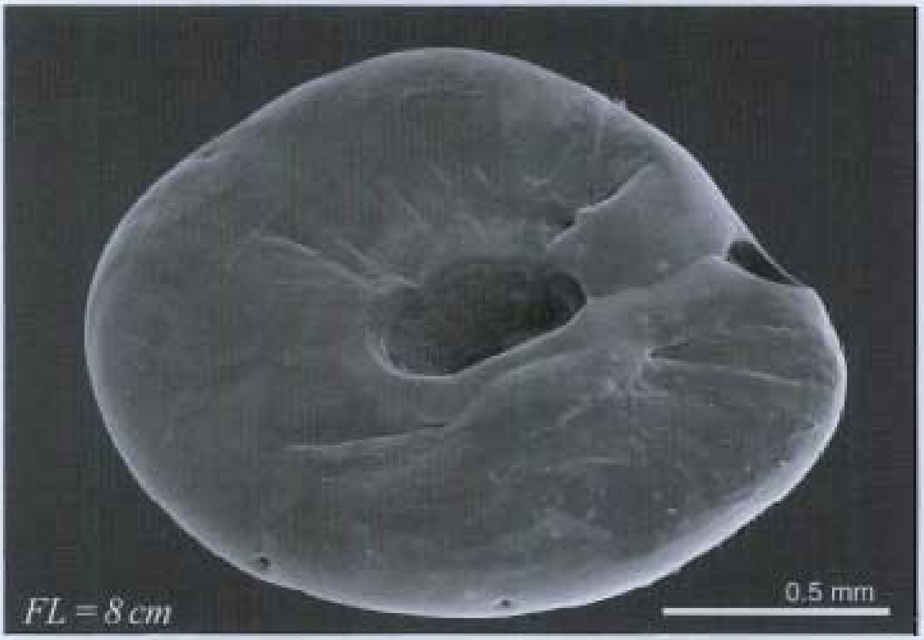


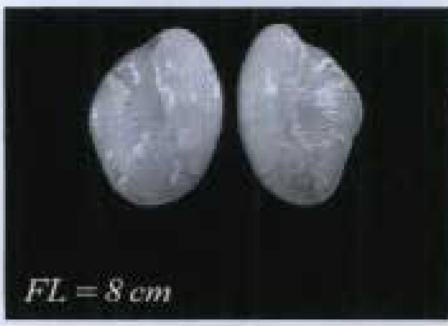
Lapilli



Scorpaeniformes

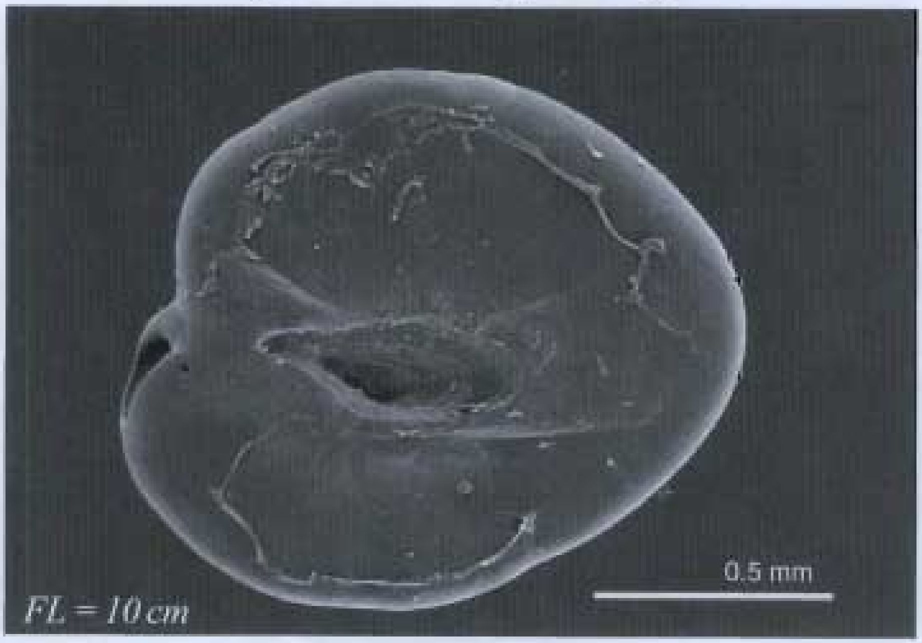
Liparidae: *Paraliparis calidus*

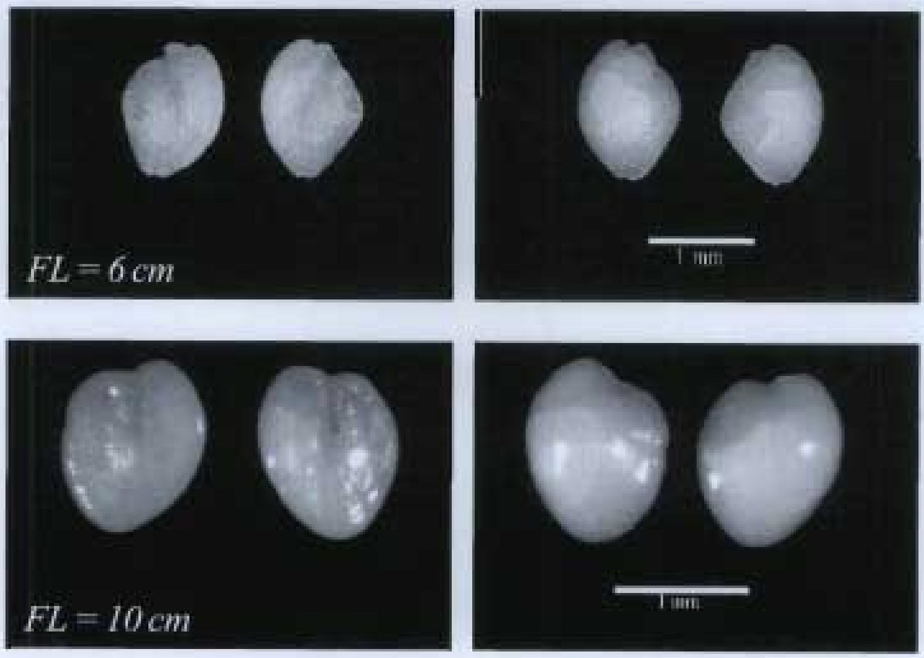




Scorpaeniformes

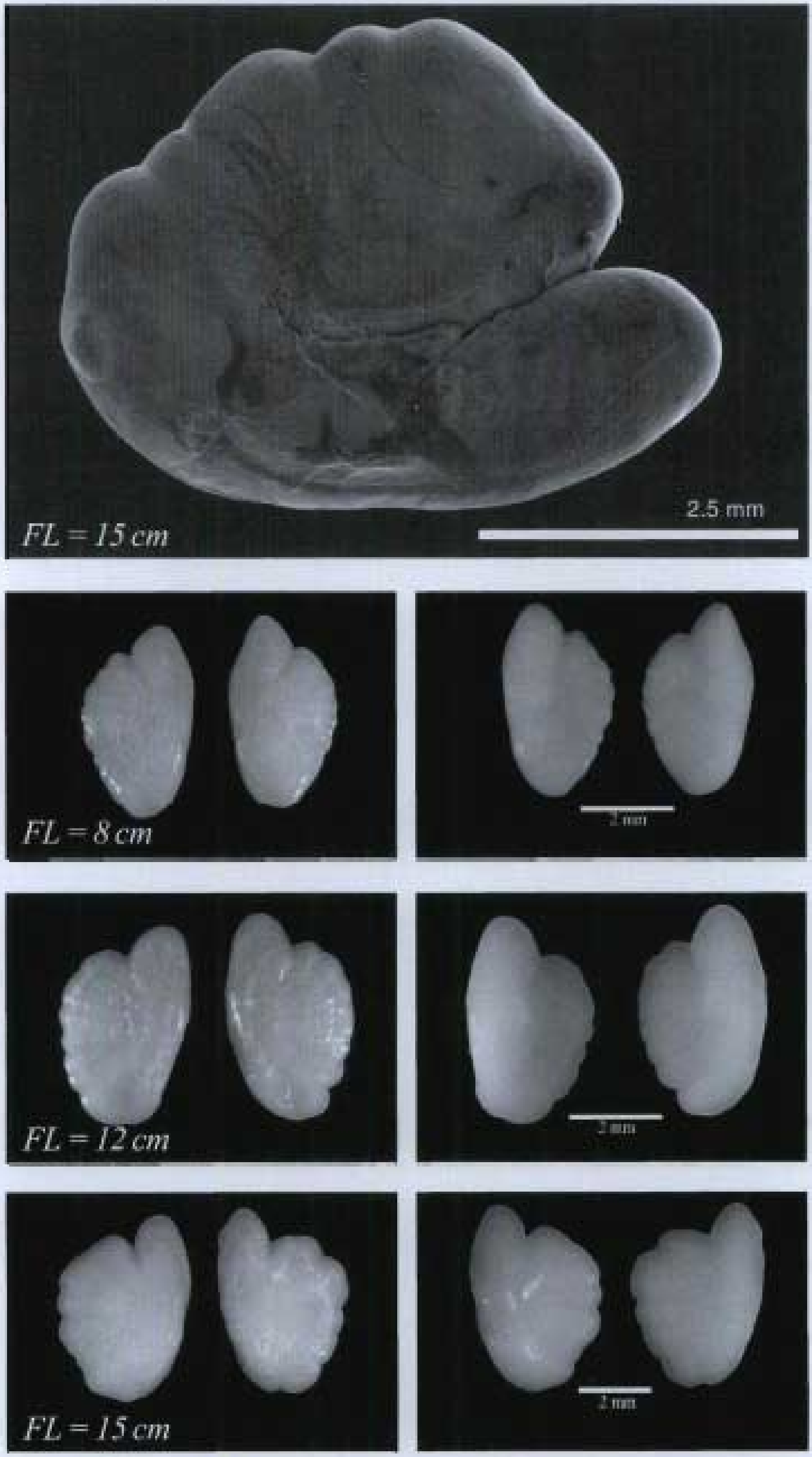
Liparidae: *Paraliparis copei*





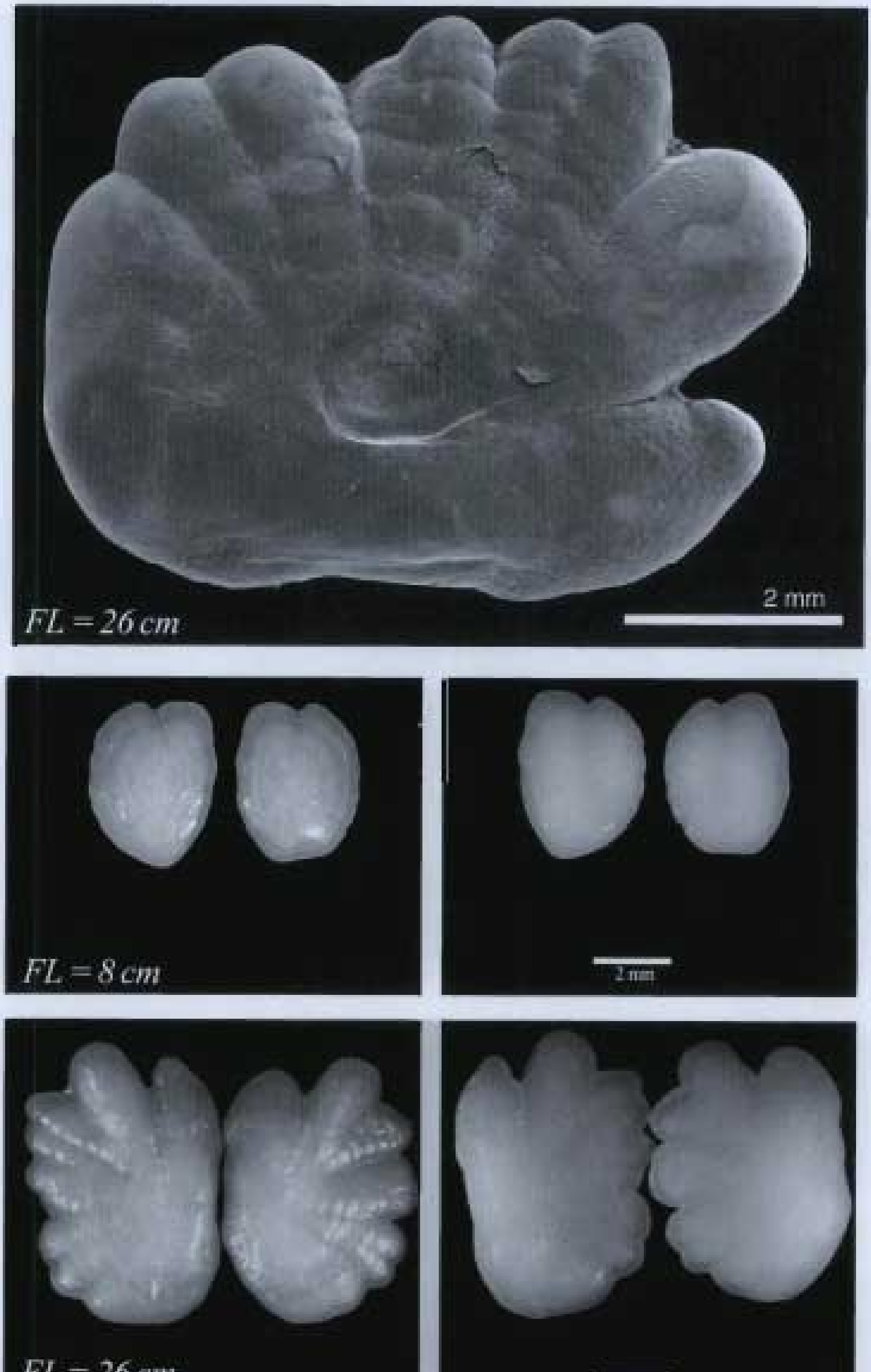
Scorpaeniformes

