Northeast Fisheries Science Center Reference Document 10-04

Brodeur's Guide to Otoliths of Some Northwest Atlantic Fishes

edited by RS McBride, JW Hauser, and SJ Sutherland

May 2010

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NOAA National Marine Fisheries Serv., 166 Water St., Woods Hole MA 02543

This second edition of Brodeur (1979) includes the original images of the sagittal otoliths for 51 common fishes of the Northwest Atlantic. Portions of the text have been updated and new citations have been included to give it a more contemporary perspective.

The companion website to the second edition is available at: www.nefsc.noaa.gov/femad/pbio/fbi/oto-guide/.

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

May 2010

Northeast Fisheries Science Center Reference Documents

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Information Quality Act Compliance: In accordance with section 515 of Public Law 106-554, the Northeast Fisheries Science Center completed both technical and policy reviews for this report. These predissemination reviews are on file at the NEFSC Editorial Office.

This document may be cited as:

McBride RS, Hauser JW, Sutherland SJ (eds). 2010. Brodeur's guide to otoliths of some northwest Atlantic fishes. Northeast Fish Sci Cent Ref Doc. 10-04; 35 p.
Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/nefsc/publications/

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Note: The otolith drawings are for a particular specimen of the length indicated. Other samples may vary.

Foreword

On the occasion of the 30th anniversary of Brodeur (1979), this guide is being issued in an updated second edition with a companion website. This guide is one of many guides used by fishery scientists, fish physiologists, zooarcheologists, etc., to identify otoliths of Atlantic Ocean fishes. Other more recent examples of otolith guides are: Hunt (1992), Campana (2004), Tuset et al. (2008), and Baremore and Bethea (2009).

Dr. Brodeur's guide to otoliths still has a place in our research today. It includes some species or some sizes of fish simply not found in any otolith guide for the marine waters of the Gulf of Maine, Georges Bank, and southern New England. A dog-eared copy of Brodeur (1979) still goes out on our Center's research vessels.

Various changes have been made in the new edition. The names of fishes have been updated to conform with Nelson et al. (2004). Newer references have been integrated into the text to give it a contemporary perspective of the literature. There is also a new montage feature that allows you to create a customized plate of otolith images.

Errors that existed in the original have been eliminated. American eel and round herring were omitted from this version because of erroneous information regarding either the fish size or the otolith size. Atlantic menhaden and armored sea robin were also omitted because there was no fish size recorded. The images for blueback herring and grubby have been switched because they had been incorrectly assigned in the original document. As in the original, there is no documentation on which sagittal otolith (left or right) was used nor labeling of the posterior–anterior orientation of the drawings.

Richard S. McBride
National Marine Fisheries Service
Woods Hole, Massachusetts
December 2009

Introduction

Fish earstones, which scientists call otoliths, are used by bony fish for hearing and balance. The value of otoliths for determining the age of fish has long been recognized by fishery biologists (Jackson 2007). Scientists involved in fisheries stock assessment use otoliths to age fish and thereby to estimate how old fish live, how fast they grow, and to predict how many fish will be available next year. There have been special symposia convened on the subject (Bagenal 1974, Summerfelt and Hall 1987, Stevenson and Campana 1992, Secor et al. 1995, Begg et al. 2005), and there are practical guides for preparing otoliths to estimate fish age (Jearld 1983, Penttila and Dery 1988, Secor et al. 1992, VanderKooy 2009).

Other scientists have used otoliths for a variety of purposes. They have been used to investigate changes in marine populations that occurred before modern fishing practices, to speculate on the evolutionary relationships between species, or to infer the fish diets of marine predators or even of pre-historic peoples.

Otoliths have become an important paleobiological tool (Campbell 1929, Frizzel and Dante 1965, Casteel 1974b, Schwarzhans 1978, Elder et al. 1996, Wurster and Patterson. 2003). Wigley and Stinton (1973) examined sediments from the Northwest Atlantic and found high densities of otoliths which they were able to assign to at least 26 species.

Otoliths are used to differentiate between closely allied species (Schmidt 1969, Casteel 1974a Price 1978, and Chao 1978) or to investigate their evolutionary relationships (Nolf 1985, Maisey 1987, Nolf 1993). Minute but constant intraspecific variations in otolith structure have been used to identify stocks or races within a fish population (Parrish and Sharman 1958, Kotthaus 1961, Messieh 1972, Rojo 1977, Begg and Brown 2000, Begg et al. 2000, Berg et al. 2005).

Otoliths have been used to construct food webs in marine ecosystems because they are often all that remains as evidence of fish predation. They have been used to identify the diet of sharks (Talent 1976), birds (Suter and Morel 1996), marine mammals (Fitch and Brownell 1968, Perrin et al. 1973, Gamboa 1992, Grellier and Hammond 2005), and prehistoric peoples (Casteel 1972, Hales and Reitz 1992).

A seminal guide to otoliths is found in a series of papers by Frost (1925a-c, 1926a-c, 1927a-b, 1928a-b, 1929, 1930a-b), who illustrated the otoliths of a large group of bony fishes and commented on their relationships. Regional otolith guides exist for coastal fishes of west Africa (Eziuzo 1963), Alaska (Morrow 1979), and Texas (Zimmerman et al. 1987). Recent guides to the otoliths of Atlantic Ocean fishes have been published by Hunt (1992), Campana (2004), Tuset et al. (2008), and Baremore and Bethea (2009). This reissue of Brodeur (1979) includes the original images of the sagittal otoliths for 51 common fishes of the Northwest Atlantic.

Methods

Otoliths were removed from fresh or frozen fish, caught primarily on NMFS bottom trawl surveys (Reid et al. 1999). Other methods of capture included baited traps, hook and line, and

scuba diving. Care was taken to insure that only otoliths from adult fish were used for this study as some morphological changes in otolith structure do occur during maturation. Some of the more delicate otoliths were stored in a solution of 40% alcohol and 60% glycerin while the others were simply stored dry in labeled vials. No otoliths were taken from fish preserved in formaldehyde, as preservation in this solution for even a short period of time dissolves away the distinguishing features. The illustrations were drawn with the aid of a binocular dissecting scope, and measurements were made using an ocular micrometer. The Fishery Biology Program of the Northeast Fisheries Science Center maintains an otolith reference collection in Woods Hole, Massachusetts.

Otolith Structure

The labyrinth system of the teleostean skull actually contains three pairs of otoliths: the sagittae, the lapilli, and the asterisci. The sagittae, found within the sacculi, are by far the largest in most species and are referred to when the general term otolith is used. The sagitta is suspended in lymph fluid obliquely in the sacculus with the concave surface facing medially. The sagitta pair is easily exposed by making a lateral cut through the posterior section of the fish brain. The main function of the sagitta is as a sound receptor. See Blacker (1974), Popper (1977), and Popper et al. (2005) for a more complete description of otolith structure and studies related to it.

There is much variation in otolith size when comparing fish species. In this study, for example, an 82 cm ocean pout (*Macrozoarces americanus*) yielded a 4.7 mm otolith, while a smaller (69 cm) haddock (*Melanogrammus aeglefinus*) had a much larger (21.5 mm) otolith. Intraspecific variation in otolith size, however, is minimal for fish of the same age and size.

Surface structure and general outline of the otolith are also species-specific. Variations and gradations do occur in the transition from juvenile to adult stages, and the fact that only adult otoliths are pictured here should be taken into consideration when using this guide. There is also some variation in otolith shape between individual fish of a given size within a species.

Figure 1 is of a typical otolith and shows some of the key morphological characters used for the identification or differentiation of species. Some of the more important features are general outline and size of otolith, depth of the excisura, length and shape of the rostrum and antirostrum, depth and shape of the sulcus, location and size of surface concretions and ridges. Often several of these characters must be examined simultaneously for closely allied species. Morrow (1979), Nolf (1985), or Tuset et al. (2008) can be consulted for more detailed definitions of the structures labeled in Figure 1 and for a more complete perspective on the variations in otolith shape.

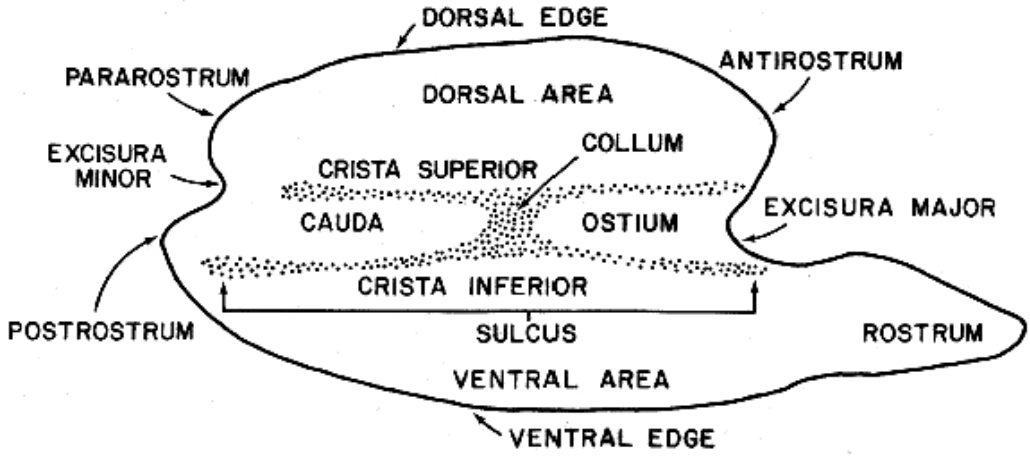

Figure 1. Diagram of inner face of left sagitta showing important characters (Modified from Messieh, 1972 & Morrow, 1979)

Species Selection

The species selected are considered important within the study area and are likely to be potential prey of Northwest Atlantic piscivores. Among the list are the most important fish in terms of biomass (Edwards and Bowman 1979) as well as other fish that are commonly caught in bottom trawls (Bigelow and Schroeder 1953, Collette and Klein-MacPhee 2002). Southern demersal species which stray into the study area during the warmer months of the year have been excluded. Inshore, anadromous, and pelagic species may be incompletely represented due to the sampling methodology employed. Common and scientific names follow Nelson et al. (2004).

Acknowledgments

Louise Dery and Paul Andrews collected and sorted otoliths. Betsey Pratt painstakingly illustrated the otoliths. Roland L. Wigley provided financial support, and Richard W. Langton provided moral support and a critical review of the original manuscript.

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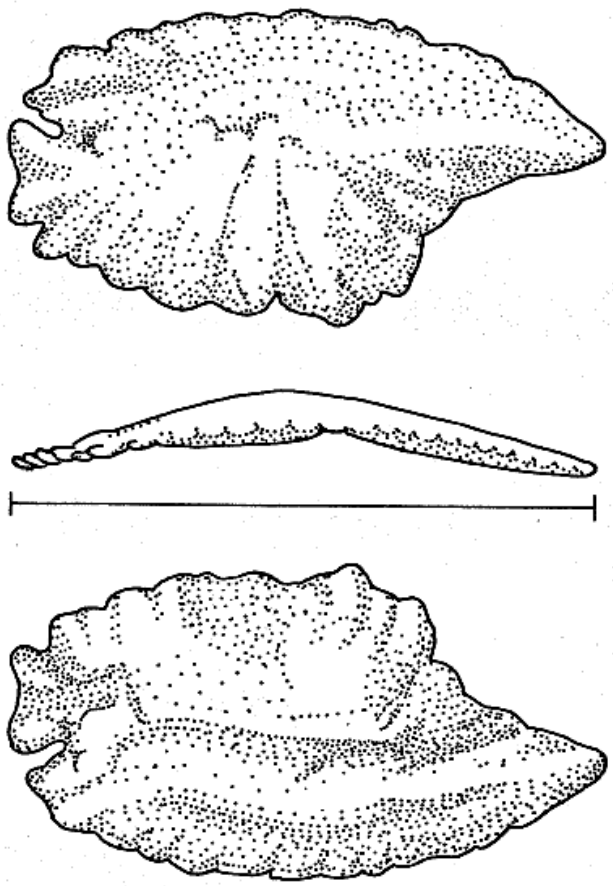
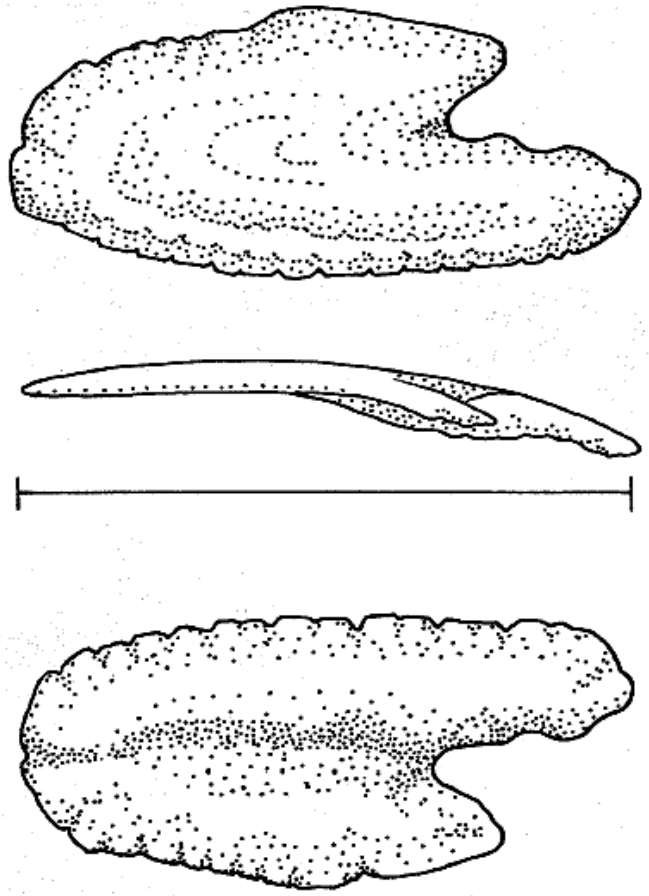
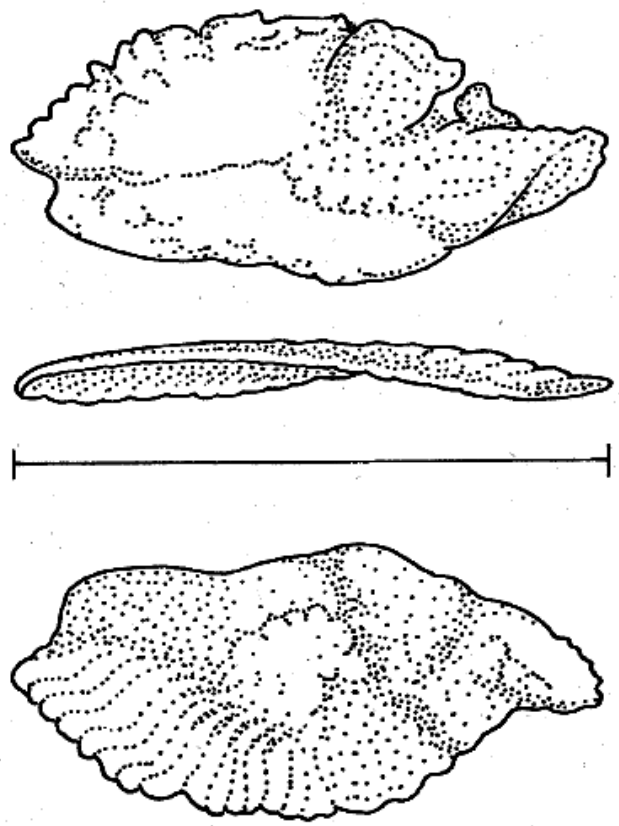
Otolith Images



