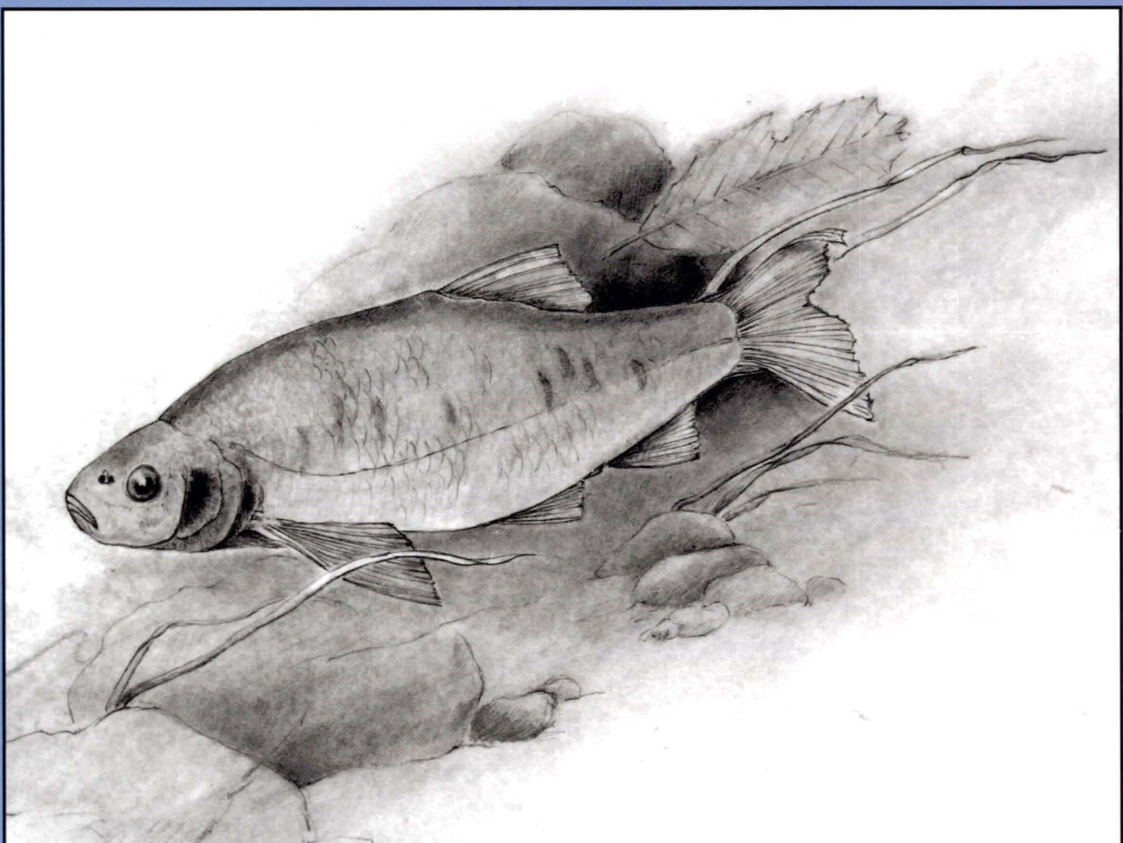
GUIDE TO THE IDENTIFICATION OF SCALES OF INLAND FISHES OF NORTHEASTERN NORTH AMERICA

BY ROBERT A. DANIELS



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CONTENTS

CONTENTS

LIST OF FIGURES

LIST OF TABLES

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R.A.D.

INTRODUCTION

Fish are a dominant component of riverine and lake faunas in northeastern North America. As such, their remains offer the researcher potentially important inferential evidence for events that occurred in the absence of substantial written or oral historical documentation. For example, fish remains may offer clues to the diets of prehistoric Native Americans and early European immigrants and settlers to the region, provide zoogeographic information on the migratory routes of fishes, or allow the reconstruction of past aquatic assemblages.