Psychrolutidae: *Cottunculus microps*



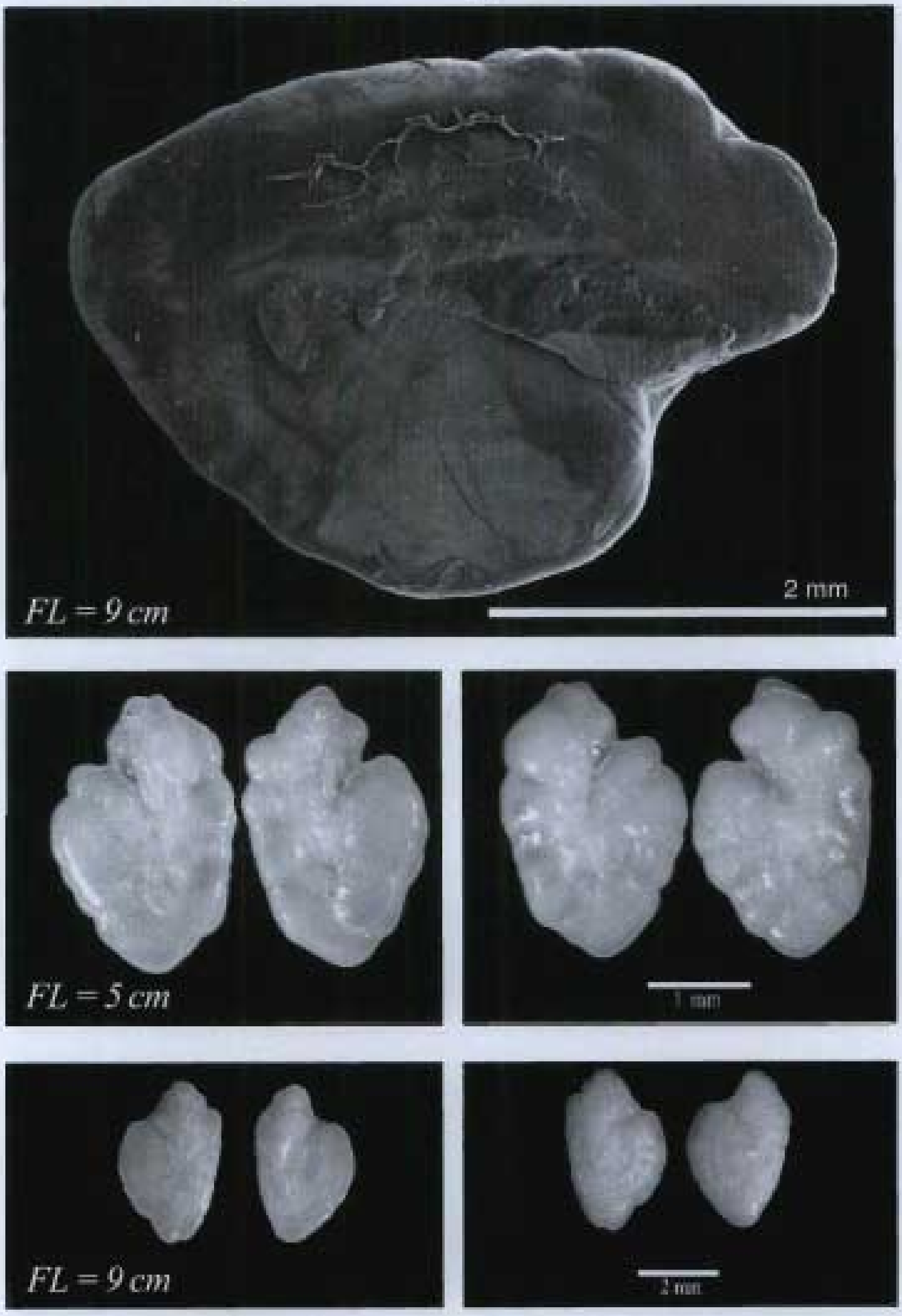
Scorpaeniformes

Psychrolutidae: *Cottunculus thomsonii*



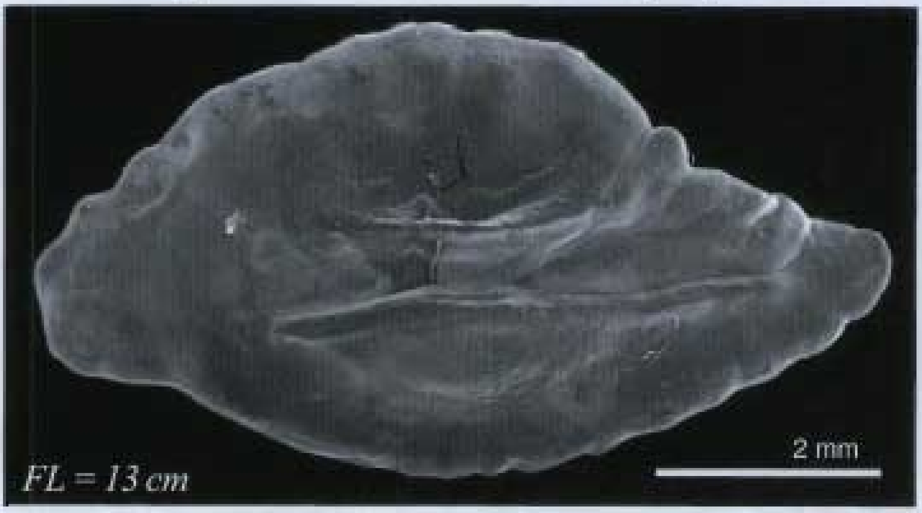
Scorpaeniformes

Scorpaenidae: *Ectreposebastes imus*



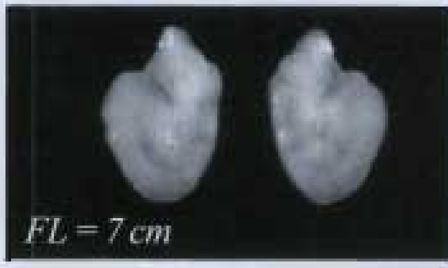
Scorpaeniformes

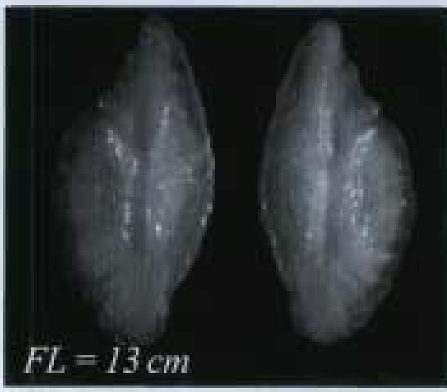
Scorpaenidae: *Helicolenus dactylopterus*