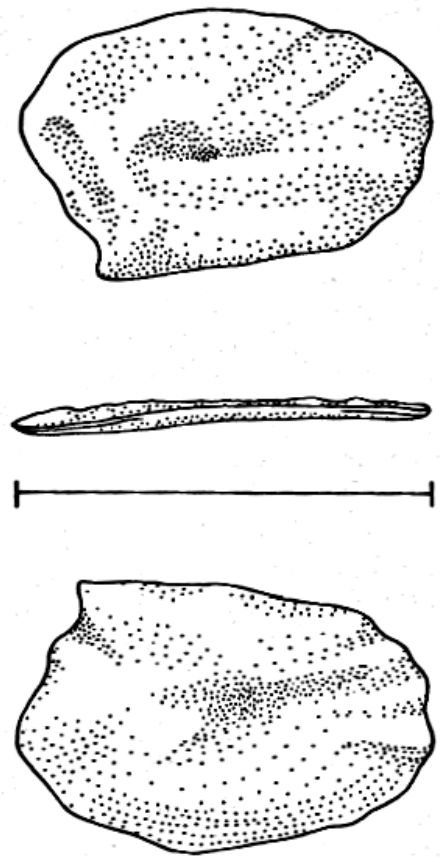
Acadian redfish
Sebastes fasciatus Storer
fish length 36 cm
scale bar 16.2 mm



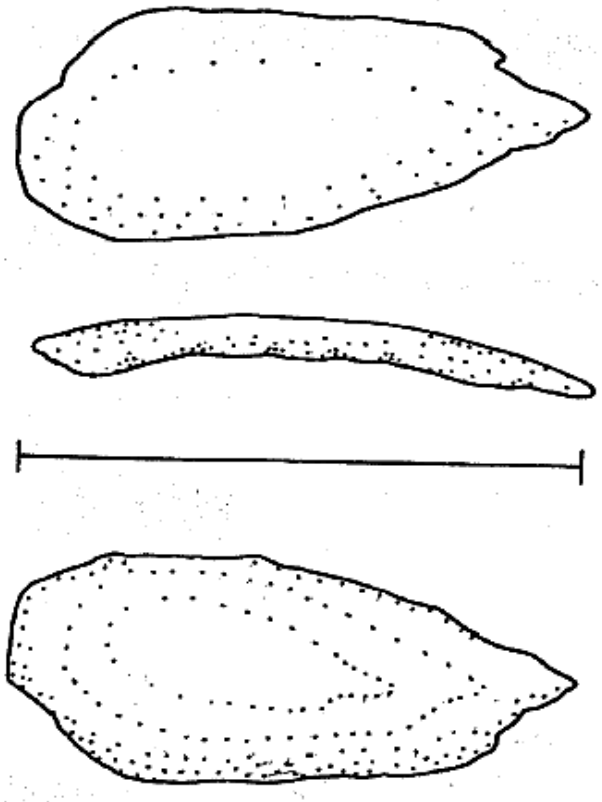
Alewife
Alosa pseudoharengus (Wilson)
fish length 25 cm
scale bar 7.4 mm



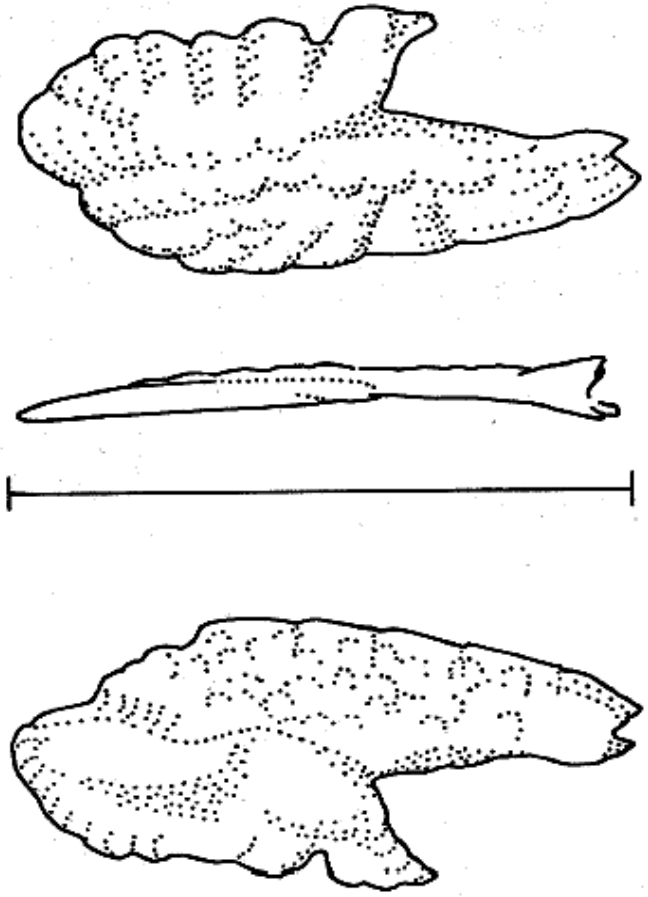
Alligatorfish
Aspidophoroides monopterygius (Bloch)
fish length 25.4 cm
scale bar 3.2 mm



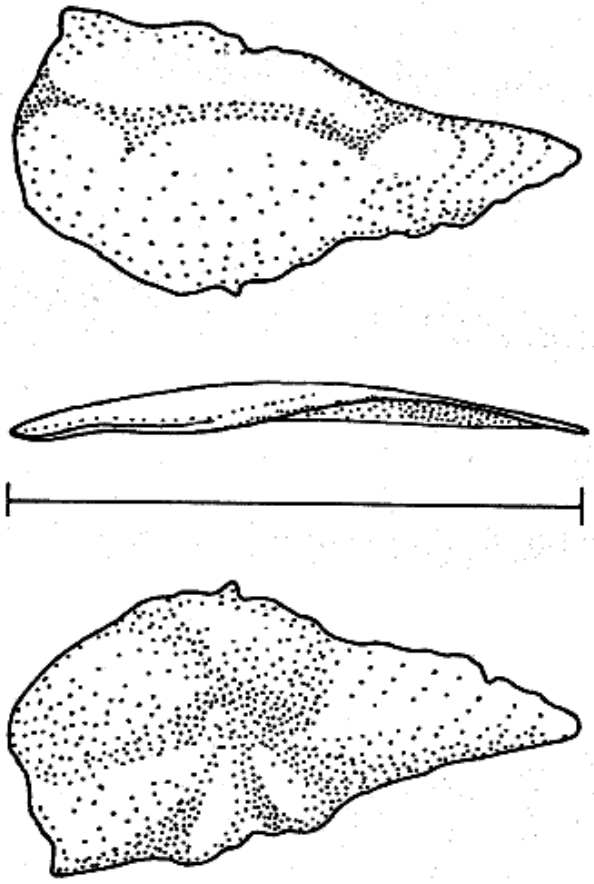
American plaice
Hippoglossoides platessoides (Fabricius)
fish length 50 cm
scale bar 9.5 mm



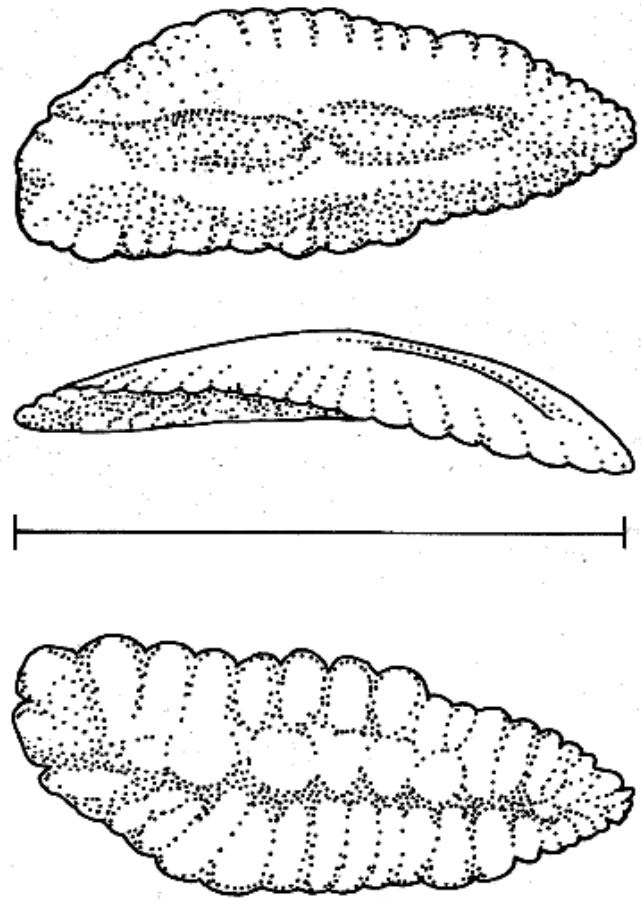
American sand lance
Ammodytes americanus DeKay
fish length 23.0 cm
scale bar 3.5 mm



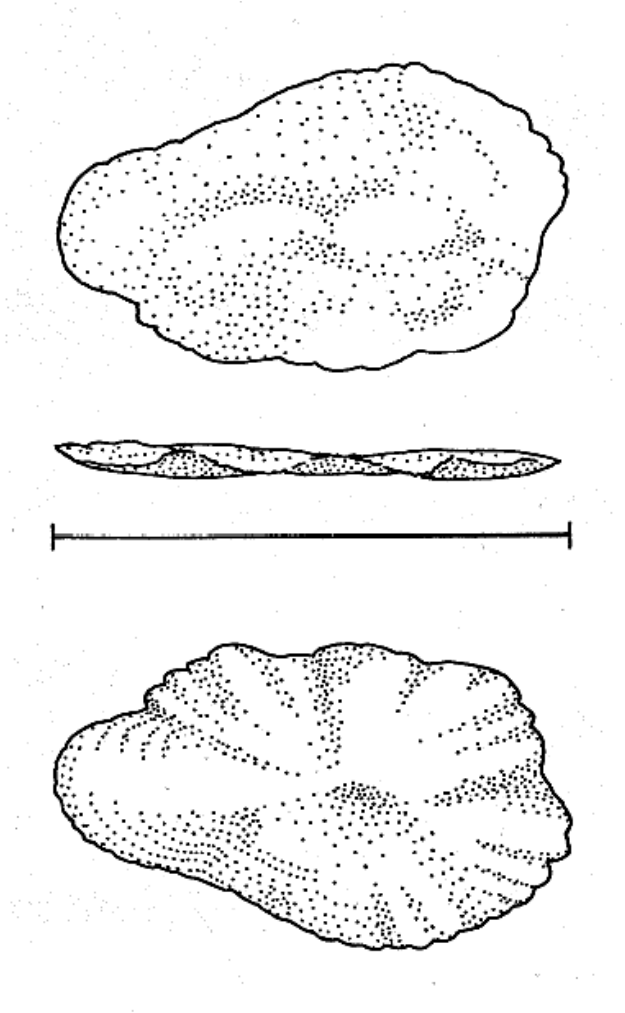
American shad
Alosa sapidissima (Wilson)
fish length 42 cm
scale bar 4.0 mm