Northeastern lakes and streams are relatively young. In fact, most have developed within the last 10,000 to 17,000 years (Cadwell 1986). Nevertheless, modern fish assemblages in this area are the result of numerous additions and deletions over time. Fish became an important component in the diets of humans and other predatory animals entering the deglaciated area c. 10,000 years ago, and for humans, fish and fish by-products became important as items for personal use and trade. Through time, changes in the sizes of human groups, shifts in their subsistence strategies, and developments in fishing technology resulted in varying pressures on fish populations. When Euro-Americans came to the Northeast, fish were further exploited and habitats were altered, again resulting in changes in the fish assemblages of northeastern inland waters. A record of fish assemblages of the past may remain in bottom sediments of lakes and ponds (Vallentyne 1960). Certainly, fish remains recovered from archaeological sites reflect the activities of early human migrants, the hunter-gatherer-fisher people who subsequently populated the Northeast, the agriculturalists, and eventually the Euro-American settlers who established farms, villages, and cities. In each case, fish remains offer clues to some of the otherwise undocumented changes that have taken place in this area over the past several thousand years.

The purpose of this bulletin is to provide, in one volume, a comprehensive reference source that will help workers in a variety of disciplines work with and identify one of the common types of fish remains–fish scales. This volume focuses upon inland fishes found in northeastern North America, specifically, New York, Pennsylvania, New Jersey, New England, the Maritime Provinces, Quebec, and eastern

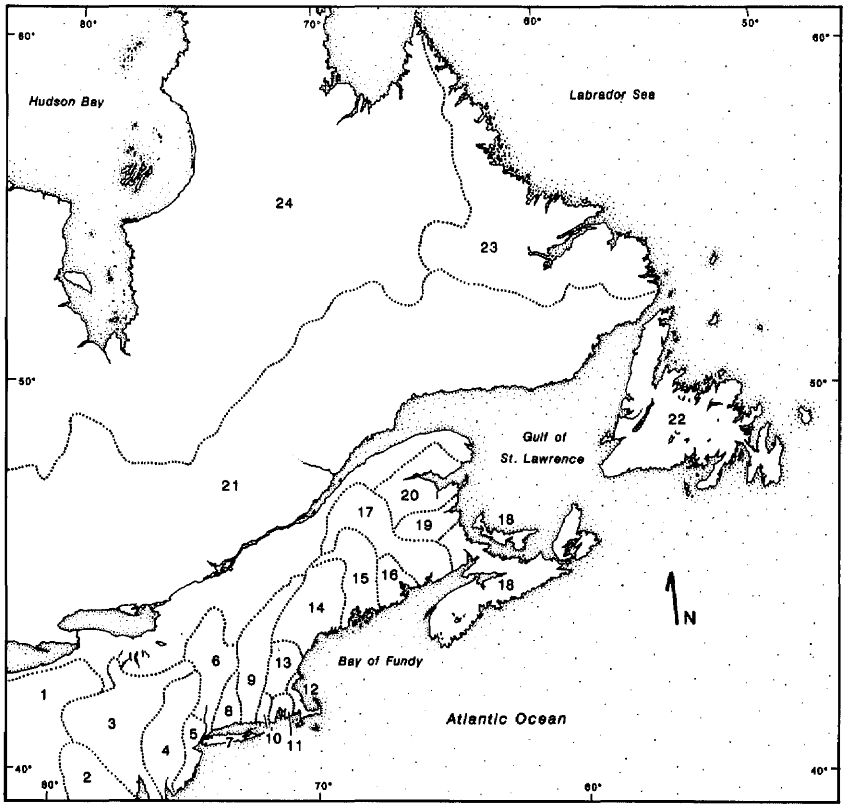


Figure 1. The river systems draining northeastern North America. 1. Ohio River; 2. Potomac River; 3. Susquehanna River; 4. Delaware River; 5. New Jersey Coastal Streams; 6. Hudson River; 7. Long Island Streams; 8. Housatonic River; 9. Connecticut River; 10. Thames River; 11. Taunton River; 12. Massachusetts Coastal Streams; 13. Merrimack River; 14. Kennebec River; 15. Penobscot River; 16. St. Croix River; 17. St. John River; 18. New Brunswick and Nova Scotia Coastal Streams; 19. Mirimichi River; 20. Restigouche River; 21. St. Lawrence River; 22. Newfoundland Coastal Streams; 23. Labrador Coastal Streams; 24. James/Hudson Bay Streams.