Asteriscii

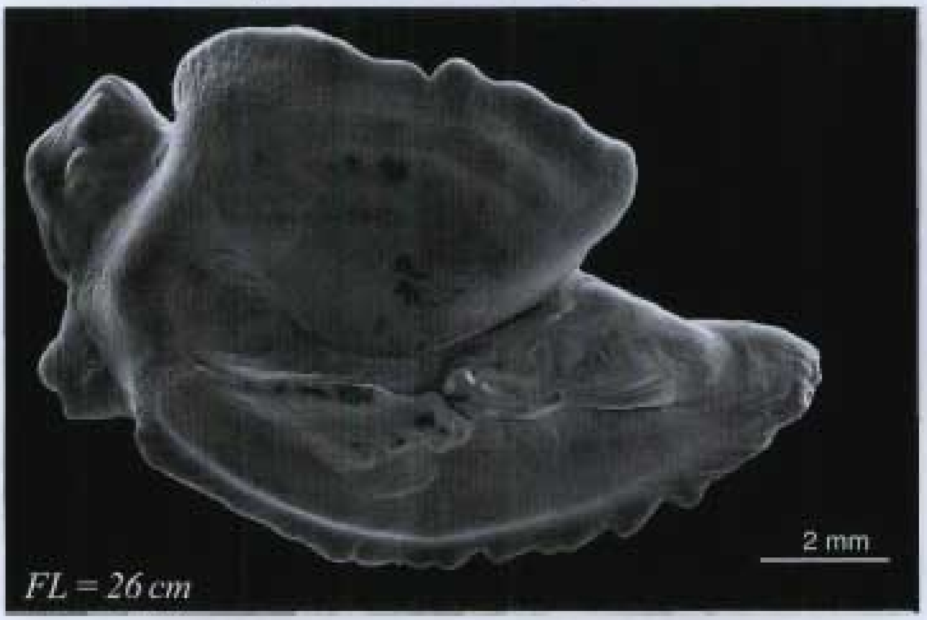
Lapilli





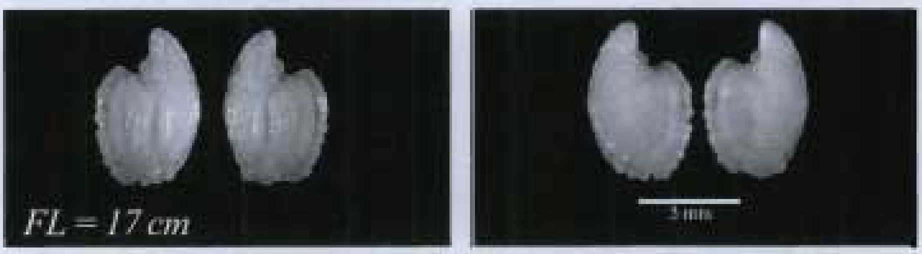
Scorpaeniformes

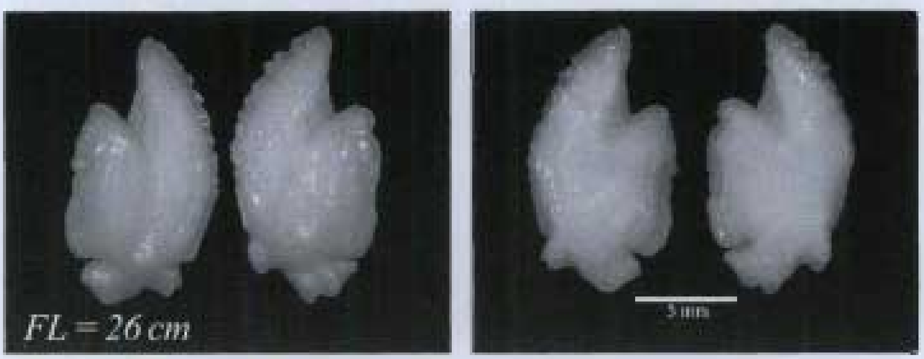
Scorpaenidae: *Sebastes fasciatus*



Asteriscii

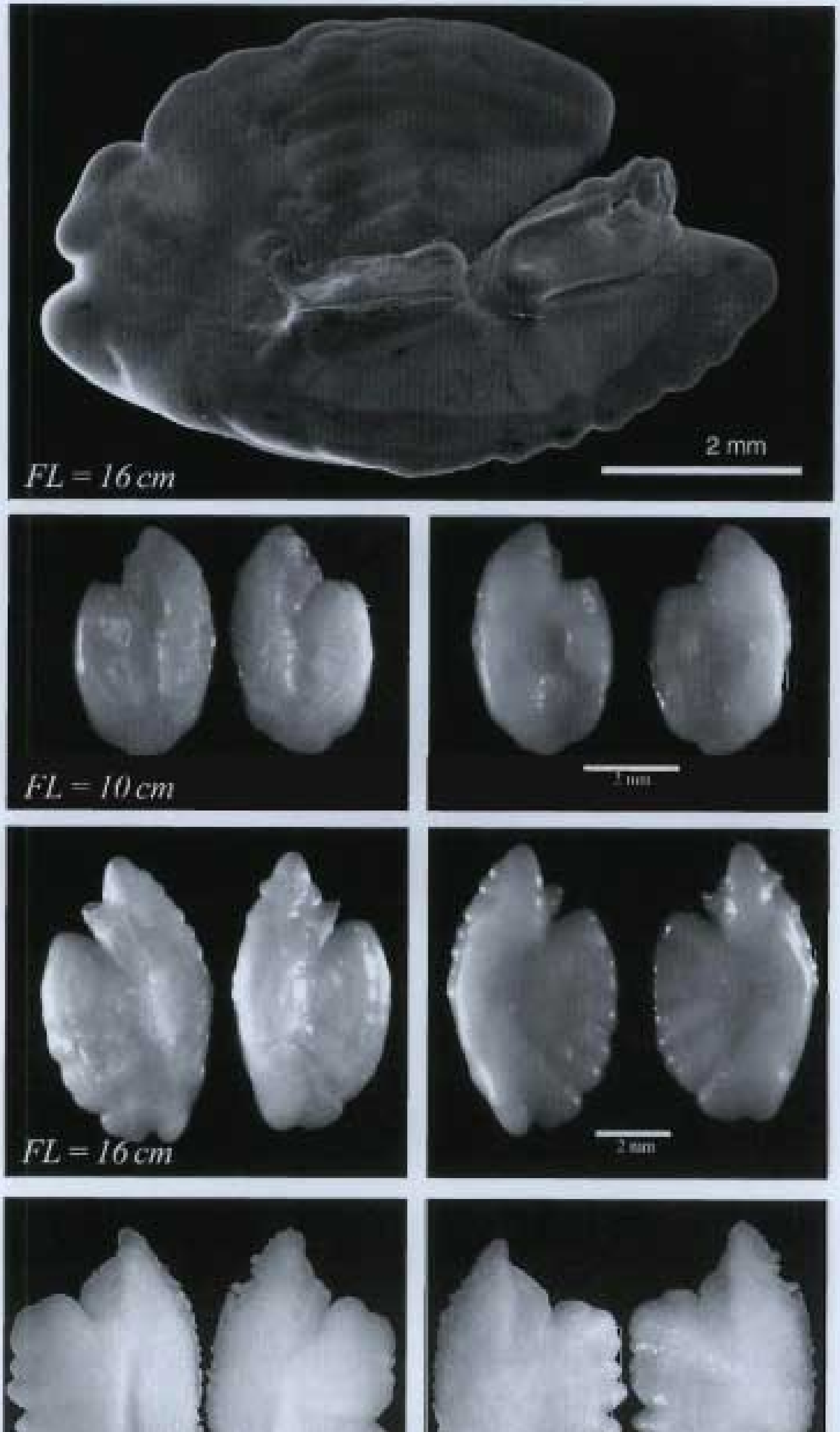
Lapilli





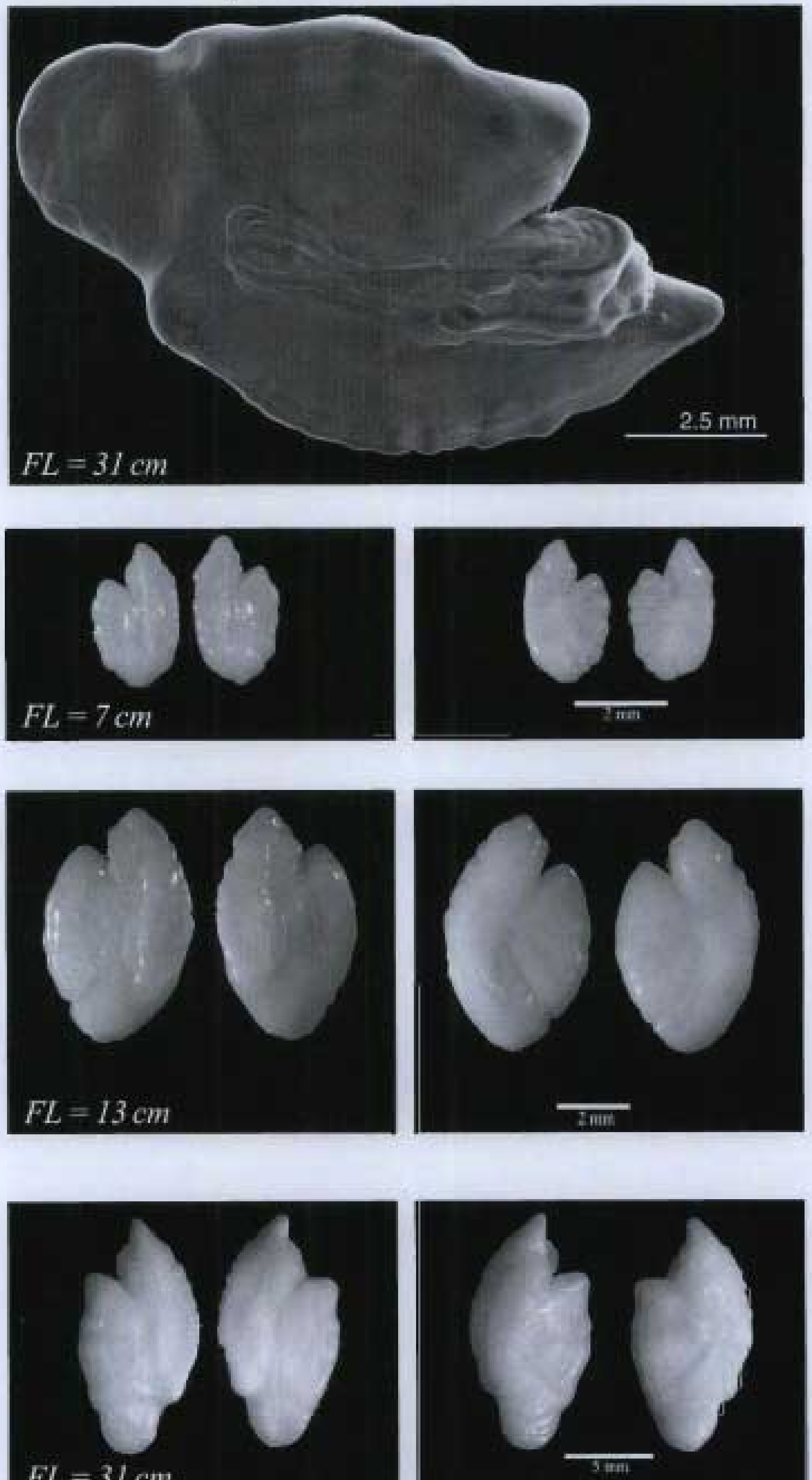
Scorpaeniformes

Scorpaenidae: *Sebastes marinus*

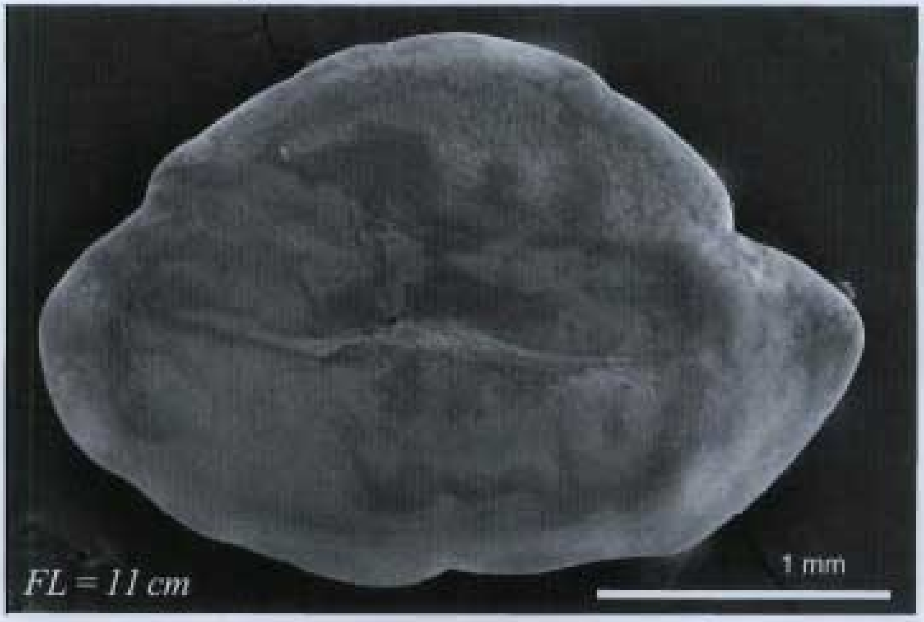


Scorpaeniformes

Scorpaenidae: *Sebastes mentella*

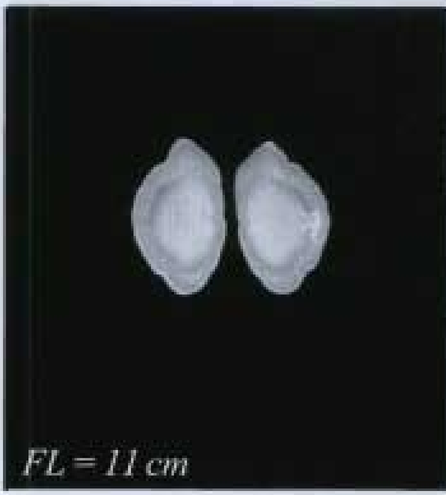


Triglidae: *Peristedion miniatum*