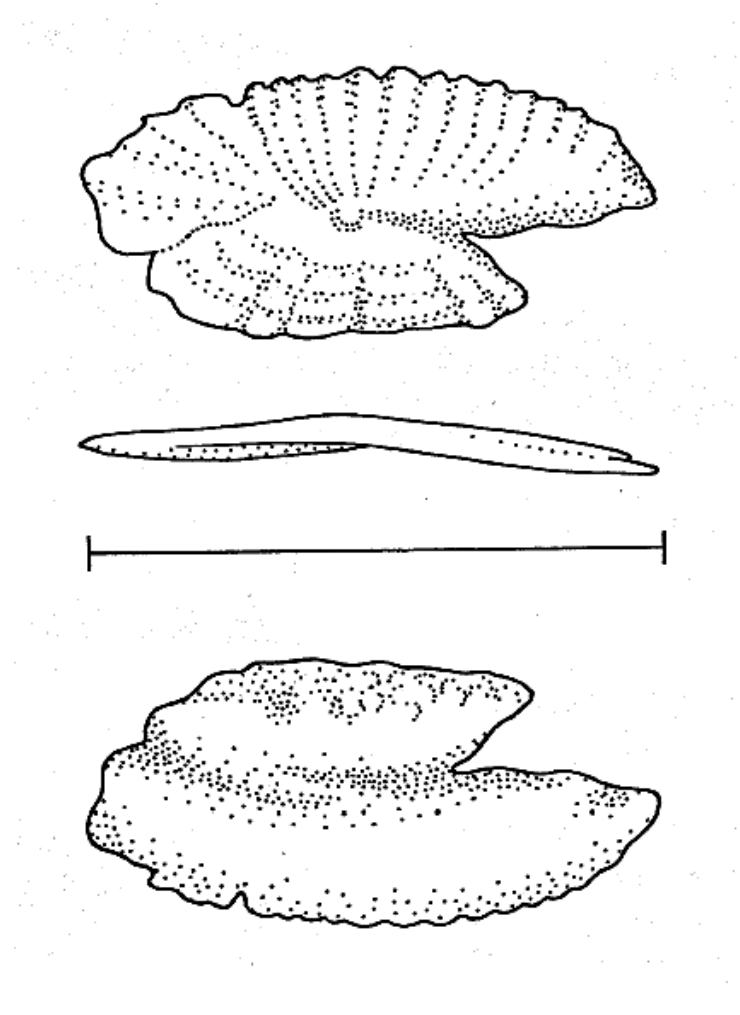
Atlantic argentine
Argentina silus (Ascanius)
fish length 37 cm
scale bar 10.0 mm



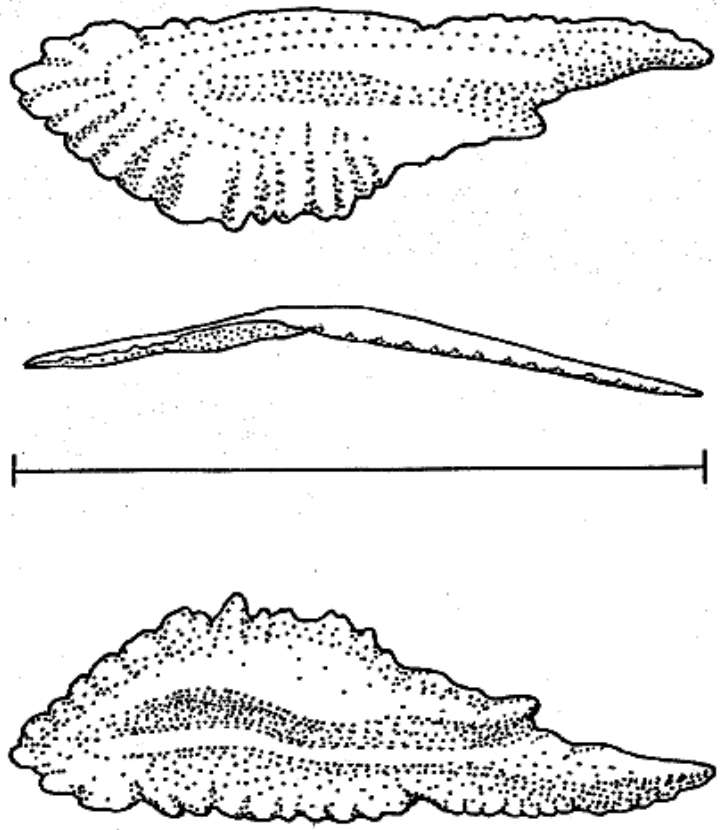
Atlantic cod
Gadus morhua Linnaeus
fish length 74.0 cm
scale bar 19.6 mm



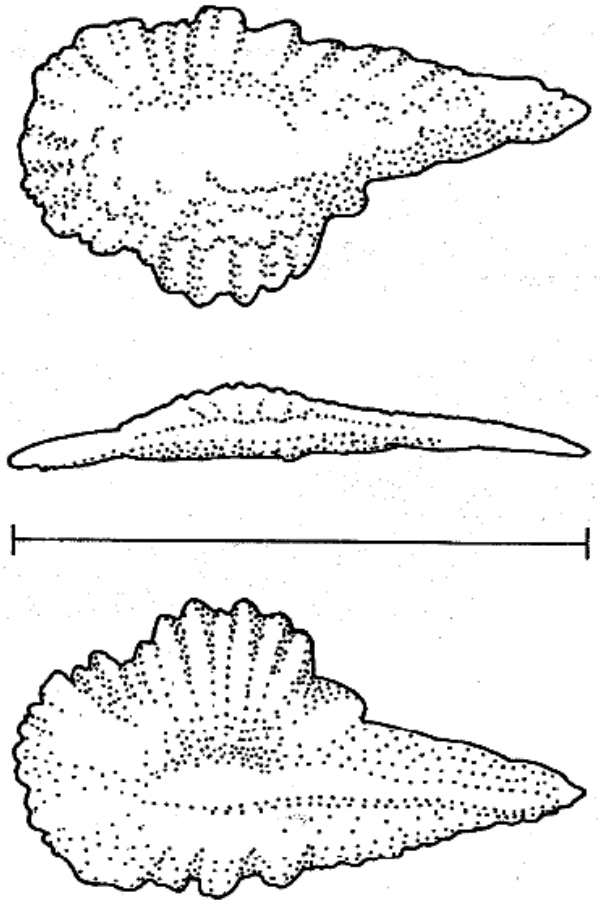
Atlantic halibut
Hippoglossus hippoglossus (Linnaeus)
fish length 108 cm
scale bar 12.5 mm



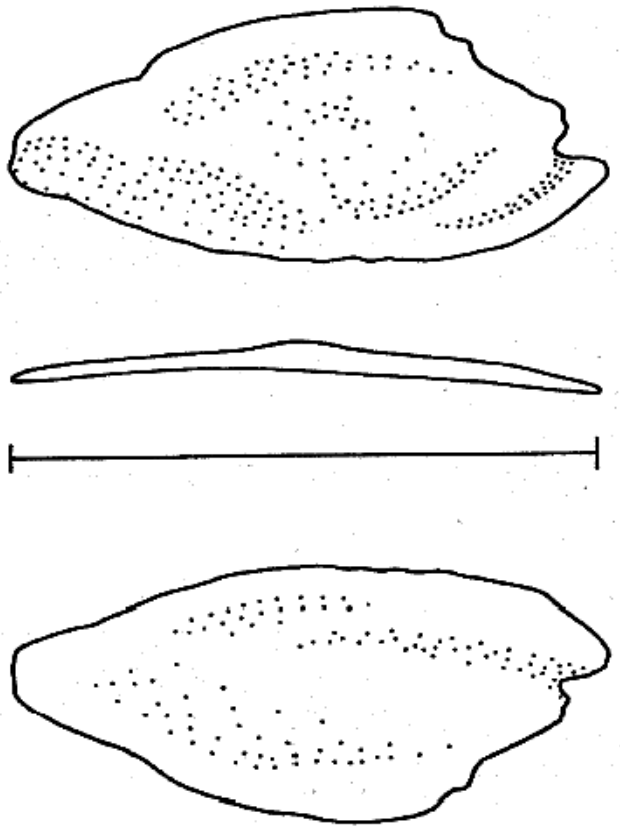
Atlantic herring
Clupea harengus Linnaeus
fish length 28 cm
scale bar 4.4 mm



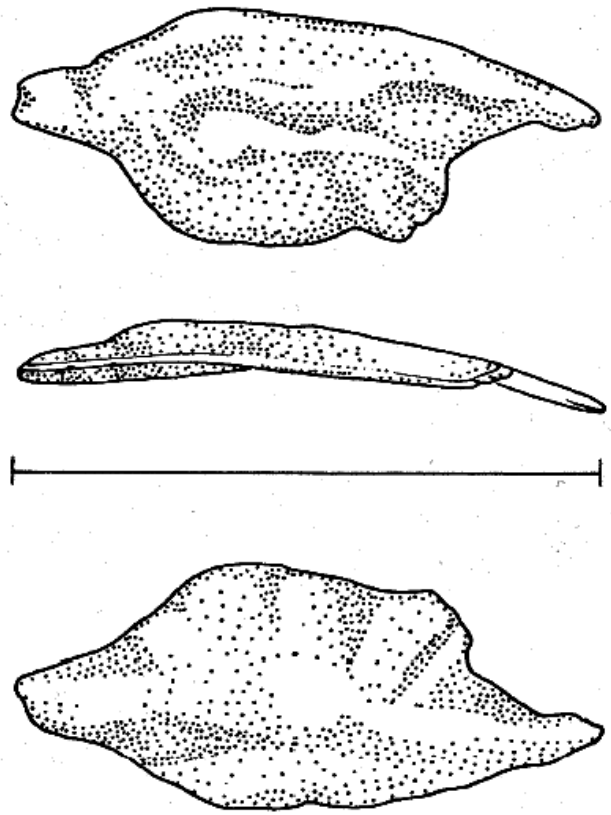
Atlantic mackerel
Scomber scombrus Linnaeus
fish length 36.7 cm
scale bar 5.2 mm



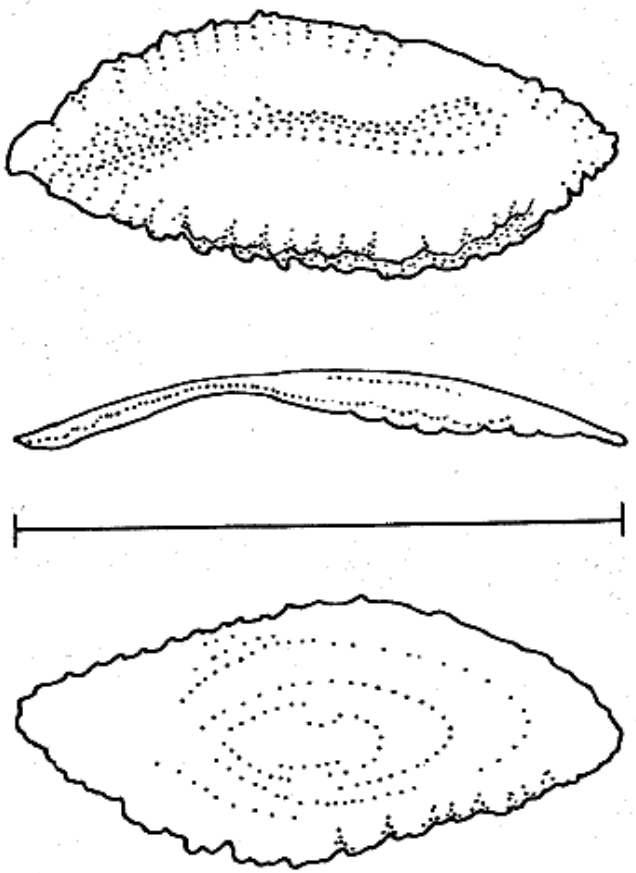
Atlantic wolffish
Anarhichas lupus Linnaeus
fish length 76.0 cm
scale bar 4.7 mm



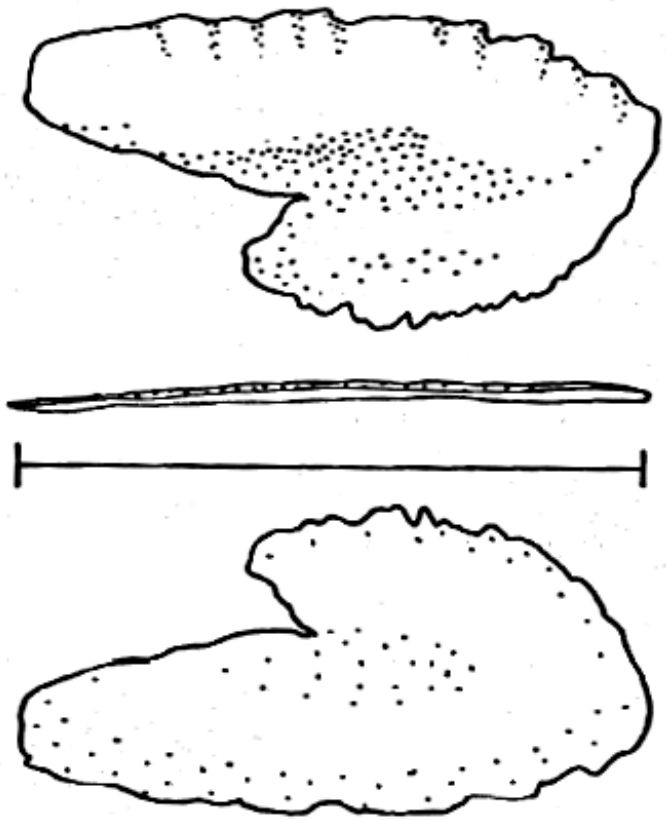
Bigeye sculpin
Triglops nybelini Jensen
fish length 21 cm
scale bar 3.9 mm