Ontario (Figure 1). Fresh-water and diadromous fishes are emphasized, but information on marine fishes that commonly stray into inland waters is also included. This volume is also, by definition, limited to fishes that have scales. Several important groups of inland fishes have no scales, such as lampreys (Family Petromyzontidae) and catfishes (Family Ictaluridae). Others, such as sculpins (Family Cottidae), have scales that are modified into small spines, and still others (Family Gobiidae) have no scaled representatives in northeastern inland waters. Although members of these families are components of inland fish assemblages, they are included in neither the key nor in the family accounts.

Some of the information contained in this volume can be found elsewhere. For example, Batts (1964), Bilton et al. (1964), Casteel (1972, 1973), Coburn and Gaglione (1992), Cockerell (1913), Galkin (1958), Koo (1962), Lagler (1947), Oates et al. (1993), Seyler (1931), Takos (1942), and others have published or written keys as aids to the identification of fish scales. However, these works do not focus on the fishes of the Northeast, do not include all the fishes of this region, are limited to fish of a single family or group, or are difficult to obtain. This work builds upon these important sources.

The geographic focus of this bulletin is narrow, since it includes only fishes reported from drainages in the northeastern part of the continent. The key and accounts are valid only for the species discussed. However, the work may have broader applicability. Scale characteristics seem to hold true within some families and subfamilies (McCully 1961), and Coburn and Gaglione (1992) have demonstrated conformity within genera. In other families, scale morphology is highly variable (Peabody 1928, 1931).

About Fish Scales

The obvious external feature of most fishes is the dermal skeleton, the scales. The type, condition, and number of scales on fish are important characteristics that are noted by workers in many disciplines. The need for, or value of, scales to the fish is more recondite, especially since the evolutionary trend in scale development has been from heavy, bony plates to light, flexible scales, to no scales at all in several taxa (Moyle and Cech 1988; Romer 1966). Scales and plates serve fish in several ways. The hard, bony exoskeleton offers some protection from predators and parasites. Scales act as a weak osmotic barrier. They also can serve as a storage area for minerals and nutrients, such as calcium and phosphorus (Van Oosten 1957). Scales also may serve more specialized functions. Brainerd et al. have (1989) described the fundamental role scales play in breathing by recoil aspiration in bichirs (Family Polypteridae). Scott and Smith (1994) have suggested that scales may have a temperature-dependent effect on locomotion. Scales may also be a determinant in fish behavior. For example, scale patterns may be important in species recognition or avoidance. Modified scales, such as those with pearl organs, can serve as contact organs important in reproductive behavior (Van Oosten 1957). Associated with any advantage that may arise from the presence of scales on a fish is an energetic cost. Additional profitable research could be devoted to detailed investigations of these advantages and costs.

Scales are characterized by the number and composition of their component layers and the amount of vascularization. Ichthyologists recognize four different kinds of scales: cosmoid, placoid, ganoid, and bony-ridge or elasmoid. All have been described in detail by Lagler et al. (1977). Cosmoid and placoid scales are found on marine or extinct fishes or relict fresh-water fishes not present in North America. Sturgeon, paddlefish, and gar possess modified ganoid scales. The bony-ridge scale is by far the most prevalent scale type found on fishes in northeastern North America.

The generalized ganoid scale is composed of three layers: a basal layer of lamellar bone; a thin layer of cosmine, which is an acellular, dentine-like substance; and a thick covering layer of a hard, noncellular enamel-like substance called ganoine (Van Oosten 1957). The layers are traversed by vascular canals. The three groups of northeastern fishes that possess ganoid scales (i.e., sturgeon, paddlefish, and gar) have modified scales which lack several of the characteristics of a generic ganoid scale. Sturgeons have five longitudinal rows of articulated scutes, or bucklers, along their lateral and dorsal aspects. Embedded in the skin between rows and on the upper lobe of the caudal fin are small, bony plates with one or more protruding spines. These plates, especially those on the tail, are rhomboidal. Sturgeon plates and scales are modified; the cosmine and ganoine layers are lost so that only the vascularized, bony layer remains. Paddlefish lack scales except for scattered rhomboid scales on the upper lobe of their caudal fins. Gar retain the ganoine layer but have lost the cosmine layer. These two-layer scales are intersected by large, unbranched canals that contain blood vessels. The scales of these fishes differ markedly in appearance from those of all other fishes in the Northeast.