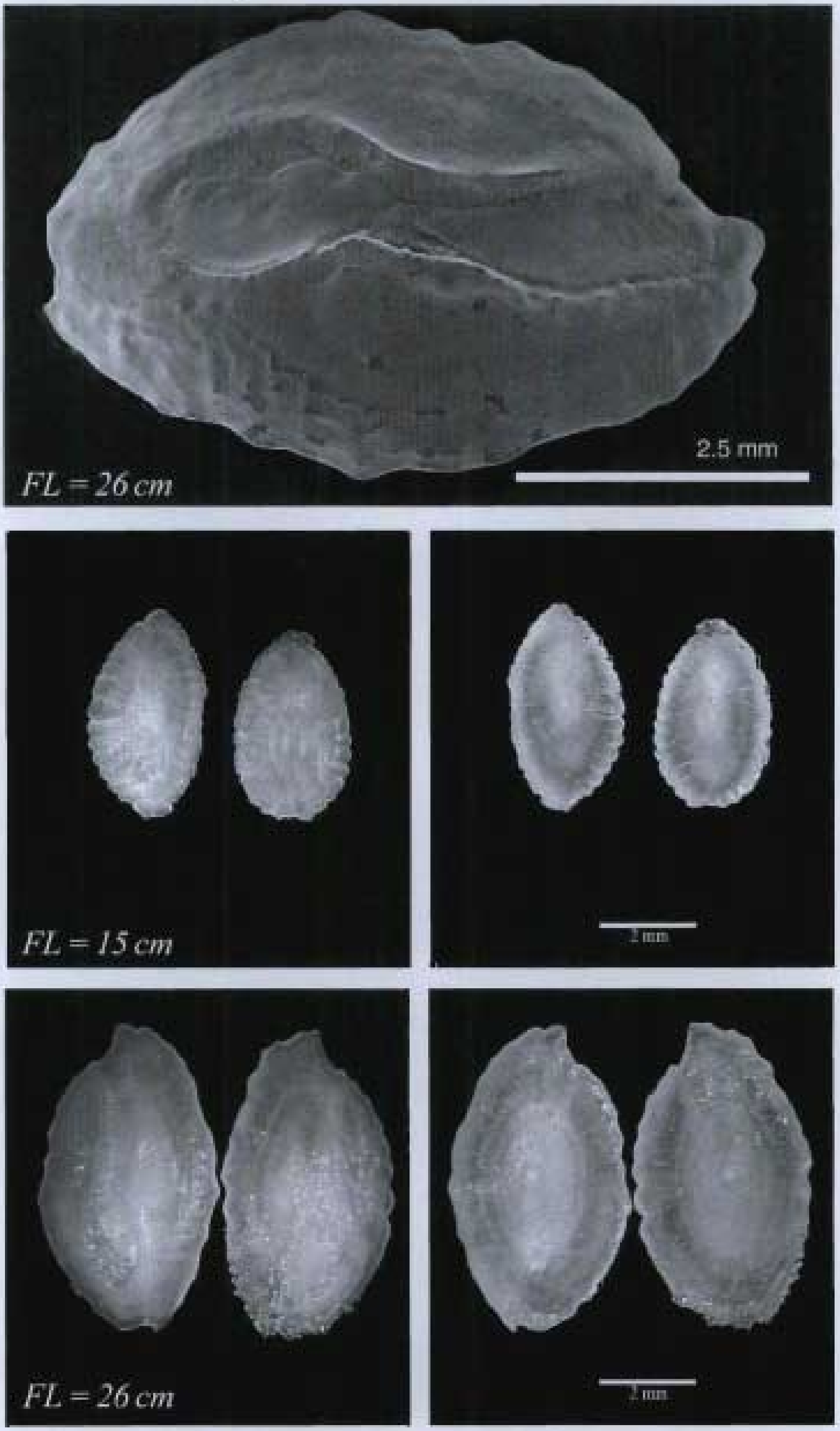
Asterisci

Lapilli



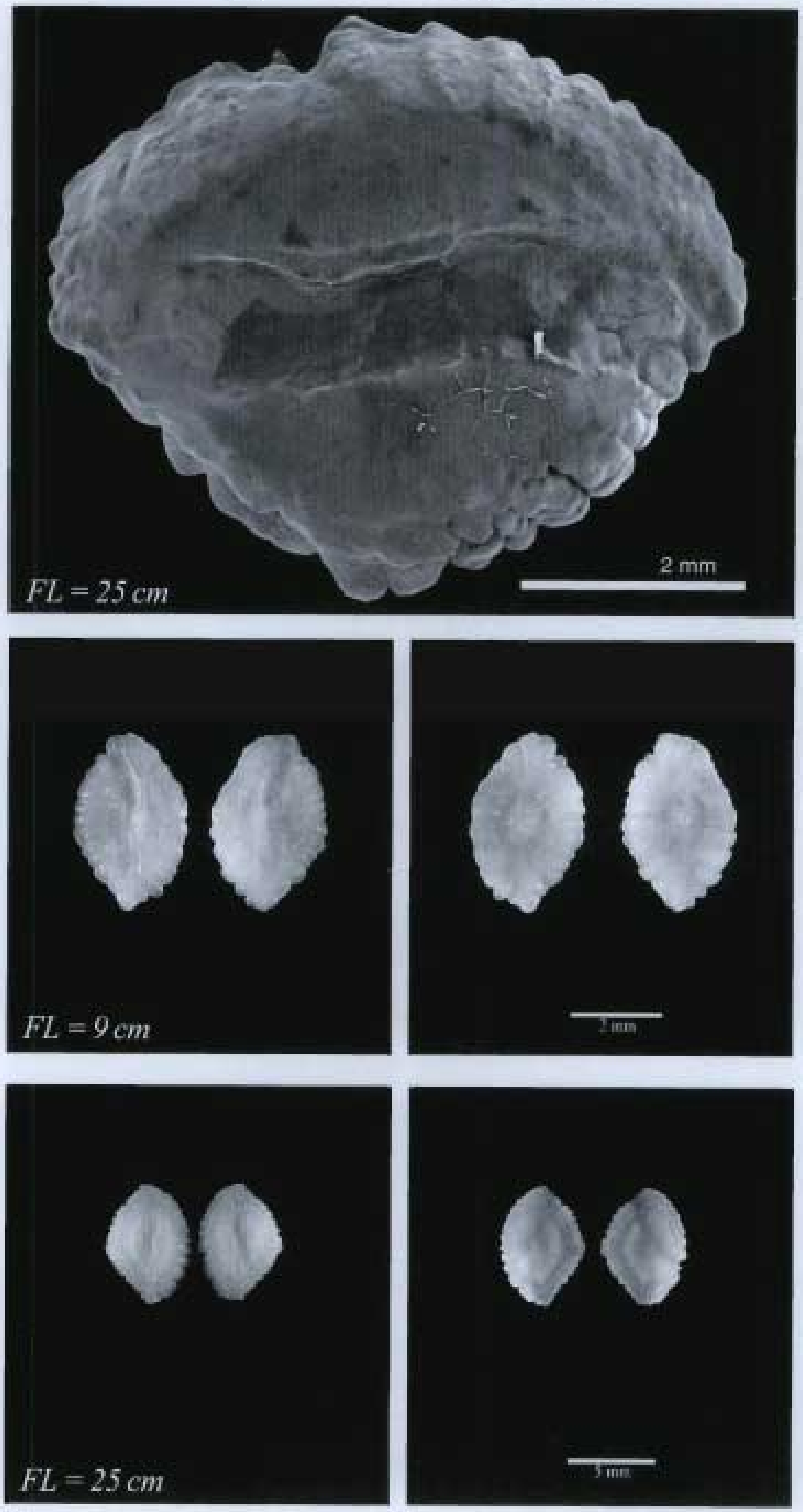
Scorpaeniformes

Triglidae: *Prionotus carolinus*



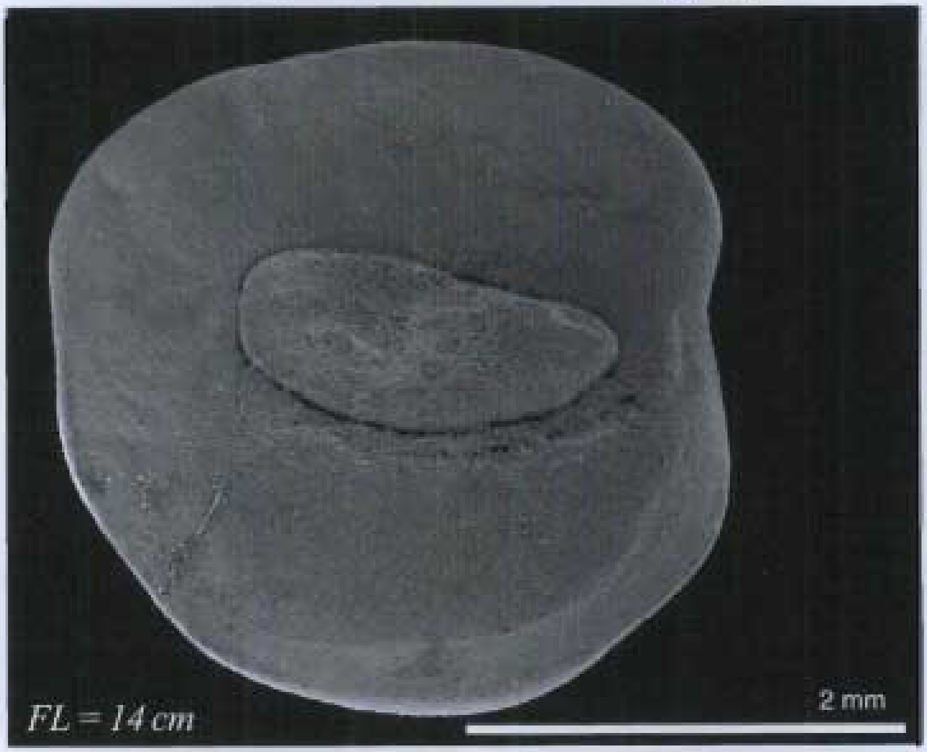
Scorpaeniformes

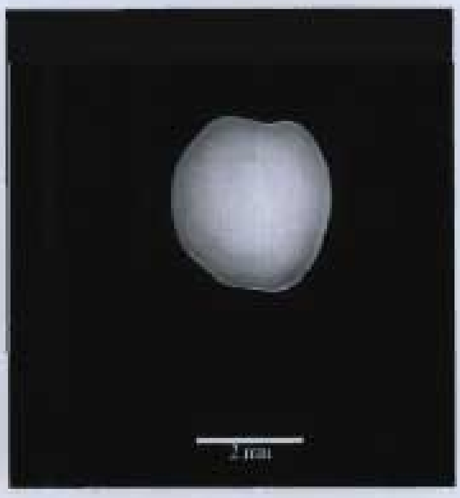
Triglidae: *Prionotus evolans*



Stephanoberyciformes

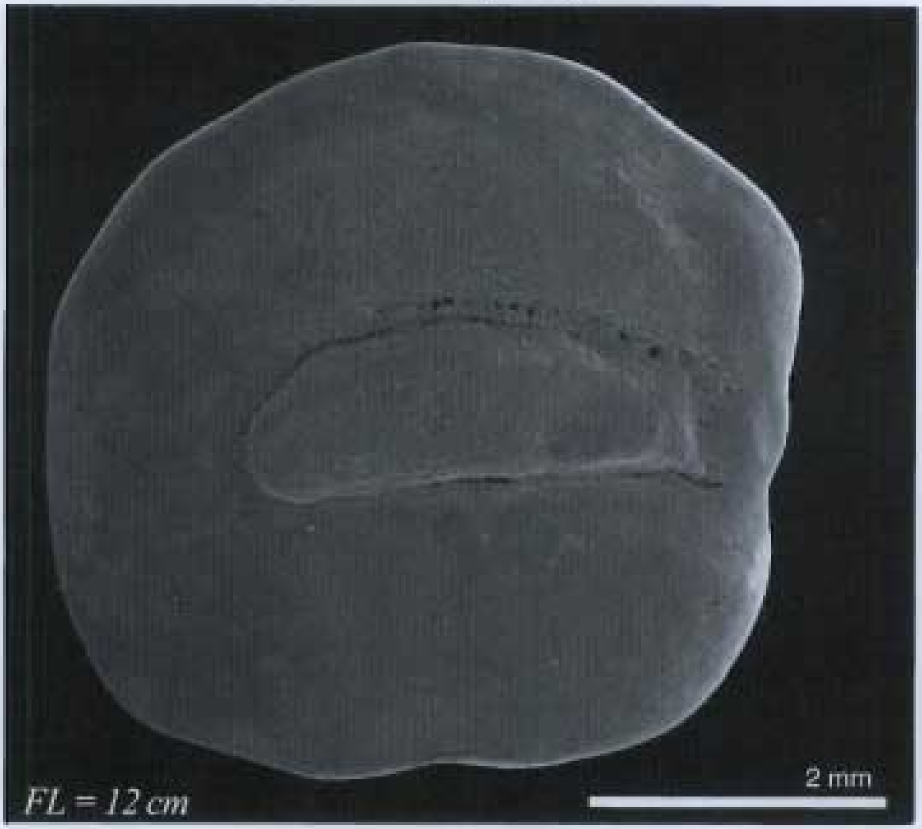
Melamphaidae: *Poromitra megalops*





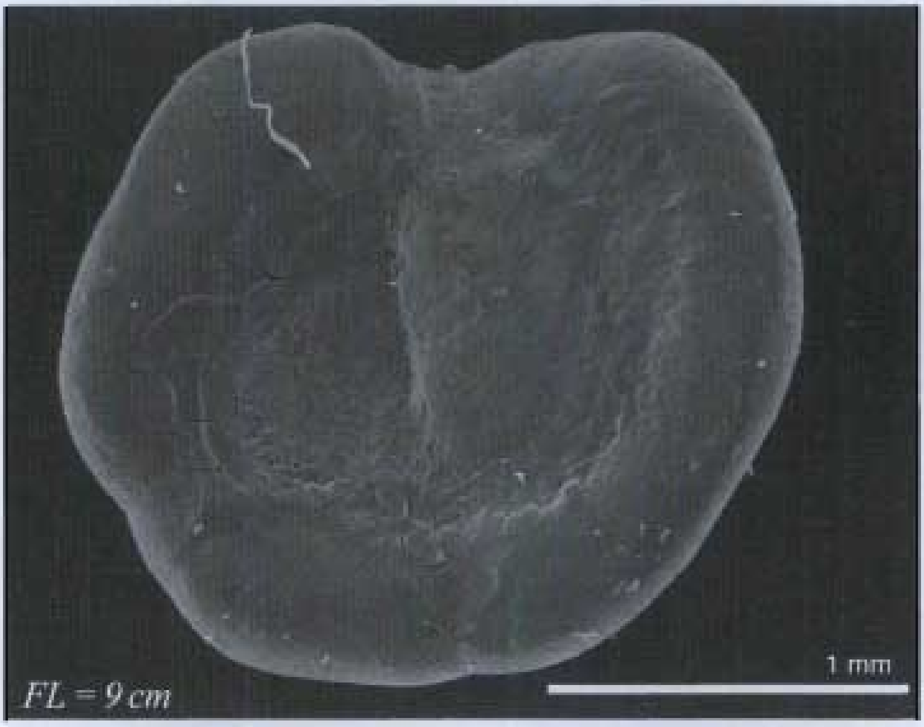
Stephanoberyciformes

Melamphaidae: *Scopelogadus beanii*



Stephanoberyciformes

Rondeletiidae: *Rondeletia loricata*