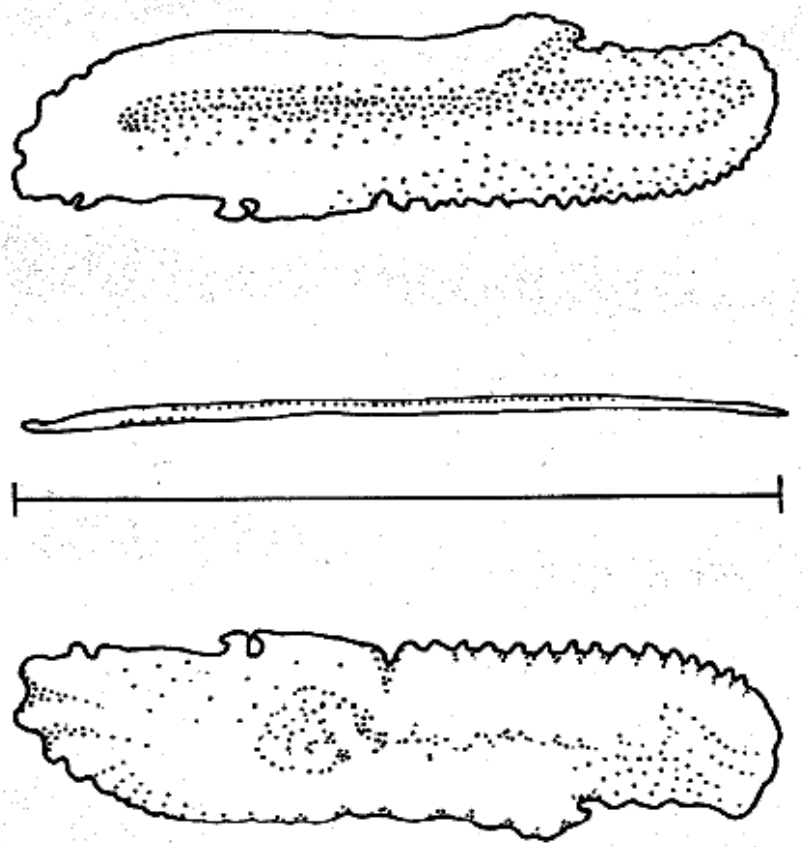
Blackbelly rosefish
Helicolenus dactylopterus (Delaroche)
fish length 36 cm
scale bar 14.7 mm



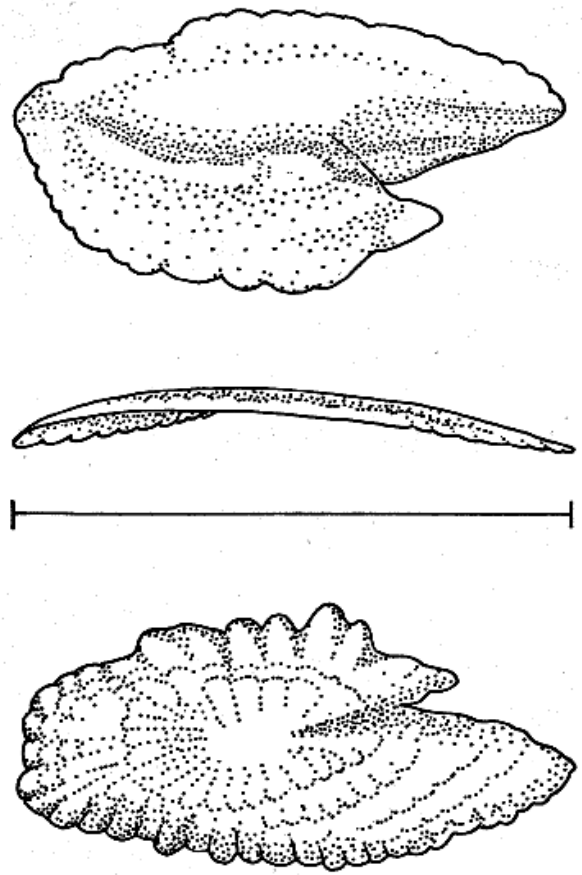
Black sea bass
Centropristis striata (Linnaeus)
fish length 33.6 cm
scale bar 11.0 mm



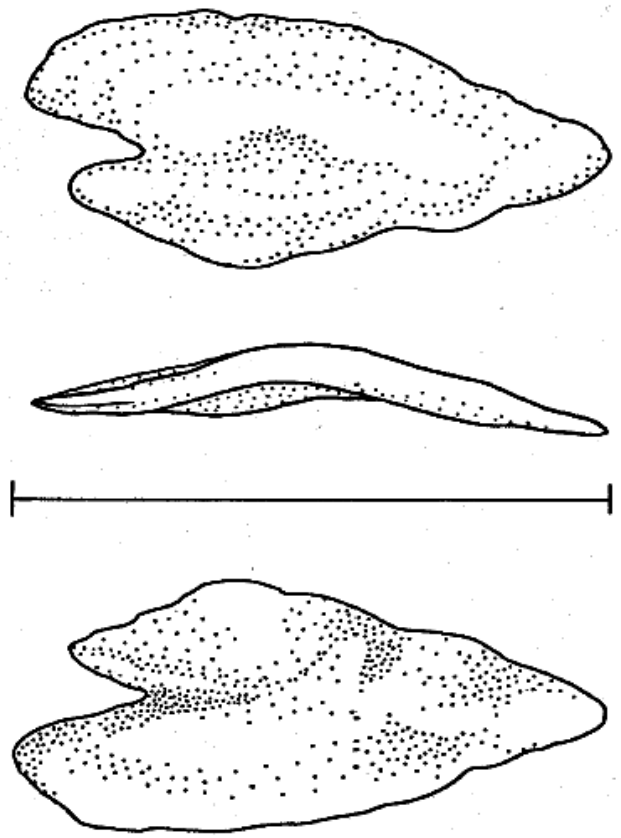
Blueback herring
Alosa aestivalis (Mitchill)
fish length 12 cm
scale bar 3.6 mm



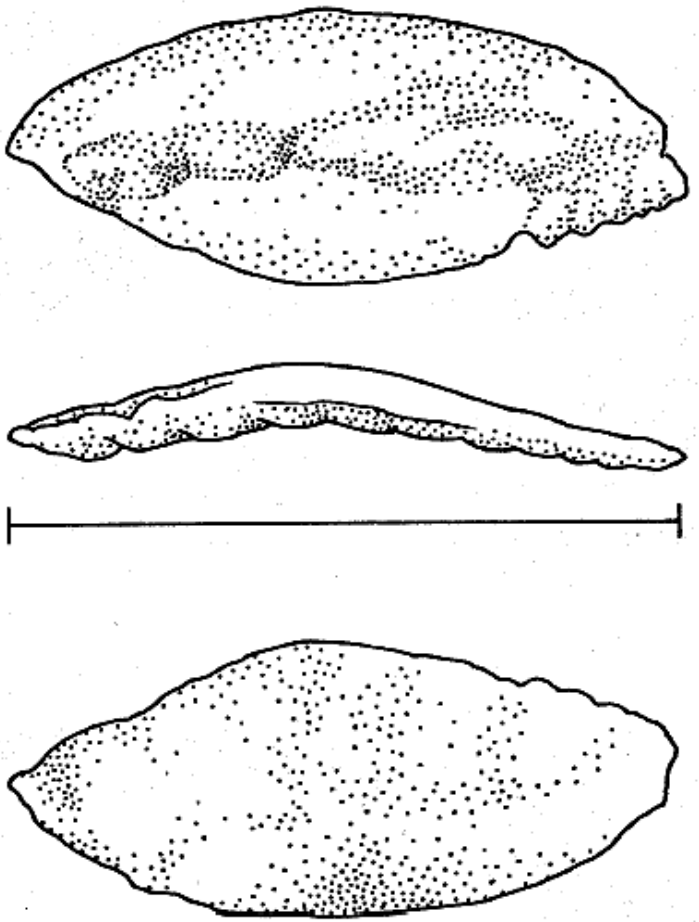
Bluefish
Pomatomus saltatrix (Linnaeus)
fish length 61 cm
scale bar 14.0 mm



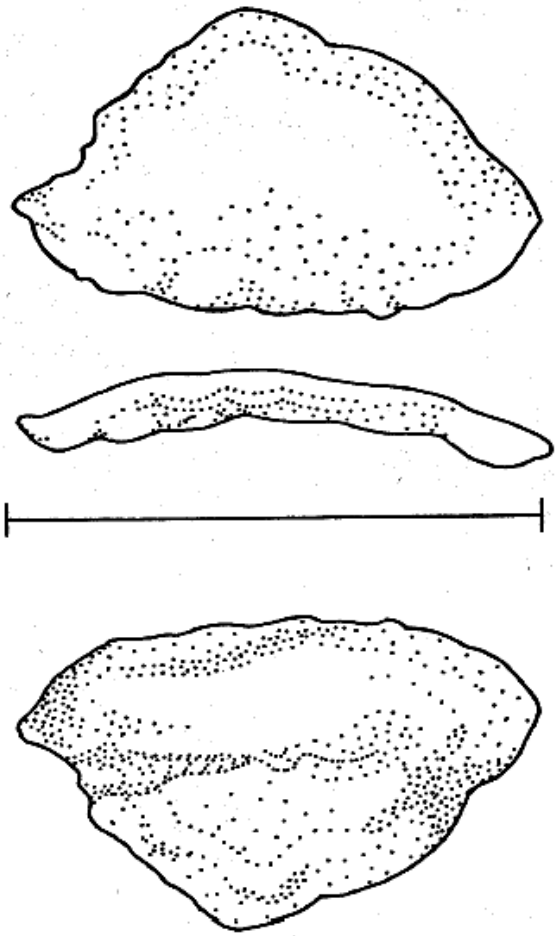
Butterfish
Peprilus triacanthus (Peck)
fish length 20 cm
scale bar 7.2 mm



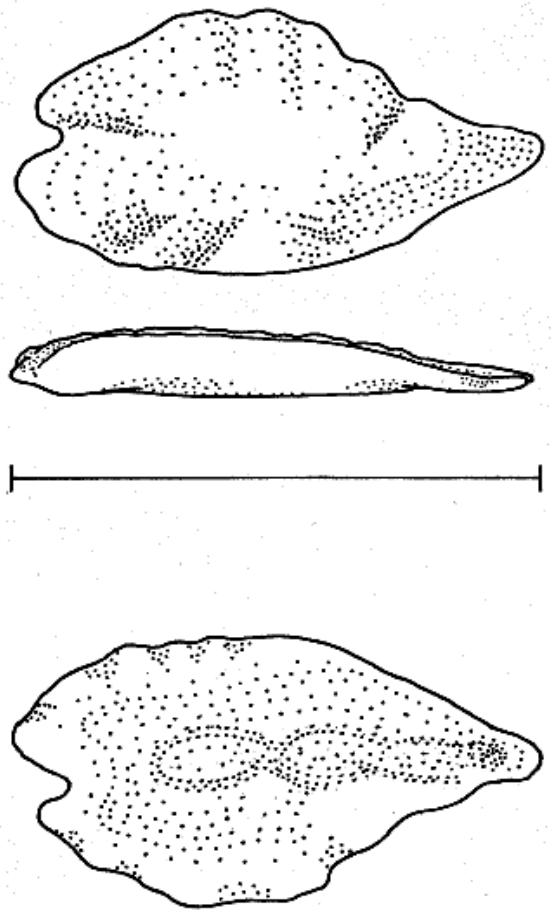
Cunner
Tautogolabrus adspersus (Walbaum)
fish length 14 cm
scale bar 2.5 mm



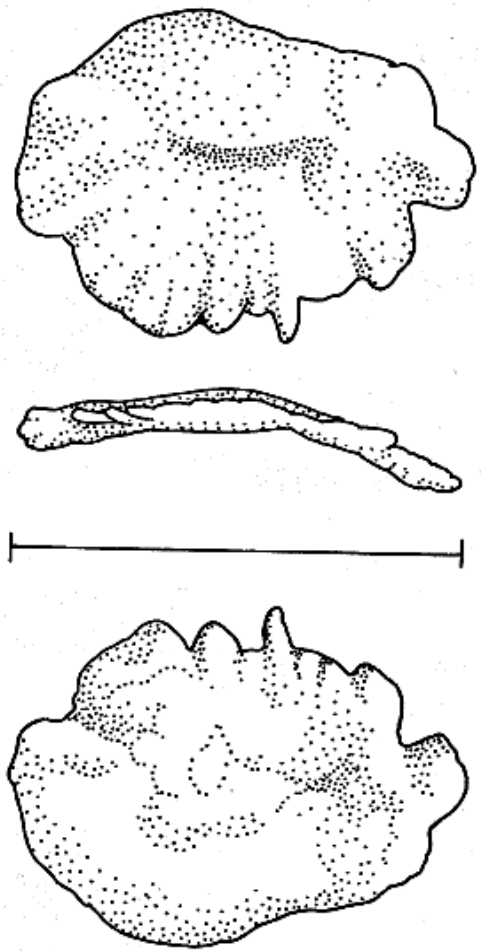
Cusk
Brosme brosme (Ascanius)
fish length 77 cm
scale bar 16.0 mm