The bony-ridge scale is a thin, flexible structure made up of two layers: a basal fibrillary plate and a bony surface layer (Wallin 1957). There are two basic types of bony-ridge scales that are distinguished by their surface ornamentation. The cycloid scale is typically found on fishes that possess other ancestral characteristics such as abdominal pelvic fins and rayed fins. Trouts and minnows are examples. These scales are not heavily ossified, and the surface structure is limited to ridges and radii. Spined scales, which have evolved several times in teleost fishes (Roberts 1993), are typically found on fishes that possess more derived characteristics such as thoracic pelvic fins and fin spines. Examples include perches and sunfishes. These scales are distinguished by spines present on the exposed or posterior field. Hughes (1981), Kobayashi, et al. (1972), Roberts (1993), Van Oosten (1957), and Wallin (1957) have provided information on aspects of scale growth and the development of the most conspicuous features of scales–the focus, ridges, radii, and spines.

The focus is the nuclear area, the part of the scale within the first ridge and/or the center of scale growth. In the bony surface layer, the growth zone is at the edges of the scale. This zone consists of an outer, initially uncalcified matrix and a zone of calcification (Wallin 1957). The osseous matrix is derived of protein supplied by osteoblasts. The growth area is relatively narrow; the central area of the scale is calcified. The focus is a feature of the surface layer only and does not extend into the fibrillary plate. Kobayashi et al. (1972) noted that the fibrillary plate begins to form after the formation of the focus, that is, after calcification begins in the osseous matrix. Fibroblast cells supply the protein needed for growth, which is achieved by adding increasingly larger layers of collagen fibers to the underside of the scale.

Ridges are crest-trough rings or lines observable on the bony surface layer of the scale. They are also referred to as striae or circuli in the literature. They develop at the edge of the scale and are laid down at a relatively constant rate. Ridges develop because the osteoblasts laying down the osseous matrix at the scale edge have different sizes and shapes. Long, flattened osteoblasts alternate with and overlap short, spherical osteoblasts. Kobayashi et al. (1972) speculated that the formation of the ridge depended upon different rates of osteogenic activity between the different cells.

Radii are grooves in the bony layer of the scale. Many authors use the broader term "sulci" and limit the use of "radii" to describe only those sulci radiating from the focus to the scale margin (McCully 1961). Wallin (1957) noted the presence of collagen fibers on both sides of radii in the osseous matrix of the growth zone at the scale margin. These fibers do not calcify, and radii therefore serve as boundaries between the calcified areas of the scale. He also noted that the fibrillary plate under the radii has a different chemical structure. Taylor (1914) suggested that radii serve as hinges that turn the relatively rigid scale into a structure with some flexibility. By noting the association between number of radii on roach (*Rutilus rutilus*) scales and the body area from which the scales were taken, Wallin (1957) provided support for this explanation.

Spines are comb- or cone-like structures present in the posterior fields of scales in many species. Roberts (1993) has recognized three types of spined scale: crenate, spinoid, and ctenoid. The simplest, or crenate, scale has projections or indentations on the posterior scale margin. Scales that are spinoid have spines that are connected to the main body of the scale. The spines, or ctenii, of ctenoid scales occur on small plates separate from the main body of the scale and exist in three distinct types: transforming, peripheral, and whole. In scales with transforming ctenii, each ctenius begins as a base and spine on a scalelet on the posterior margin of the scale (Hughes 1981; McCully 1961). The scalelets that hold the ctenii are visible as a patch on the posterior or exposed part of the scale. Generally, they appear to be fitted into a mosaic of rows and columns. Hughes (1981) examined the development of ctenii in platycephalids (rockfish-like fishes) and reviewed the literature on other groups. She concluded that growth of the posterior field of the scale occurred at the posterior margin with the addition of a row of ctenii. The number of ctenii in the new row was about one-half of the total number of ctenii on the posterior margin, indicating that alternating columns add ctenii simultaneously. In many species, including the platycephalids, distal ctenii (i.e., ctenii on the scale margin) have spines. The proximal part of the ctenial patch is made up of ctenial bases from which the spines have been lost. Other scales have a single row of ctenii (sometimes a second row of smaller ctenii is also present) on the scale margin. Roberts (1993) has referred to these as peripheral ctenii. Scales with whole spines at the margin and proximally are rare; Roberts (1993) has referred to these as whole ctenii.