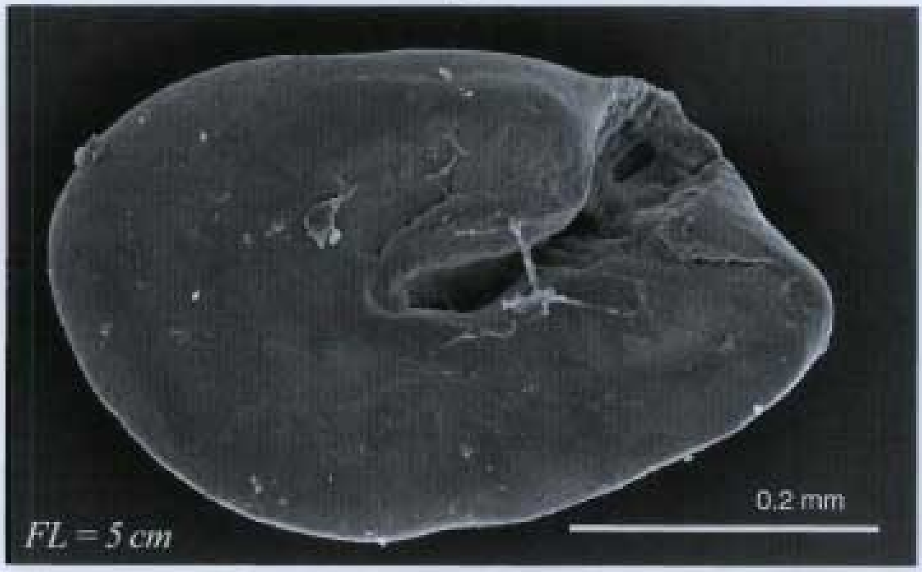


Asteriscii

Lapilli

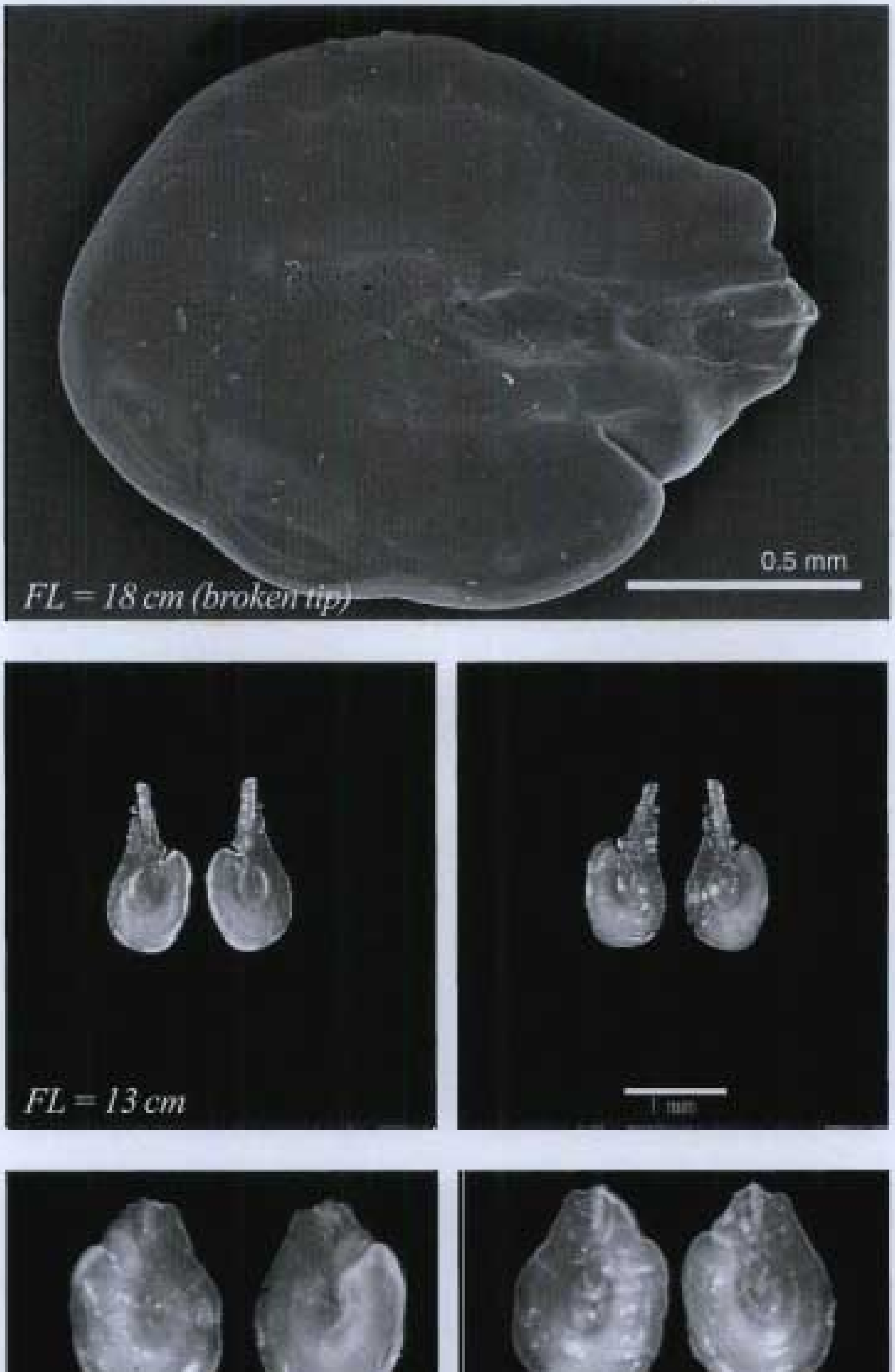
Stomiiformes

Gonostomatidae: *Cyclothone microdon*



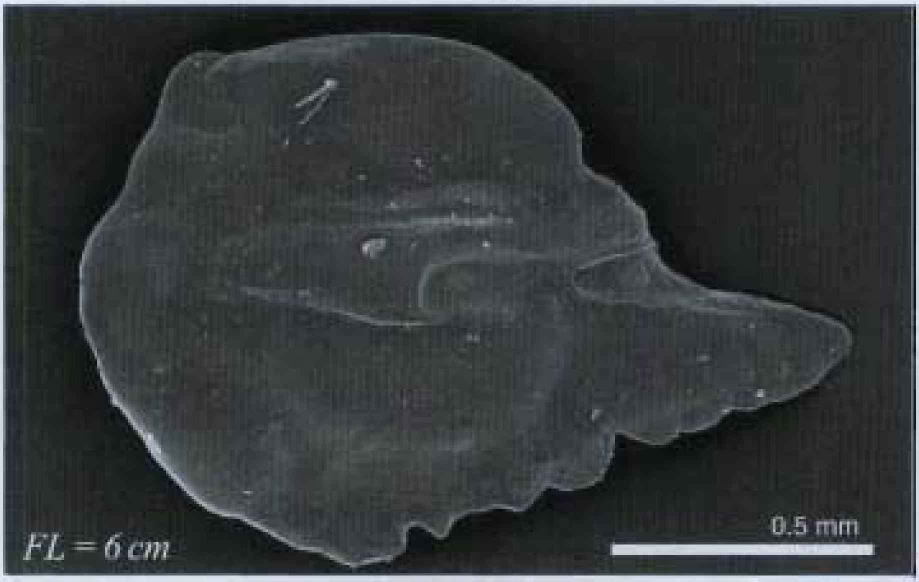
Stomiiformes

Gonostomatidae: *Gonostoma elongatum*



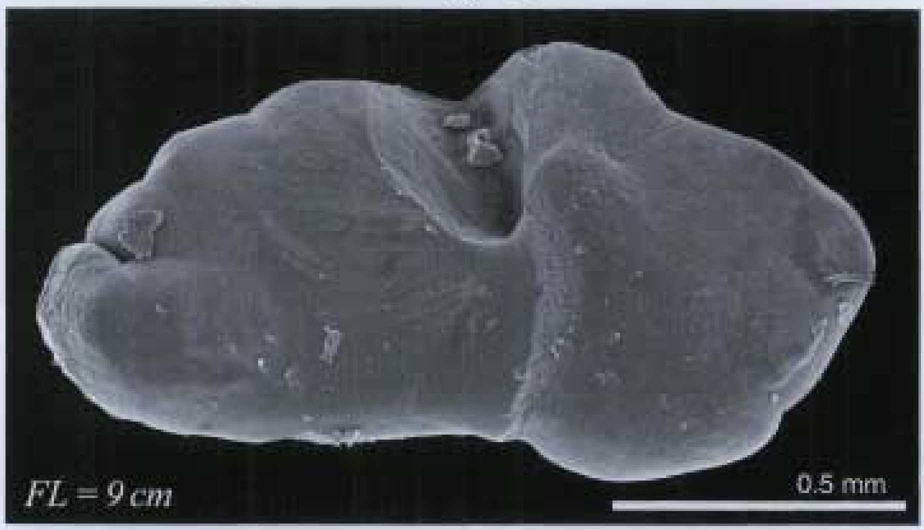
Stomiiformes

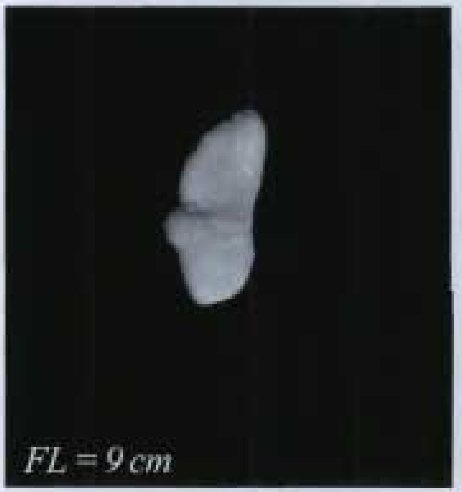
Gonostomatidae: *Vinciguerria nimbaria*

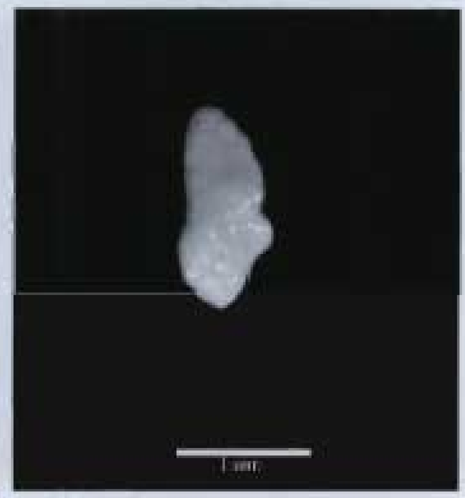


Stomiiformes

Sternoptychidae: *Argyropelecus aculeatus*

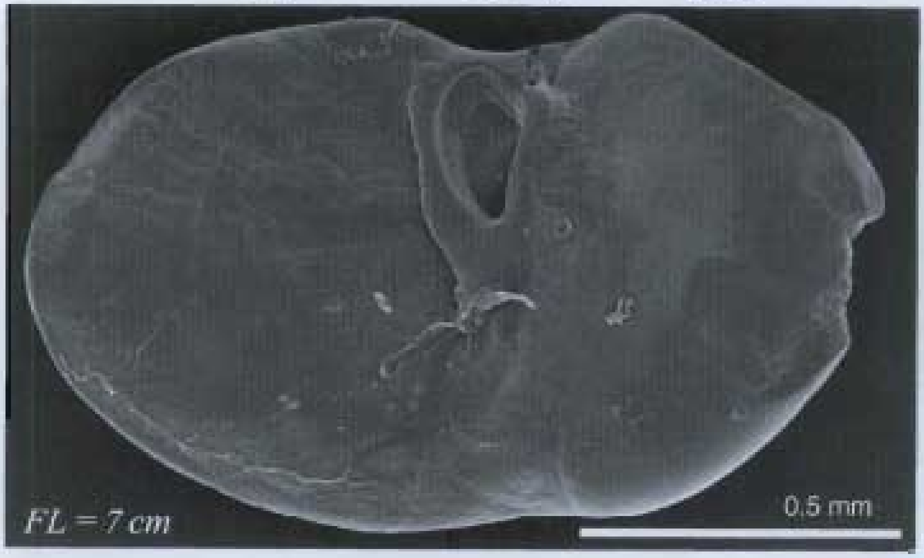