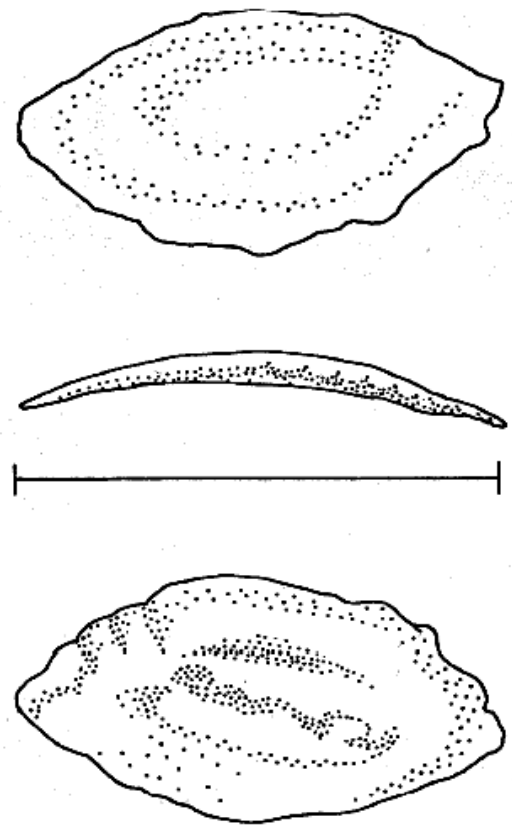
Fourbeard rockling
Enchelyopus cimbrius (Linnaeus)
fish length 26 cm
scale bar 4.8 mm



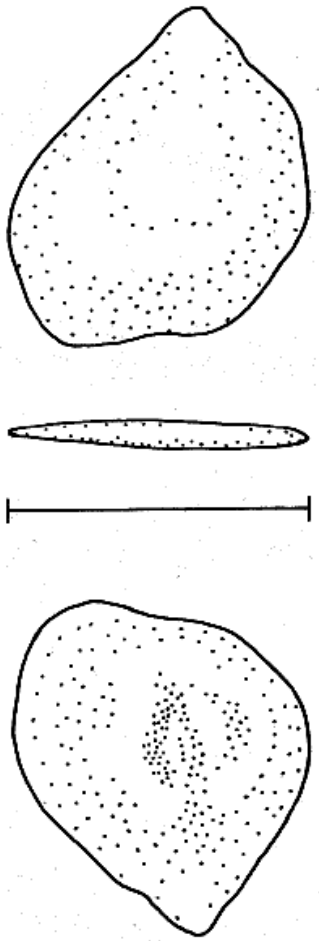
Fourspot flounder
Paralichthys oblongus (Mitchill)
fish length 39.5 cm
scale bar 8.0 mm



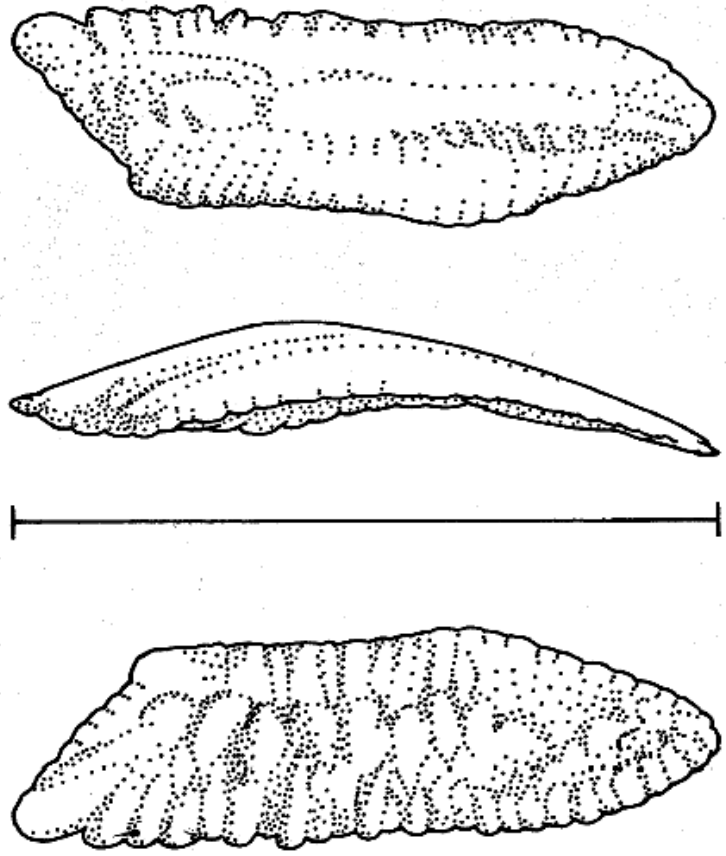
Goosefish
Lophius americanus Valenciennes
fish length 61.8 cm
scale bar 8.5 mm



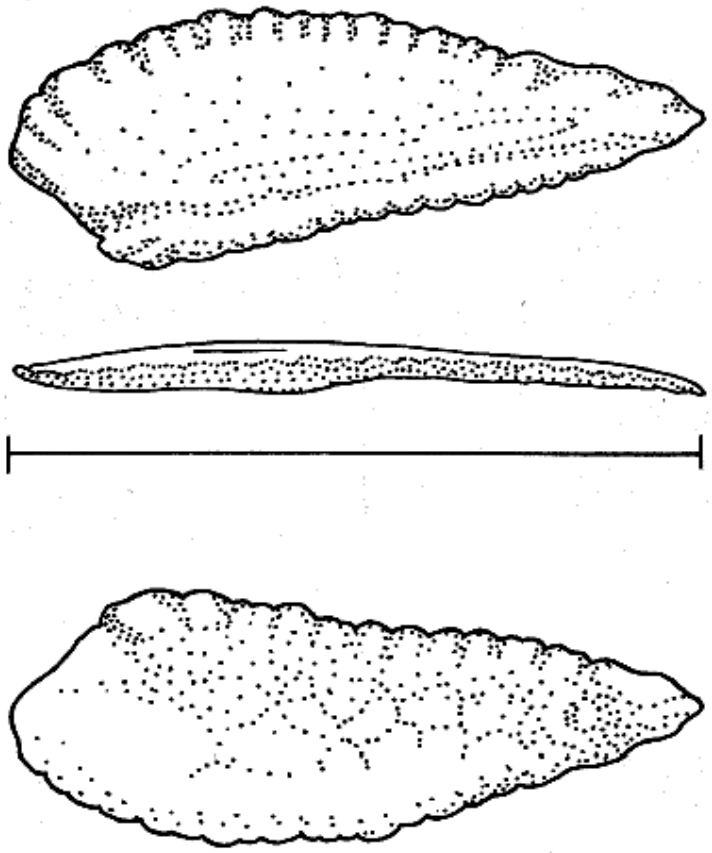
Grubby
Myoxocephalus aenaeus (Mitchill)
fish length 12 cm
scale bar 3.3 mm



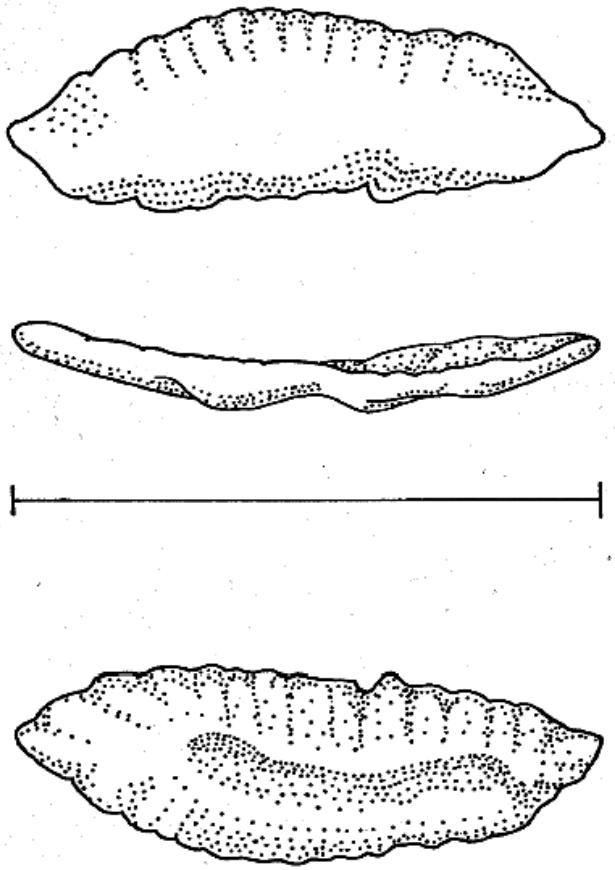
Gulf Stream flounder
Citharichthys arctifrons Goode
fish length 19 cm
scale bar 3.0 mm



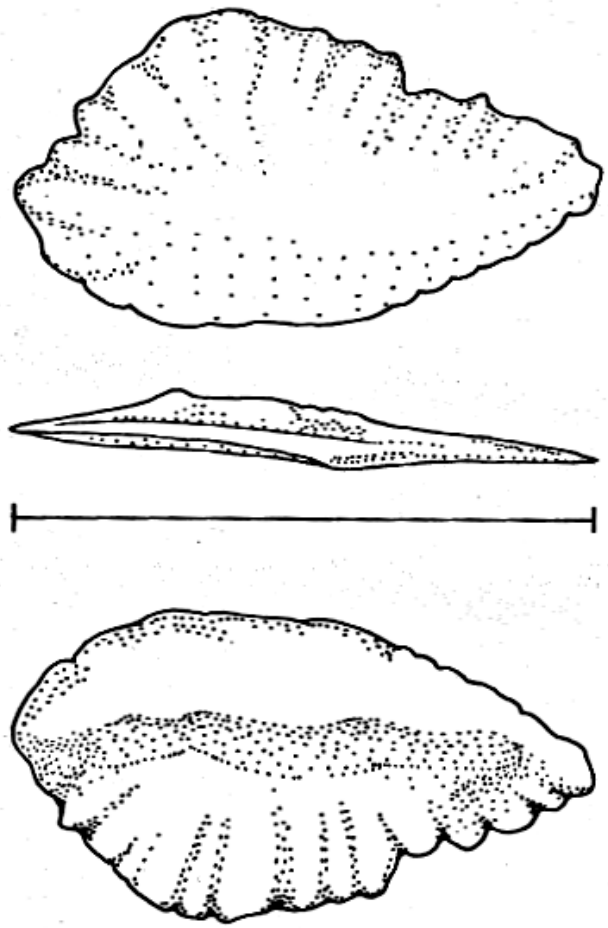
Haddock
Melanogrammus aeglefinus (Linnaeus)
fish length 69 cm
scale bar 21.5 mm



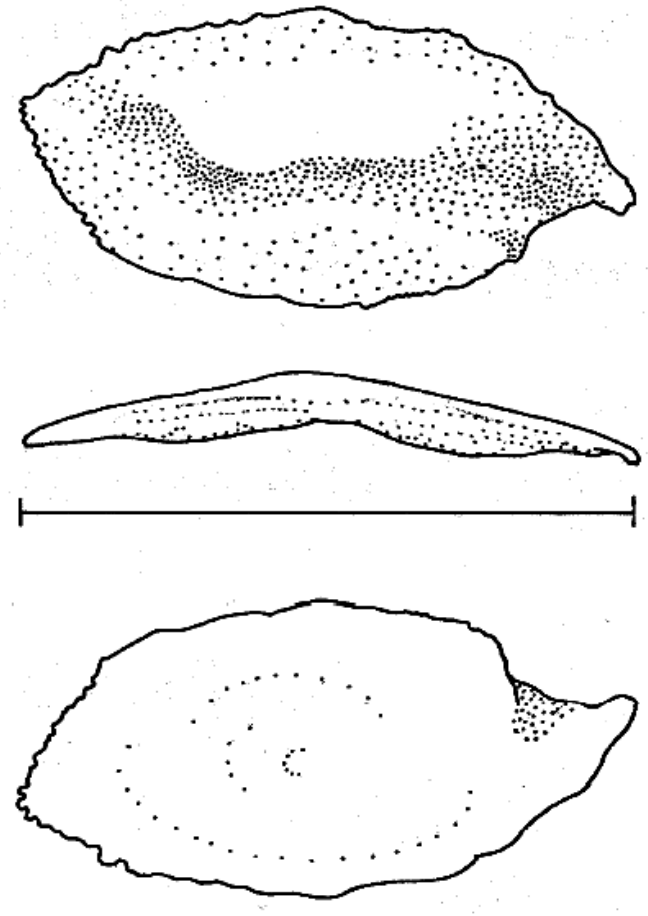
Longfin hake
Urophycis chesteri (Goode & Bean)
fish length 20 cm
scale bar 8.1 mm