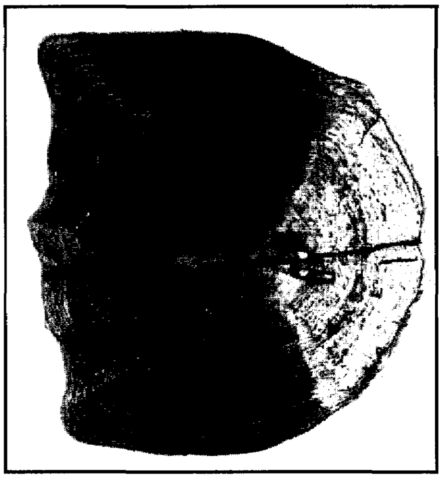


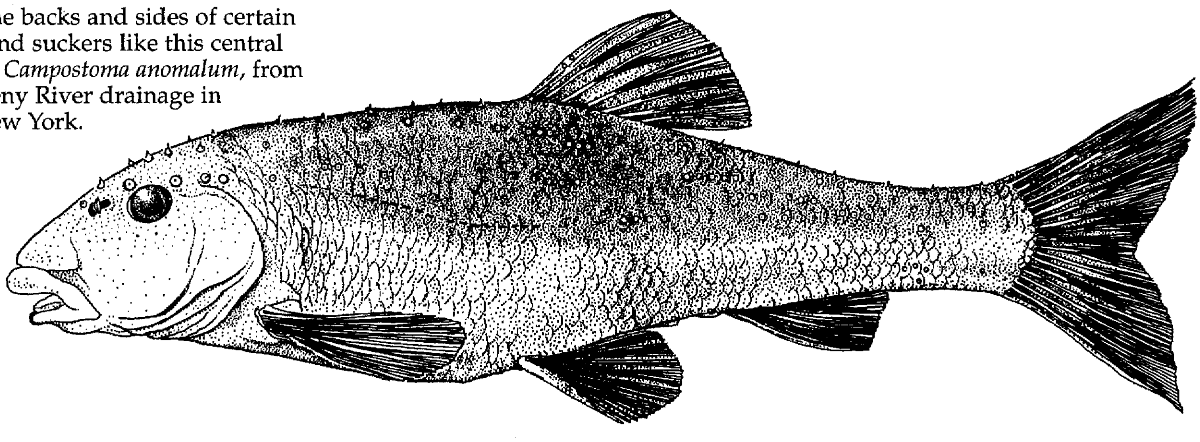
Figure 2. Modified scales cover the lateral line of most fishes. This scale is from a 182-mm rudd, *Scardinius erythrophthalmus*, NYSM 42040. Longitudinal dimension of scale is 8.5 mm.

Other types of structures are visible on certain scales. Most fish possess a lateral-line canal as part of their sensory system. The neuromasts, or sensory cells, present in the canal must be open to the environment in order to be stimulated. In most fishes, the scales overlying the lateral line have an opening in them to allow contact with the external environment. The opening differs among species (DeLamater and Courtenay 1973). In fishes found in the Northeast, the opening may be in the form of a pore or an open-ended tube (Figure 2).

Nuptial tubercles, or pearl organs, may appear on the scales of certain minnows and suckers during the breeding season (Figure 3). These tubercles are small, horny outgrowths of different sizes and shapes. They disappear after the spawning season (Collette 1965, 1977; Wiley and Collette 1970).

Most fish also have regenerated scales. When a fish loses a scale, it can rapidly replace the scale with one of equal size and similar construction materials, but without the external sculpturing typical of the species. Thus the replaced, or regenerated, area of the scale lacks a focus or nuclear area, ridges, radii, and ctenii. As the fish continues to grow, the scale grows in a normal manner. The result is a scale with an amorphous center and edges characteristic of the species (Figure 4).

Figure 3. Nuptial tubercles are bony growths found on the head and some scales on the backs and sides of certain minnows and suckers like this central stoneroller, *Campostoma anomalum*, from the Allegheny River drainage in western New York.