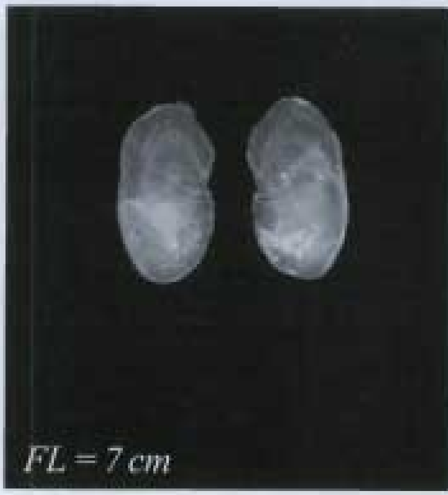
Stomiiformes

Sternoptychidae: *Argyropelecus gigas*

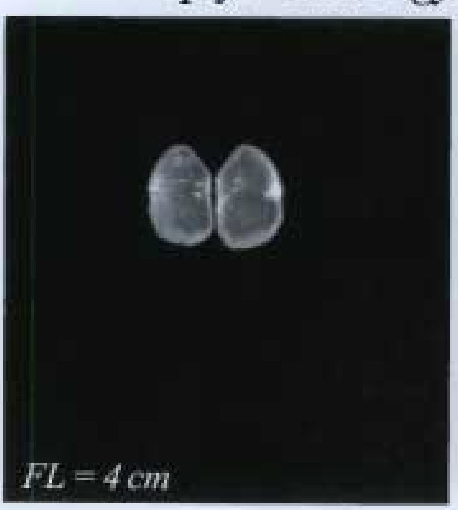


Asteriscii

Lapilli

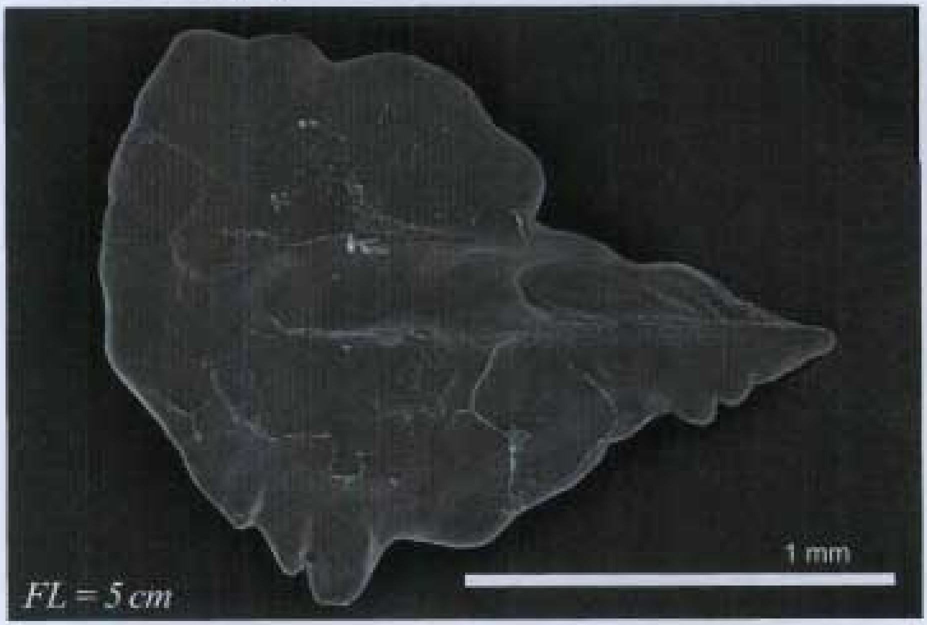


Sternoptychidae: *Argyropelecus hemigymnus*



Stomiiformes

Sternoptychidae: *Maurolicus muelleri*

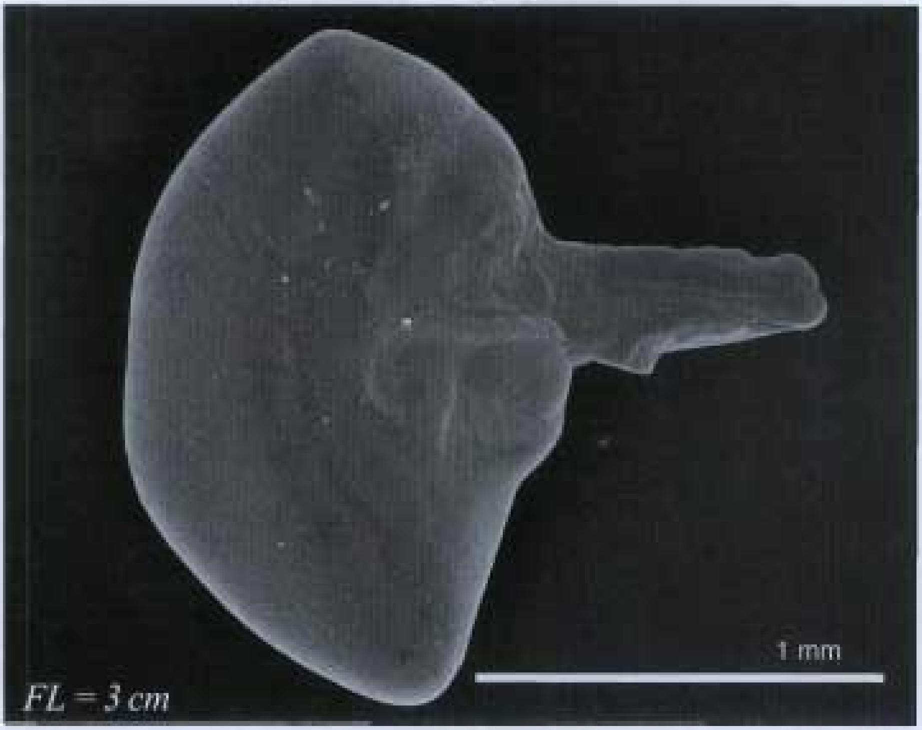


Asteriscii

Lapilli

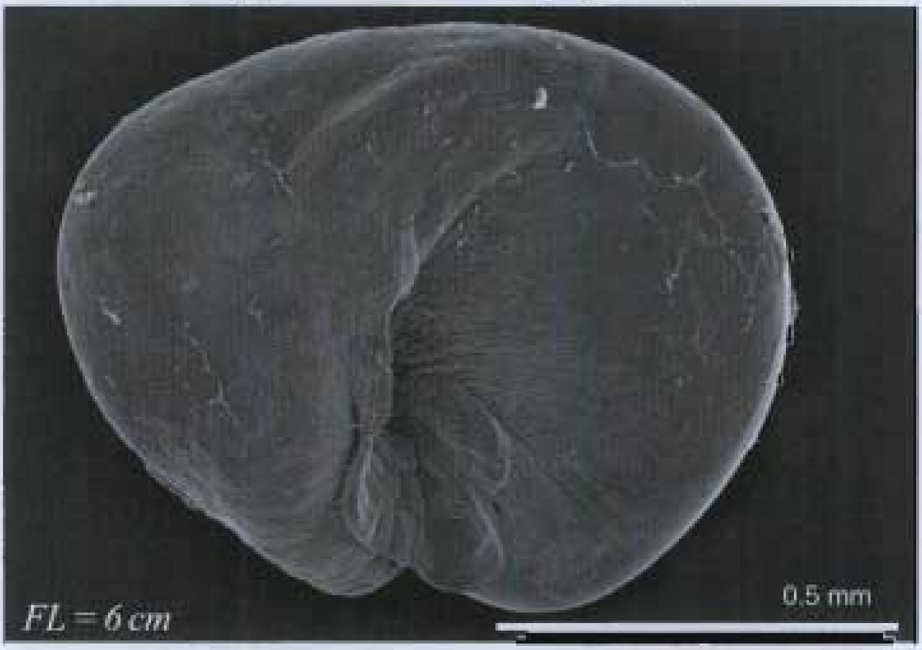
Stomiiformes

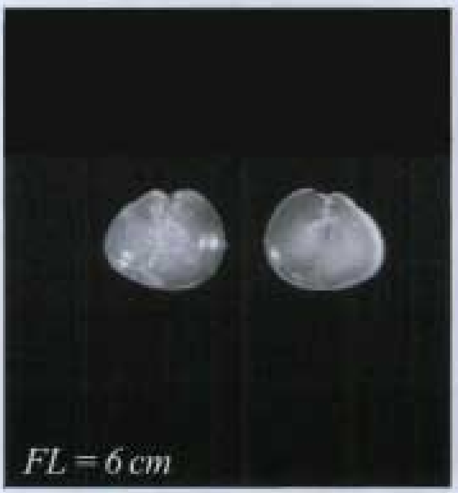
Sternoptychidae: *Polyipnus asteroides*

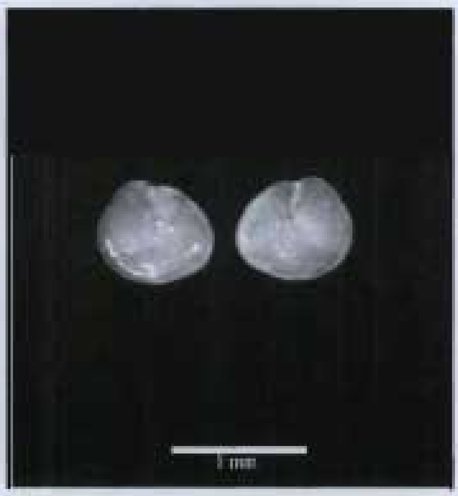