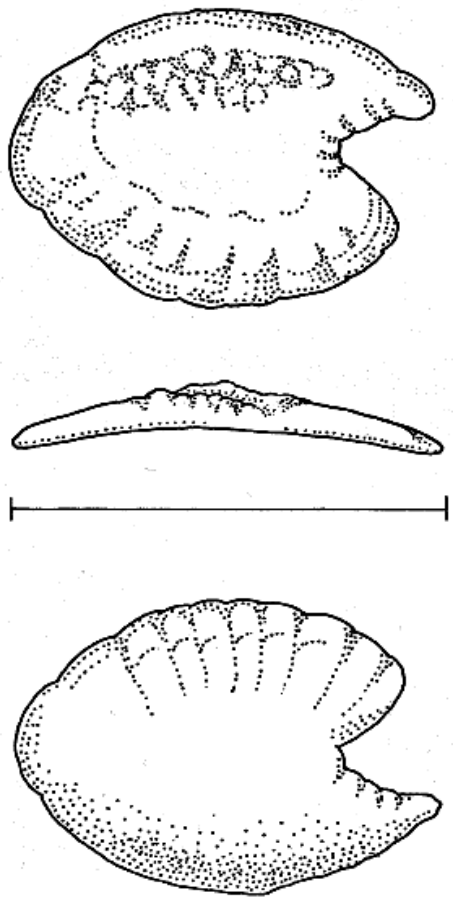
Longhorn sculpin
Myoxocephalus octodecemspinosus (Mitchill)
fish length 22 cm
scale bar 8.6 mm



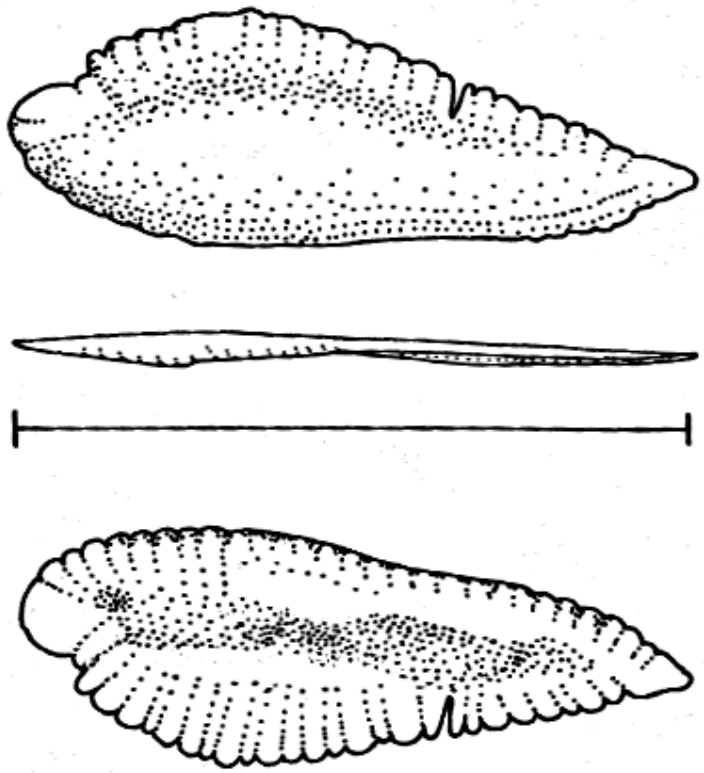
Marlin-spike
Nezumia bairdii (Goode & Bean)
fish length 31 cm
scale bar 19.0 mm



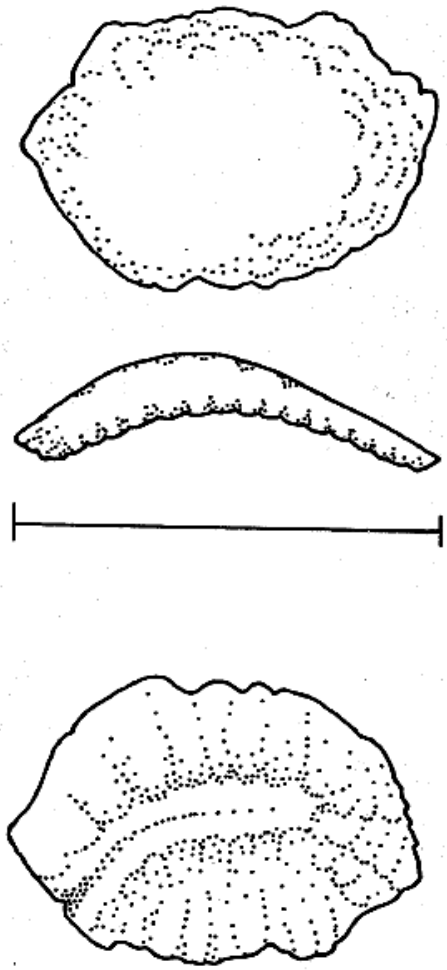
Northern searobin
Prionotus carolinus (Linnaeus)
fish length 31.6 cm
scale bar 8.6 mm



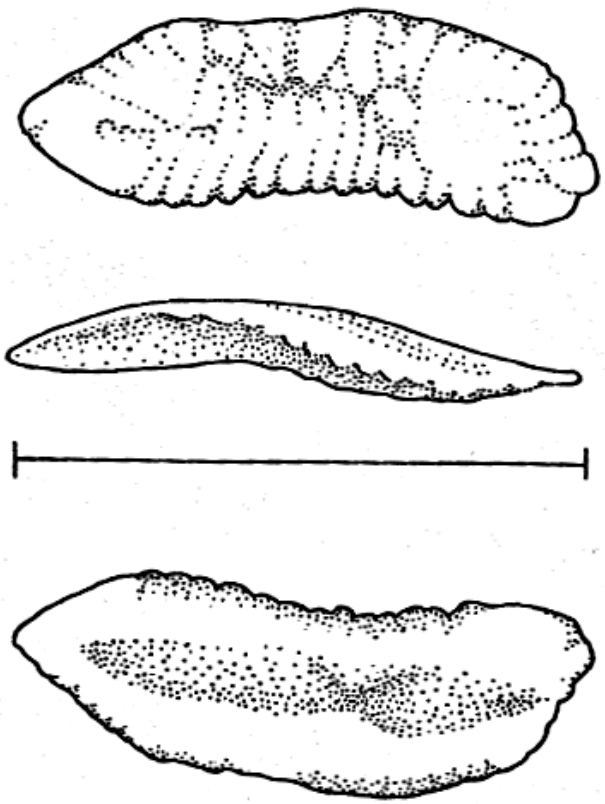
Ocean pout
Zoarces americanus (Bloch & Schneider)
fish length 82 cm
scale bar 4.7 mm



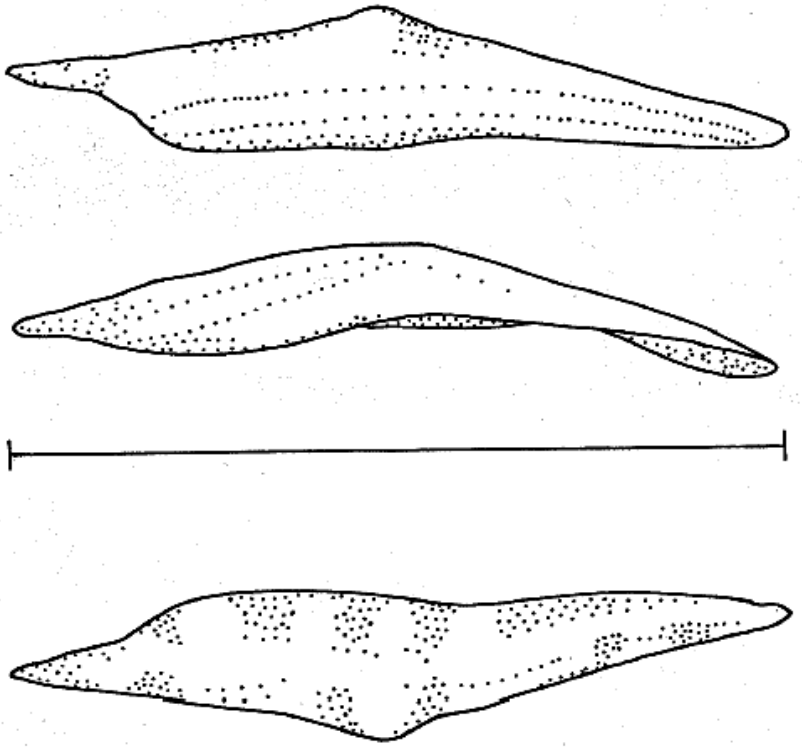
Offshore hake
Merluccius albidus (Mitchill)
fish length 52 cm
scale bar 24.0 mm



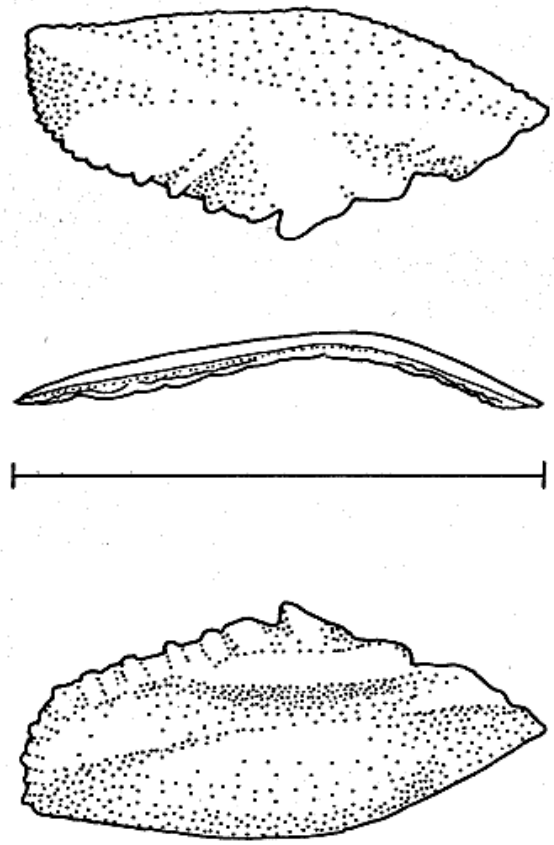
Oyster toadfish
Opsanus tau (Linnaeus)
fish length 24 cm
scale bar 7.0 mm



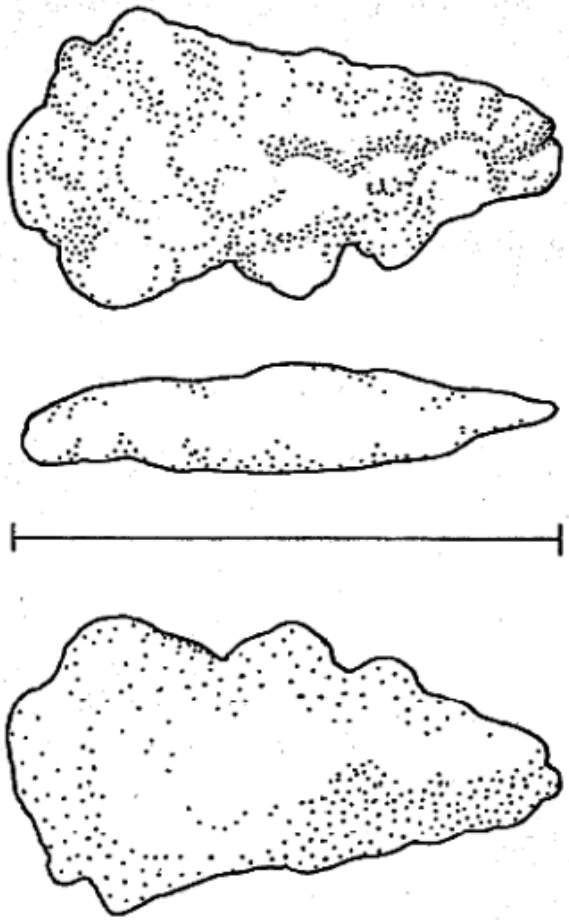
Pollock
Pollachius virens (Linnaeus)
fish length 66 cm
scale bar 17.0 mm