How Scales Are Used in Research

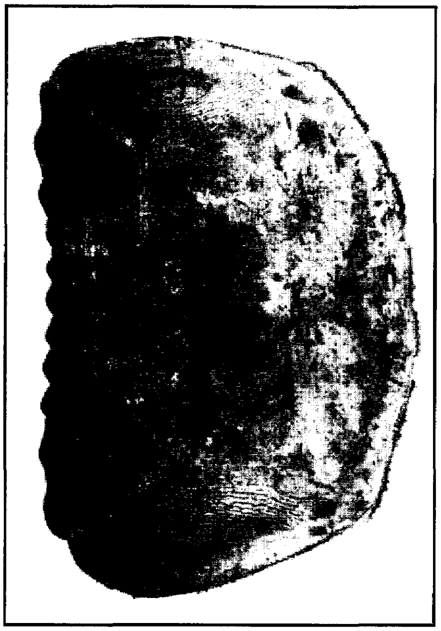


Figure 4. Most fish can regenerate lost scales. Regenerated scales lack the surface ornamentation of original scales as exemplified by the scale of this 147-mm scup, *Stenotomus chrysops*, NYSM 11468. Longitudinal dimension of scale is 6.5 mm.

Workers in many disciplines recognize that fish scales can provide useful information about fish and the environment in which they live. Natural historians and managers have used scales to age fish since the 1890s (Ricker 1975) because scales reflect the growth history of the fish (Moyle and Cech 1988). Typically, these studies deal with extant fish populations, but Casteel et al. (1977) used scales preserved in 11,000-year-old lake deposits to assess ancient growth rates. Fish continue to grow throughout their lives. As fish grow, they lay down ridges on the surface layer of their scales and additional layers on the basal fibrous plate, which increases the thickness of the plate differentially. Standard ageing techniques assume that the number of ridges and their proximity to each other are related to the rate of somatic growth. Periods of rapid growth are associated with the formation of widely spaced ridges (Bagenal and Tesch 1978), and periods of slow growth appear on the scale as an area of closely spaced ridges. In temperate climates, fish scales often show a pattern where widely spaced ridges are followed by ridges that are closely spaced. Numerous studies have argued that this pattern is repeated annually on the scales of many different species of fish. The annulus, or year mark, is considered to be the outer border of the closely spaced ridges (Bagenal and Tesch 1978). Ideally, the age of the fish corresponds to the number of annuli on the scale. There is, however, reason to be cautious in using scales for ageing fish or in interpreting the pattern of seasonal variation found on fish scales (Van Utrecht 1979) since the relationship between scale growth and that of the fish is complex. Furthermore, growth is highly specific to an individual, and within any population, individual variation in growth rates and patterns is great. Any variation in growth must be assessed, and the general technique of ageing should be validated for each study (see Bagenal 1974; Bagenal and Tesch 1978; Colley 1990; Jearld 1983).

Scales have also been used to assess diet in piscivorous vertebrate populations. In some cases, scales have been used to document the prehistoric presence of fish in lakes (e.g., Casteel and Rymer 1975; Casteel et al. 1977; Jordan 1927; Lagler and Vallentyne 1956; Pennington and Frost 1961) or drainages (Gobalet 1990a, 1993) or to identify members of past fish assemblages (Gobalet 1990b; Gobalet and Fenenga 1993; Peteet et al. 1994). DeVries (1988) noted the value of fish scales and bones from sediments in assessing climate change. Fish remains, including scales, have also been used to assess habitat changes (Casteel 1976; Gelbach and Miller 1961) and prehistoric trade (Gobalet 1992).

The use of scales in fish classification has had a mixed history. Agassiz developed a short-lived classification of fishes based on four scale types (Roberts 1993). Traditionally, most taxonomists have not dwelt on scale appearance in describing or defining taxa, although early (Cockerell 1909) and recent (Coburn and Cavender 1992; Coburn and Gaglione 1992) works attest to their value in this field.

Use of This Bulletin

The key and the family accounts provided here are to be used in concert when attempting to identify a scale. The key is dichotomous. Each couplet contains an affirmative and negative statement; the statements are mutually exclusive. In order to identify a scale, the reader should take the advice following each affirmative statement. This advice will lead either to another couplet or provide the identity of the scale. Once the scale is tentatively identified, the reader is directed to the family accounts.