Stomiiformes

Sternoptychidae: *Sternoptyx diaphana*

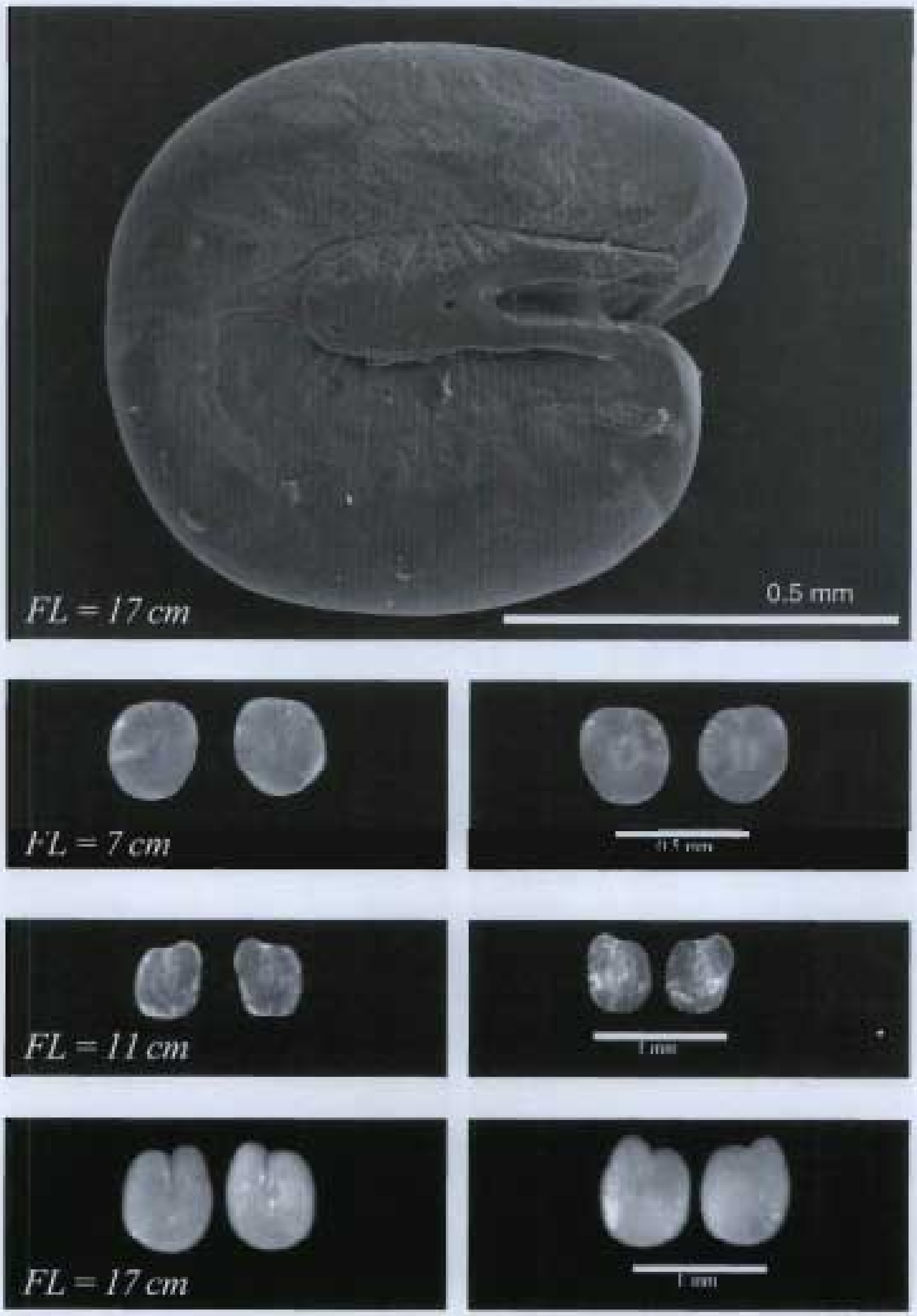






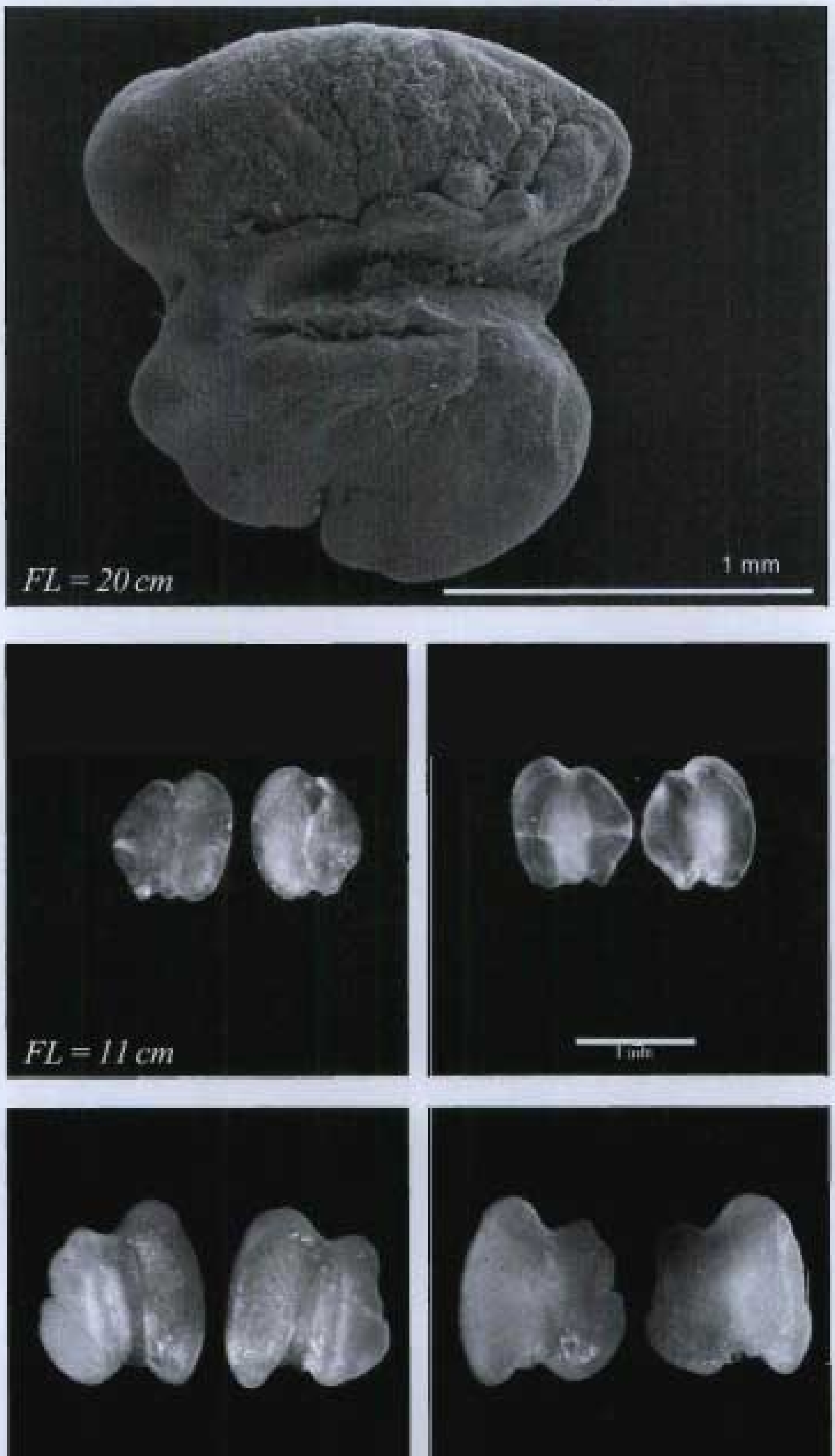
Stomiiformes

Stomiidae: *Chauliodus sloani*



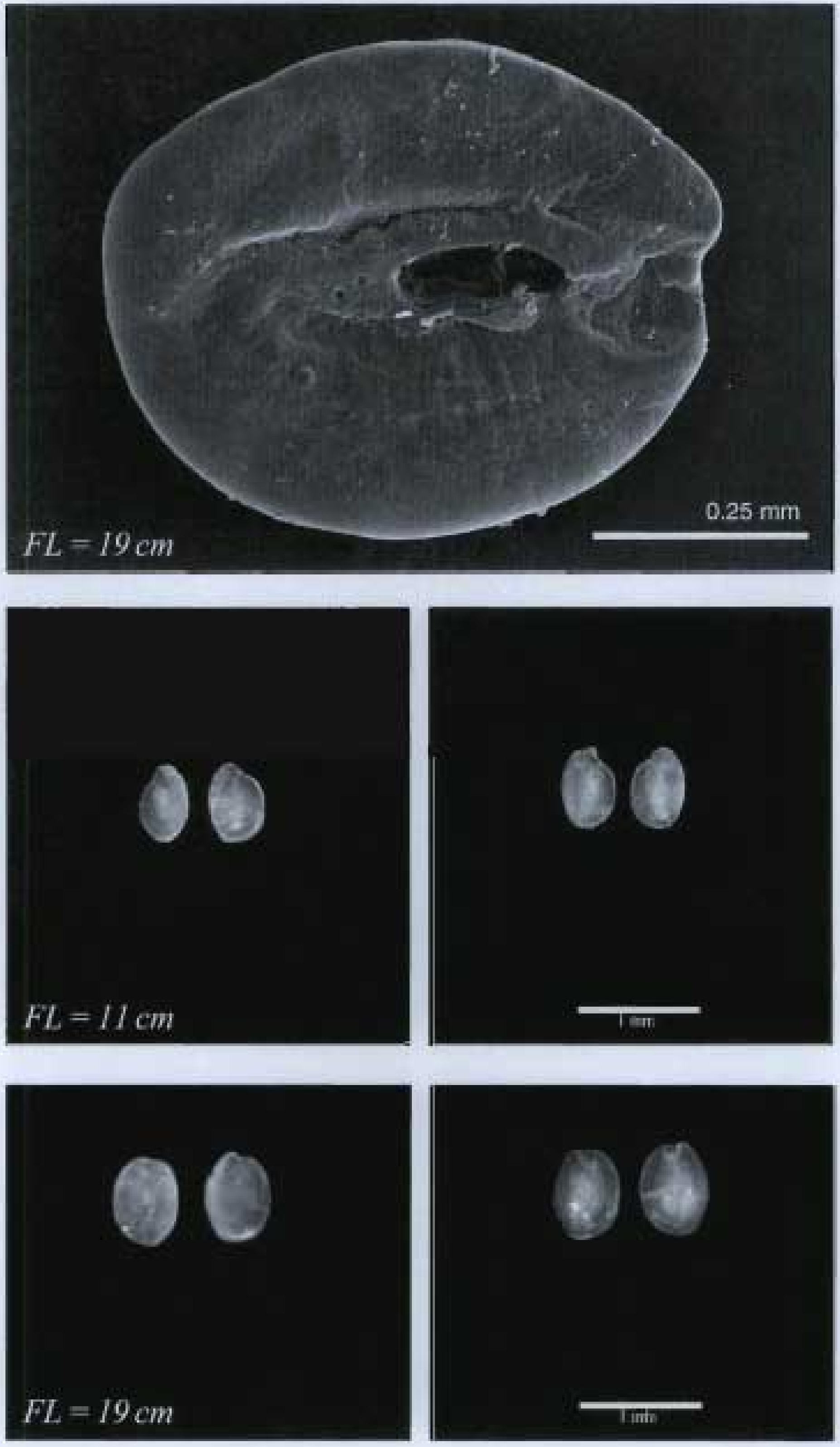
Stomiiformes

Stomiidae: *Malacosteus niger*



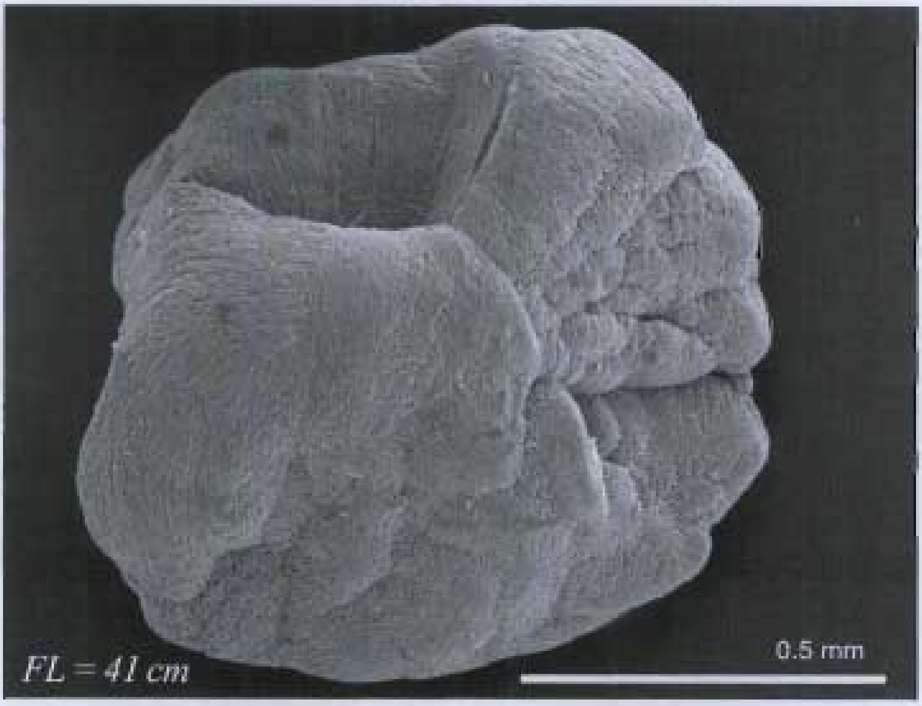
Stomiiformes

Stomiidae: *Stomias boa*



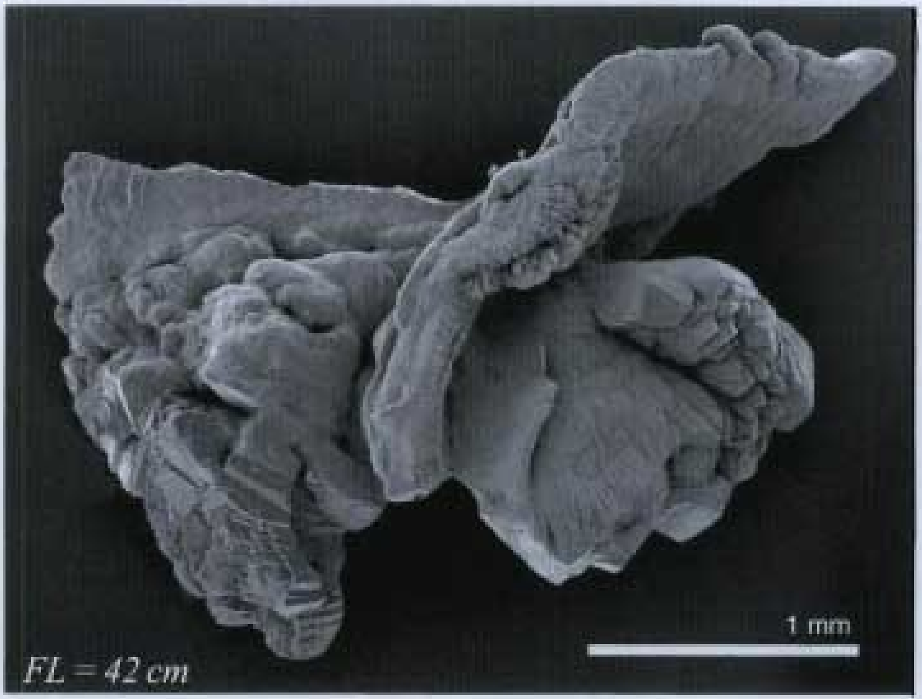
Stomiiformes

Stomiidae: *Trigonolampa miriceps*



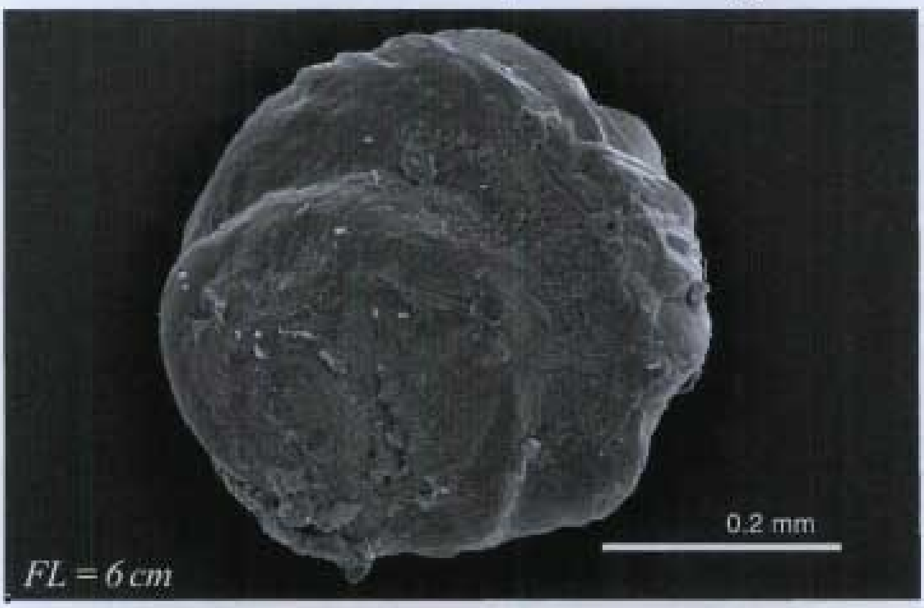
Tetraodontiformes

Balistidae: *Balistes capriscus*