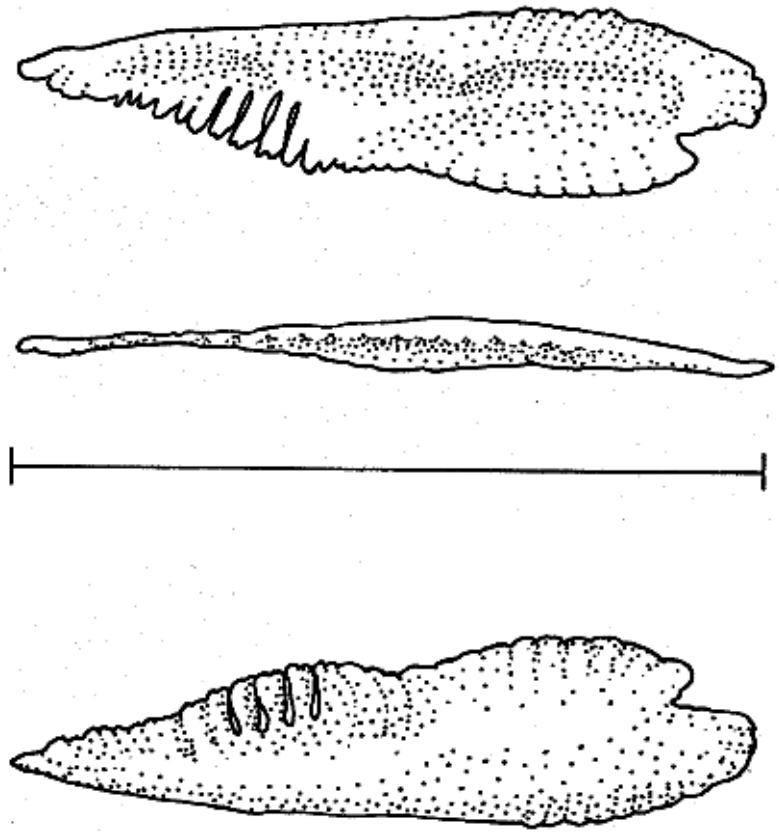
Red hake
Urophycis chuss (Walbaum)
fish length 58 cm
scale bar 22.3 mm



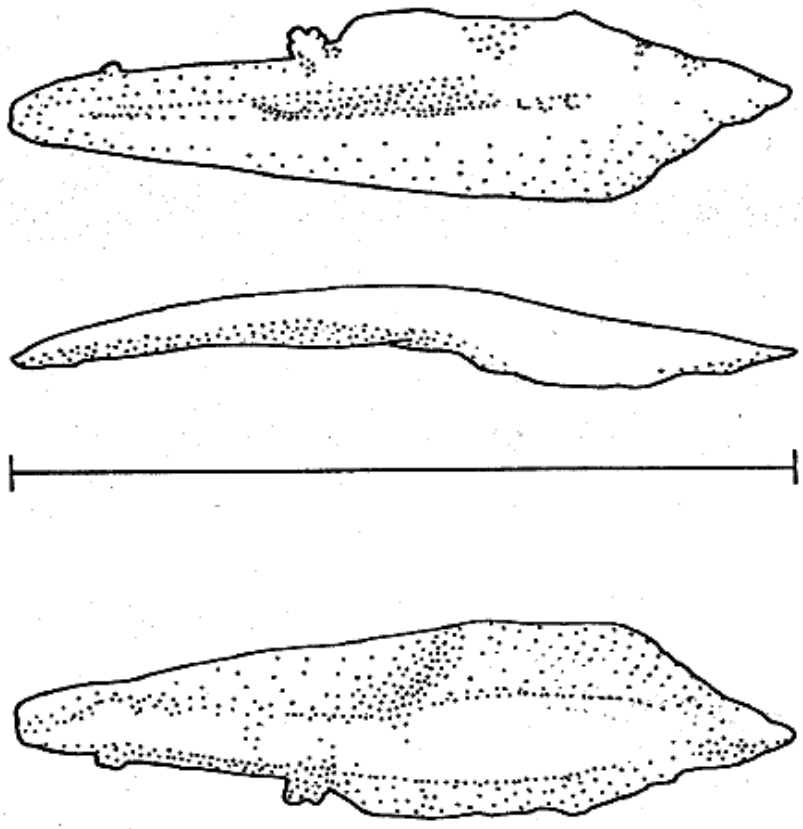
Scup
Stenotomus chrysops (Linnaeus)
fish length 26 cm
scale bar 10.0 mm



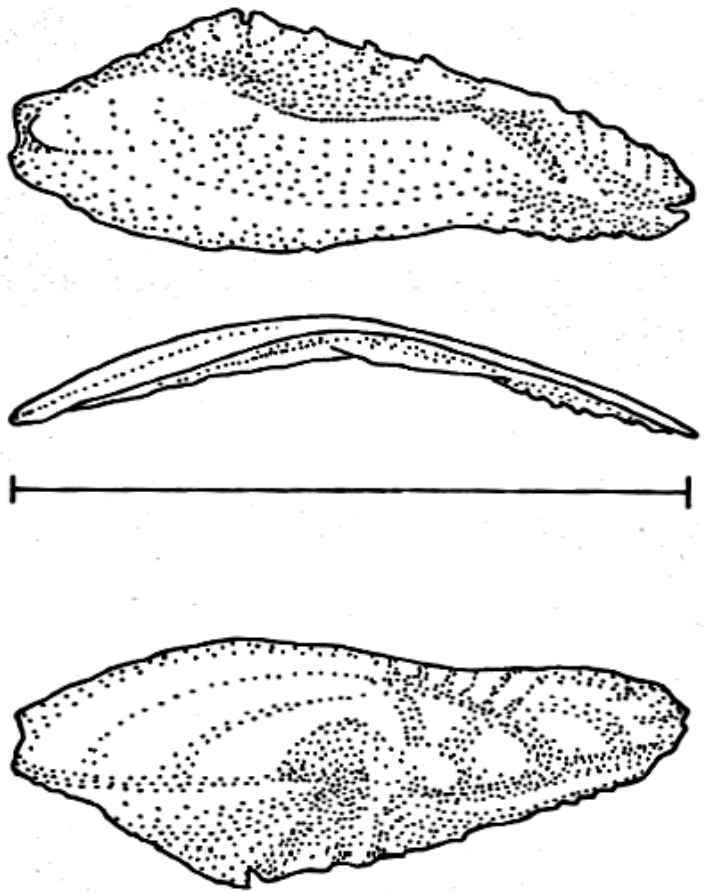
Sea raven
Hemitripterus americanus (Gmelin)
fish length 35.4 cm
scale bar 4.6 mm



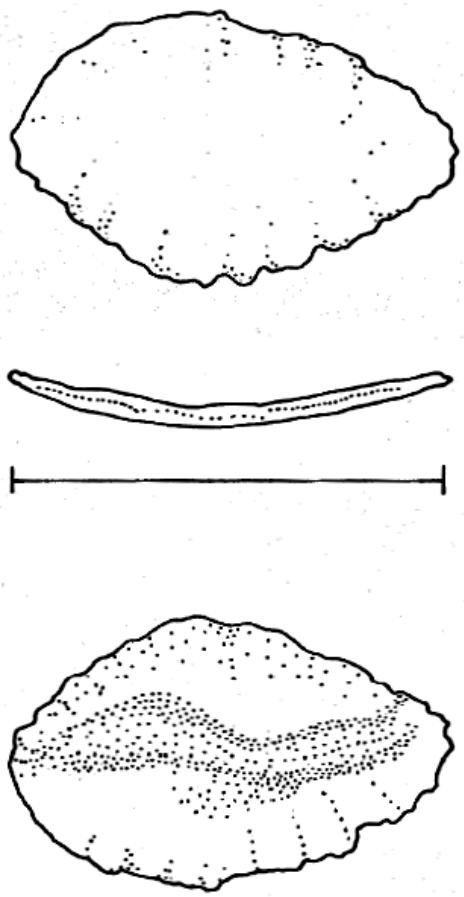
Silver hake
Merluccius bilinearis (Mitchill)
fish length 45 cm
scale bar 21.6 mm



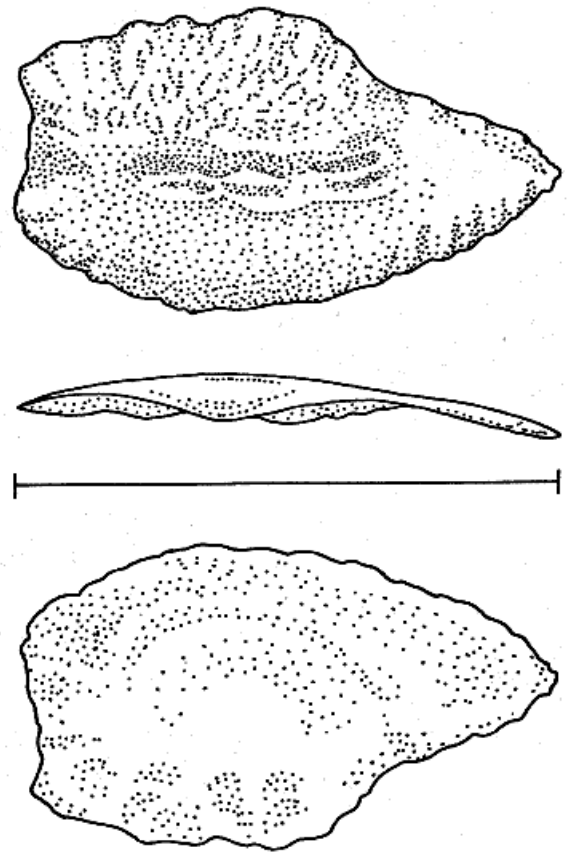
Spotted hake
Urophycis regia (Walbaum)
fish length 36 cm
scale bar 13.2 mm



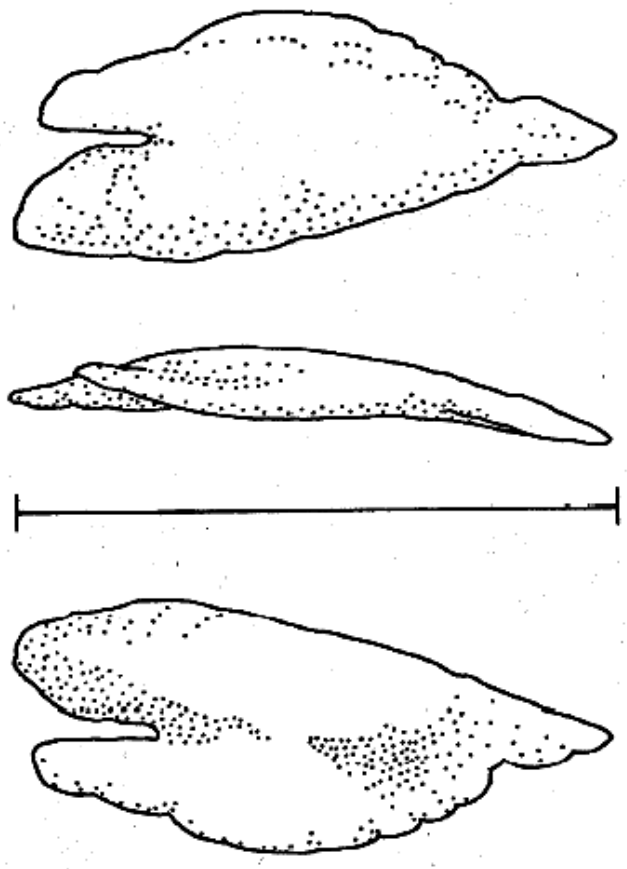
Striped bass
Morone saxatilis (Walbaum)
fish length 25.8 cm
scale bar 16.0 mm



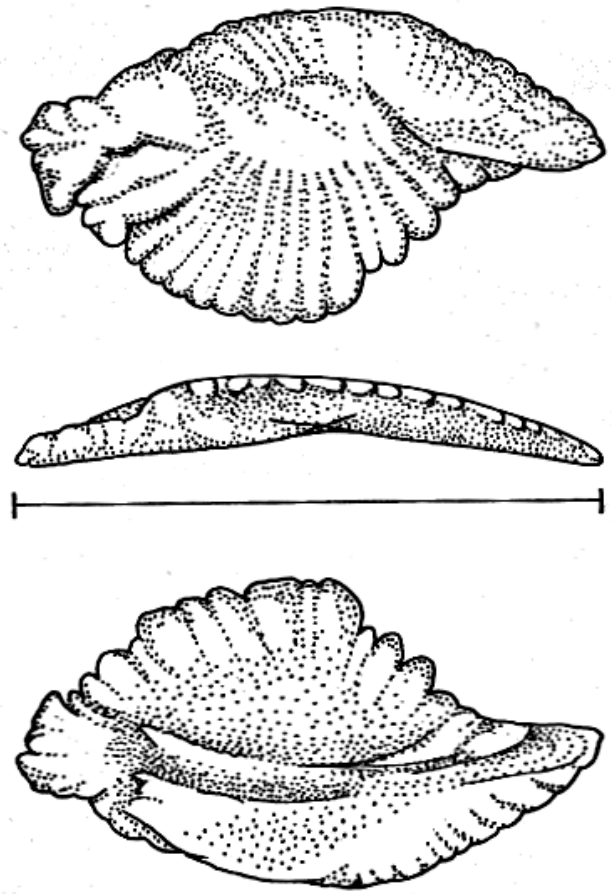
Striped searobin
Prionotus evolans (Linnaeus)
fish length 32.7 cm
scale bar 9.0 mm