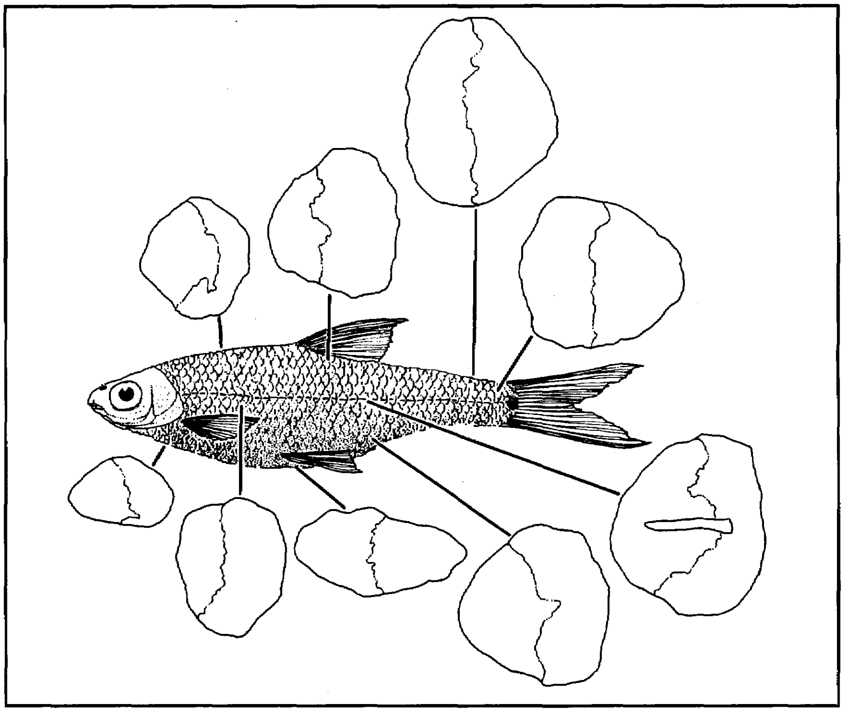


Figure 5. Individual scales on many fish vary in size and shape. The outlines of scales from different areas of this spottail shiner, *Notropis hudsonius*, provide an indication of how great the differences can be. Scales from these areas were used in developing the information in the family accounts.

Information on the scales is concentrated in the family accounts. Family, generic, scientific, and common names follow the conventions set by Robins et al. (1991). Information is provided for species reported present in inland waters of northeastern North America. Each account includes information on how common the species is in the Northeast and whether or not abundance varies seasonally; the presumed native range of the species; and, where appropriate, the areas into which it has been introduced. In families with many species, this information is tabulated. The typical habitat in which the fish is found, size range of the fish, and certain behavioral traits are also described. This information is provided to serve as a check. For example, if a scale is identified as that of a European minnow, and it was taken from sediments dated at 8,000 years bp, then the identity of the scale, the sample integrity, our current assessment of ichthyogeography, or some combination of these factors must be re-examined.

This general information about the species is followed by a more detailed description of the lateral scales of the genus or species. In most northeastern fish species, most scales are lateral (i.e., present on the sides of the fish). Lateral scales tend to be similar in shape, although they vary in size. Non-lateral scales (e.g. scales found on the head, back or belly of the fish) often differ from lateral scales in size and shape (Figure 5). Evans (1915) noted that, despite such differences, scales could be used to identify several species found in the Northeast. With experience, use of the key will lead to a successful identification of non-lateral scales as well. However, in some cases, non-lateral scales are so different that the key will either not lead to an identification or will lead to a misidentification. To alleviate this problem, non-lateral scales are described briefly.

On occasion, the researcher may be faced with the need to identify a broken or incomplete scale. Using the key to successfully identify