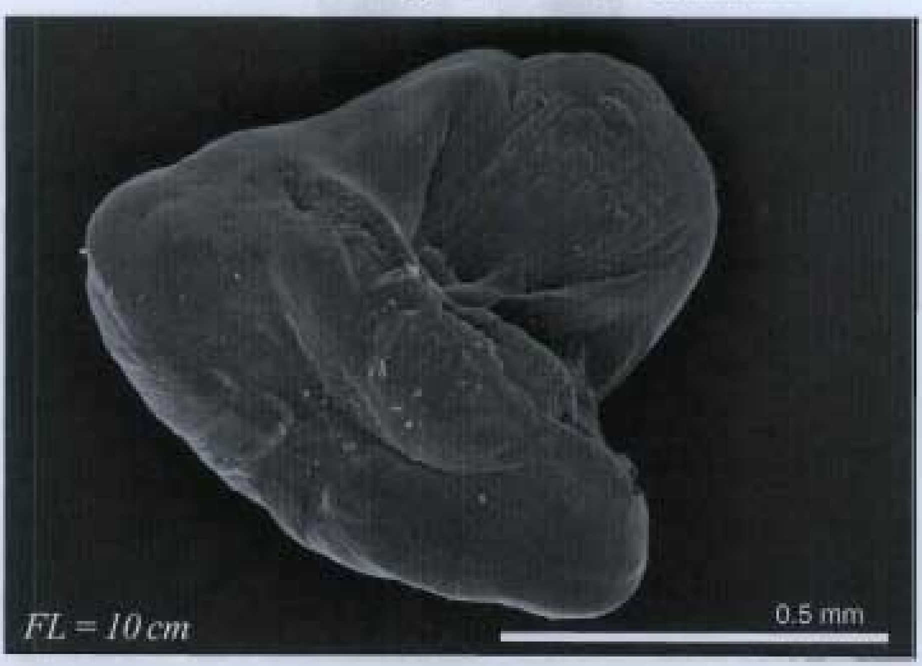
Tetraodontiformes

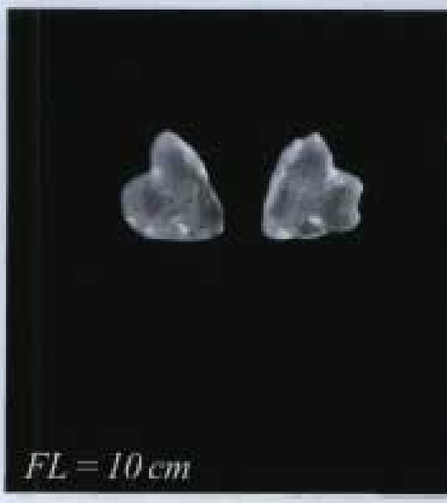
Diodontidae: *Chilomycterus schoepfi*



Tetraodontiformes

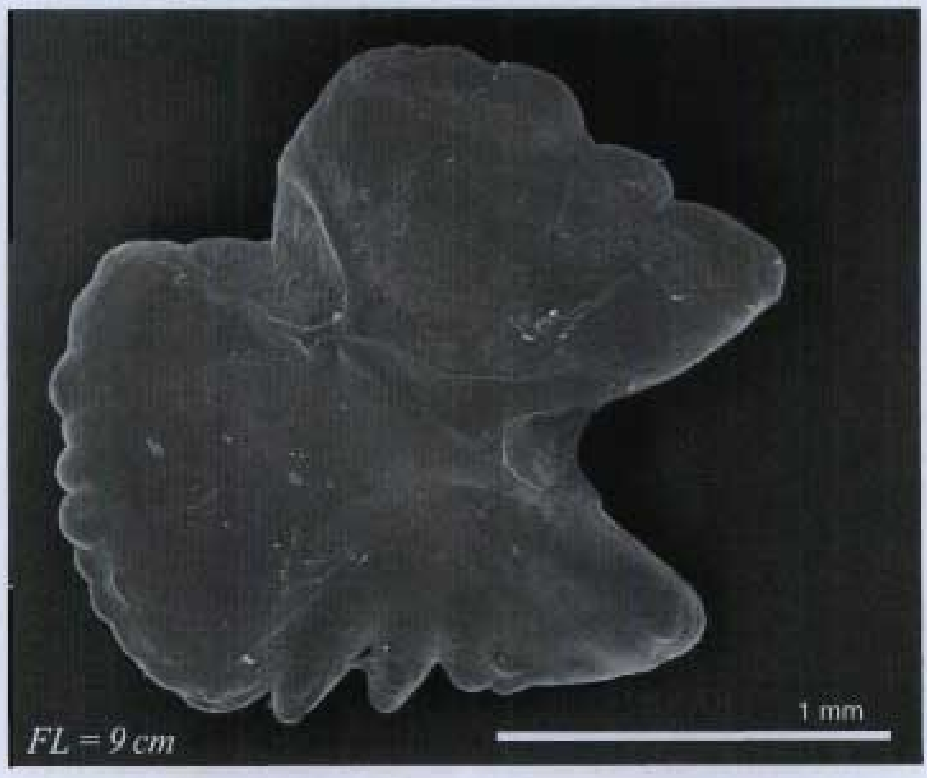
Tetraodontidae: *Sphoeroides maculatus*





Zeiformes

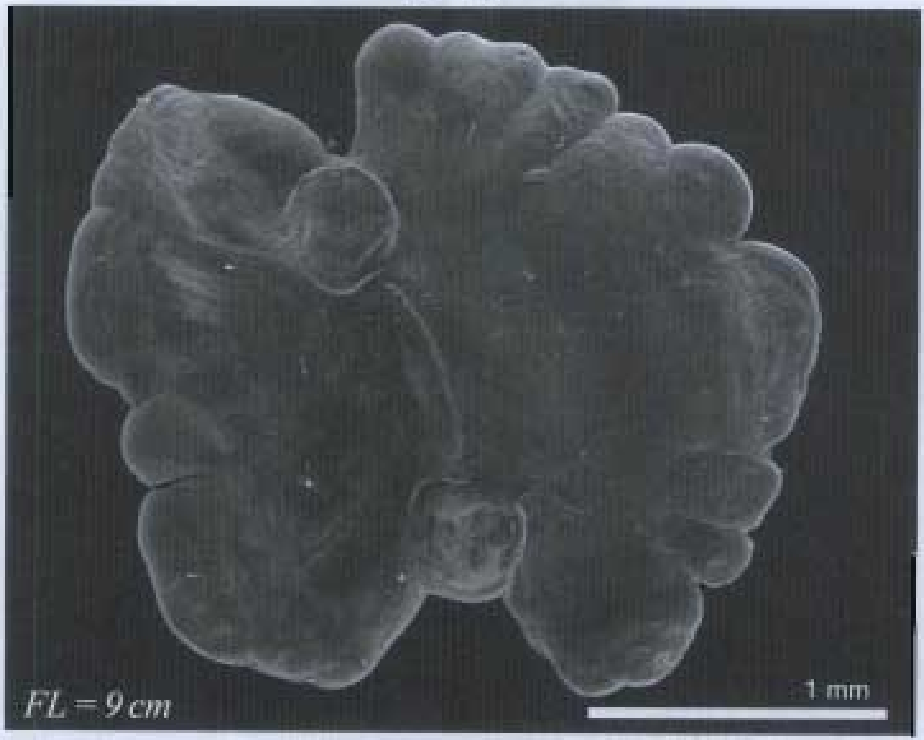
Grammicolepididae: *Daramattus americanus*



Zeidae: *Cyttopsis roseus*

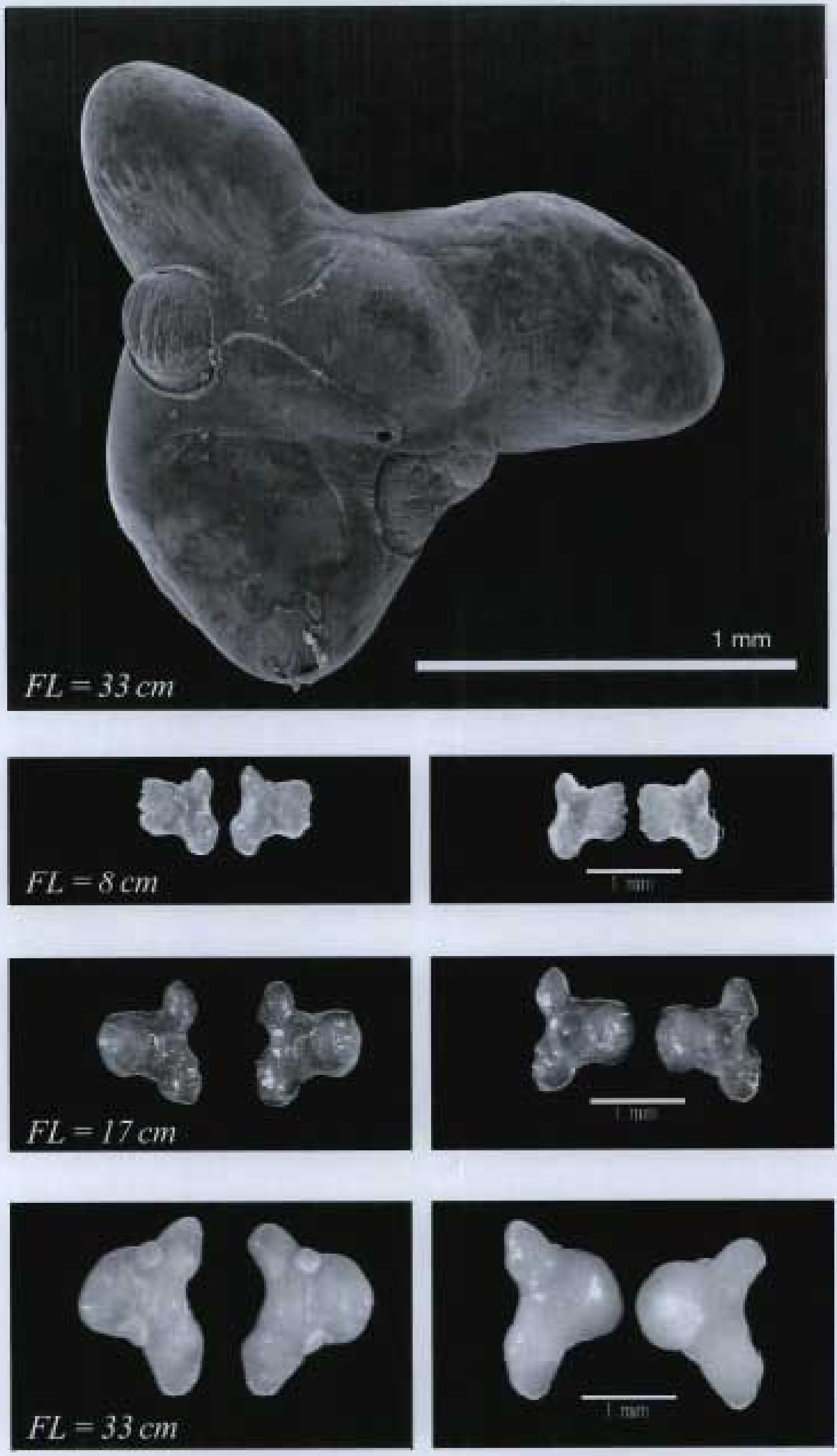
Asteriscii

Lapilli



Zeiformes

Zeidae: *Zenopsis conchifera*



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