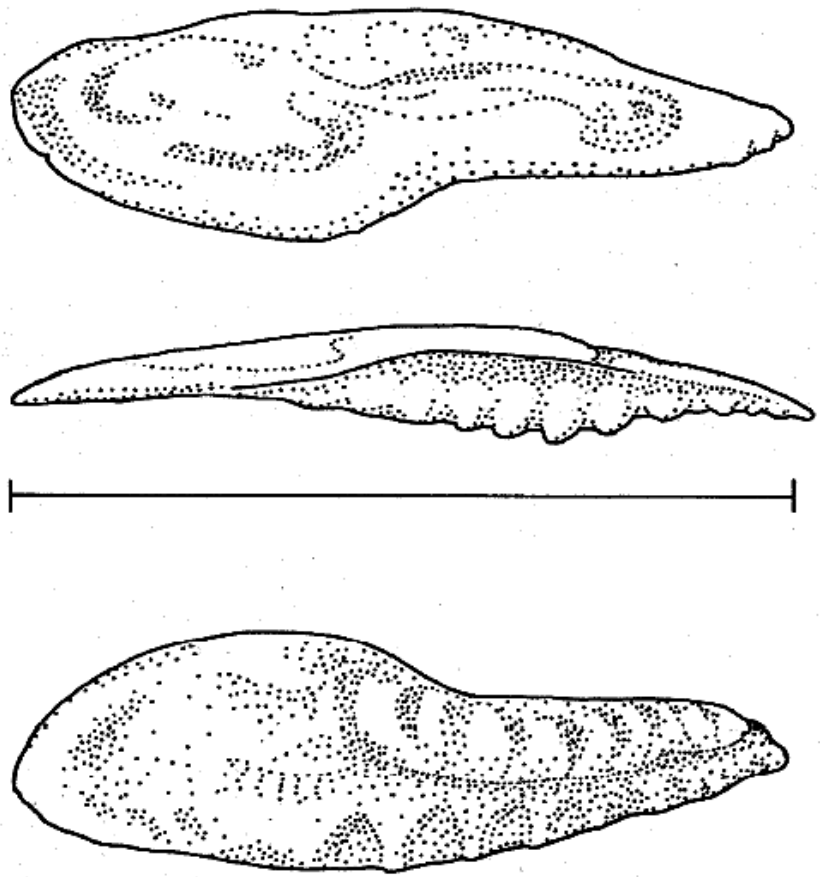
Summer flounder
Paralichthys dentatus (Linnaeus)
fish length 59 cm
scale bar 9.0 mm



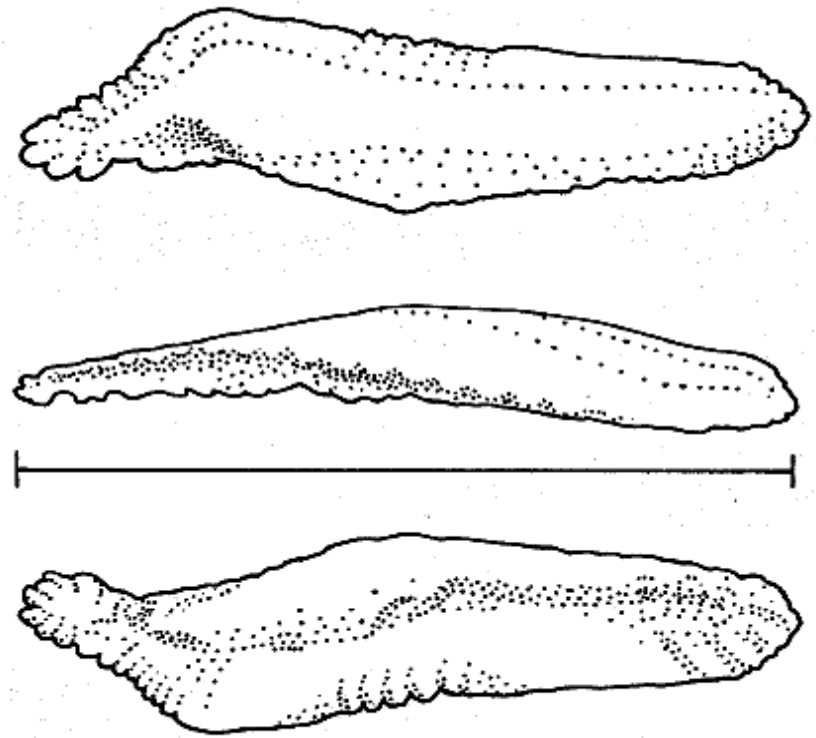
Tautog
Tautoga onitis (Linnaeus)
fish length 18 cm
scale bar 3.3 mm



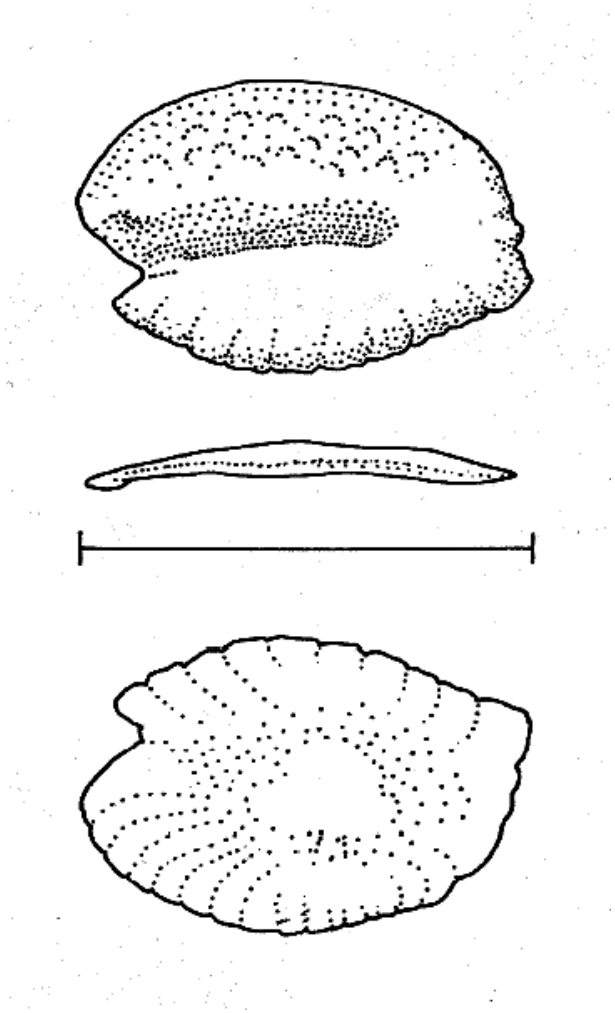
Tilefish
Lopholatilus chamaeleonticeps Goode & Bean
fish length 57 cm
scale bar 18.8 mm



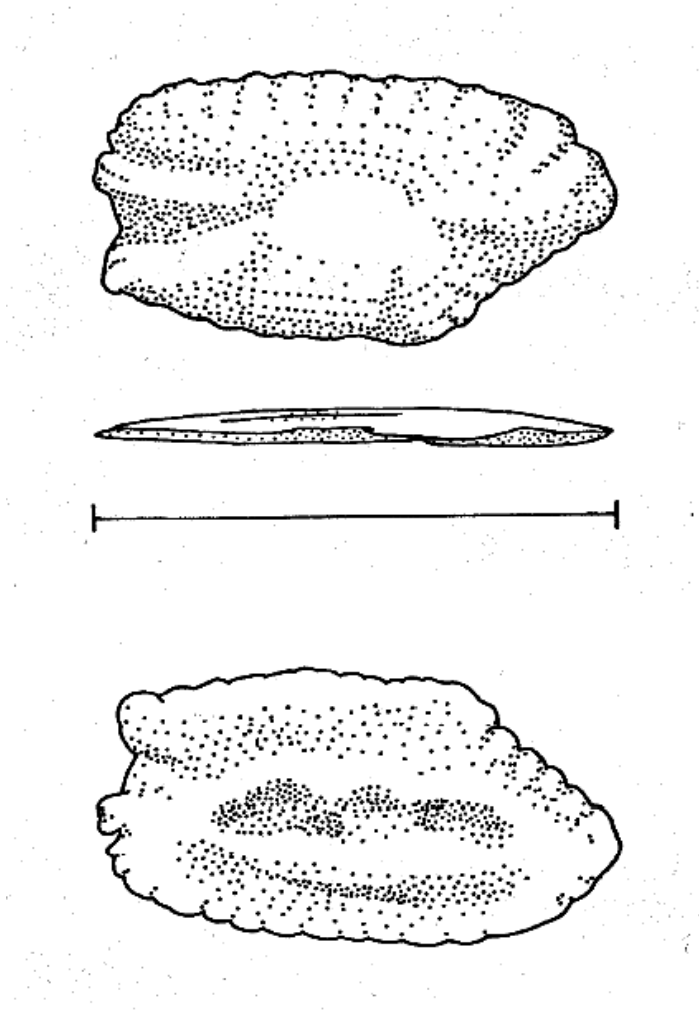
Weakfish
Cynoscion regalis (Bloch & Schneider)
fish length 76 cm
scale bar 32.0 mm



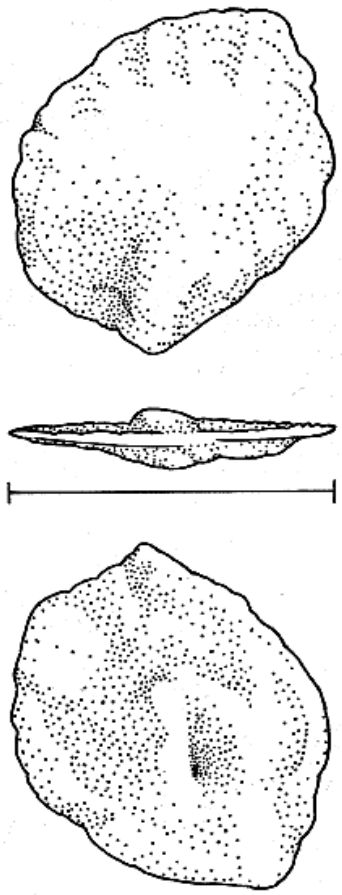
White hake
Urophycis tenuis (Mitchill)
fish length 77 cm
scale bar 26.8 mm



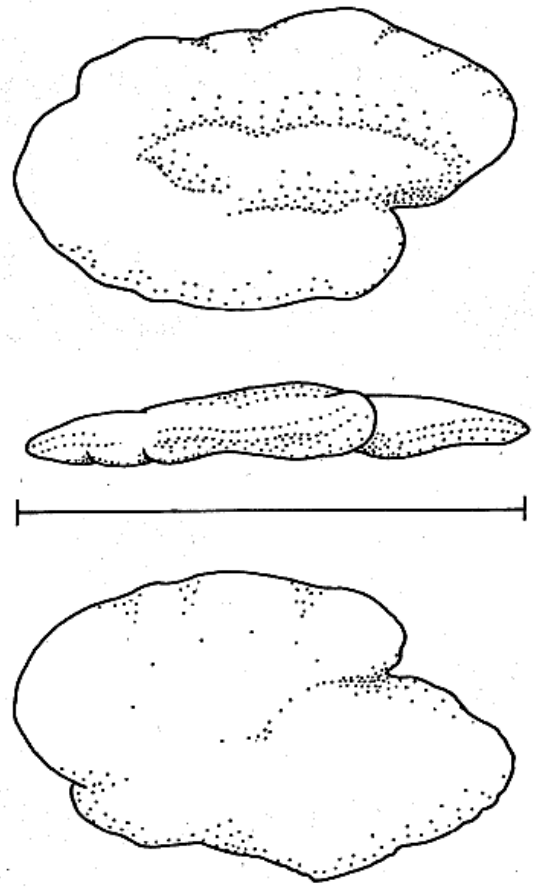
Windowpane
Scophthalmus aquosus (Mitchill)
fish length 30 cm
scale bar 4.7 mm



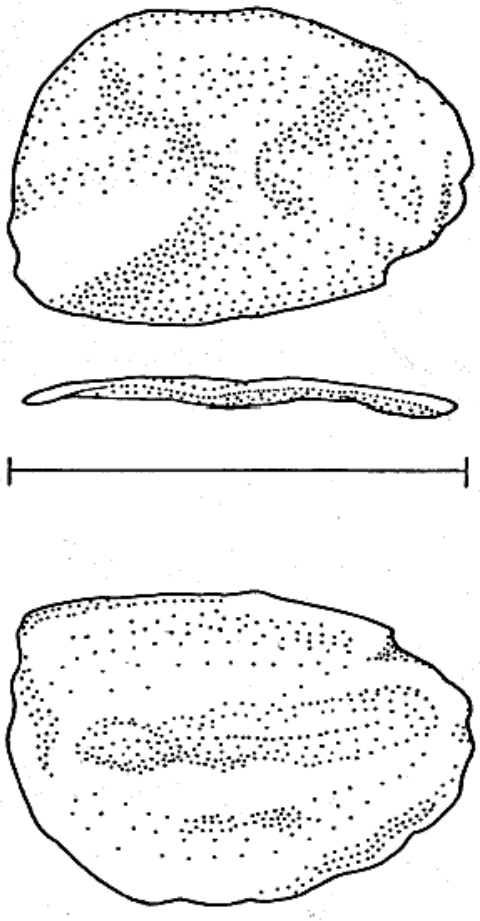
Winter flounder
Pseudopleuronectes americanus (Walbaum)
fish length 51 cm
scale bar 7.3 mm



Witch flounder
Glyptocephalus cynoglossus (Linnaeus)
fish length 57 cm
scale bar 8.0 mm



Wrymouth
Cryptacanthodes maculatus Storer
fish length 80.3 cm
scale bar 10.2 mm



Yellowtail flounder
Limanda ferruginea (Storer)
fish length 37 cm
scale bar 7.2 mm

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