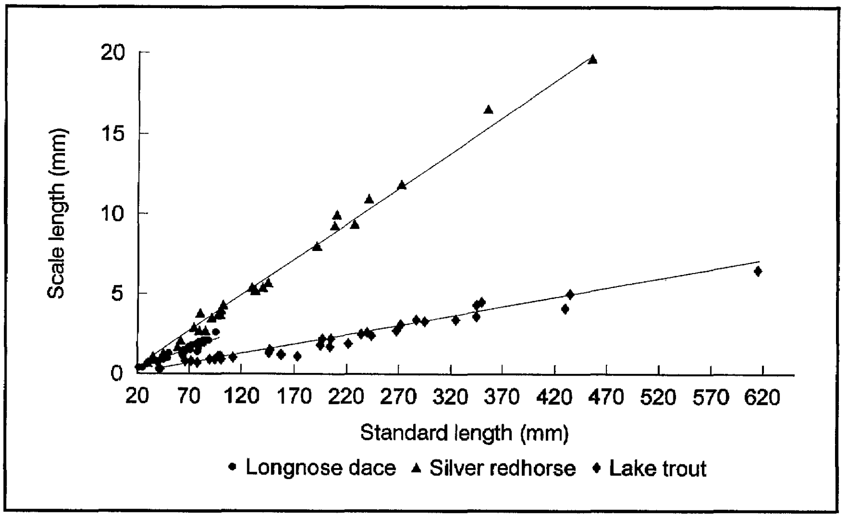


Figure 6. Since scale size increases as individual fish grow, it is an inadequate characteristic for use in scale identification. These lines illustrate the relationship between standard length and scale length within and among three representative species of fish inhabiting northeastern North American inland waters: longnose dace, *Rhinichthys cataractae*; silver redhorse, *Moxostoma anisurum*; and lake trout, *Salvelinus namaycush*.

fragmented scales will be problematic and will depend upon how much and what part of the scale are available for identification. In general, if parts of the anterior and posterior fields are present, the scale should be identifiable.

Scale size is avoided in the descriptions since scale size is related to fish size (Figure 6). However, information on the relationship between scale length and fish length is included for selected species. These measurements can serve as a guide to the size range expected within a species. The relationship between scale length and fish length is highly variable–a fact that should be noted carefully when making comparisons. Counts of ridges and numbers of rows of ctenii are avoided as criteria for distinguishing species. The number of secondary radii (i.e., radii that do not begin at the focus) depends upon the size of the scale. Secondary radii counts are not used here to identify scales. However, the number of primary radii (i.e., radii that run from the focus to the margin) does not seem to vary with fish age or size in most species (Wallin 1957) and is used as a distinguishing characteristic for some species.

All figures are arranged so that the anterior margin of the scale is on the left and the posterior margin on the right. The sizes of photographed scales are reported in the captions and represent the length of the scale.

Mounting and Viewing Scales

For most identifications, scales are best viewed under a dissecting microscope with transmitted light. They can be prepared for viewing in many ways. The simplest method is to place the scale between two microscope slides and secure the two slides with tape. This method is quick, requires few supplies, and the mount is not permanent. Scales can also be placed between a glass slide and cover slip using white, clear-drying glue or polyvinyl lactophenol. This method provides a mount for long-term storage of material, which is ideal for reference collections. A second advantage is that both these glues are water soluble so that the scales can be retrieved if necessary.

For more permanent mounts, scales should be cleaned and securely mounted. Sediment can often be removed with a fine brush and mild detergent. Epithelial tissue can be removed with a mild caustic solution (1.5% cold sodium hypochlorite; Hughes 1981) or can be cleared with an enzyme solution (trypsin; Coburn and Gaglione 1992). Scales can be stained with Alizarin Red S to emphasize calcified areas (McCully 1961).

The scale itself can be mounted, or an impression of it can be made on acetate. Hughes (1981) used clear cellophane tape that was sticky on both sides to secure scales to a slide. McClure (1984) flattened scales between acetate sheets and clear vinyl shelf paper. A number of materials and products can be used as substitutes; clear, adhesive address labels and glass slides achieve the same result. Bagenal and Tesch (1978) described the method of preparing an impression of the outer, or sculptured, surface of the scale. With this technique, the scale is placed, outer side down, on a thin, clear cellulose acetate slide. The scale and slide are placed between two other acetate slides and run through a roller press. A vertical press and heat can also be used.

METHODS

Scales were removed from preserved specimens of fishes reported from inland waters of northeastern North America. All relevant families and genera and most species are represented in the database. Specimens are from the New York State Museum (NYSM), Royal Ontario Museum (ROM) or the American Museum of Natural History (AMNH) and are listed in Appendix A. In general, two specimens of each species from different lots were used for the general database. Scales were removed from 13 areas on each fish (Table 1, Figure 5). Exceptions to this include several smaller specimens borrowed from other institutions; on these specimens only four lateral scales were removed.

The scales were removed with fine forceps and mounted between two glass microscope slides. Slides were viewed under a dissecting microscope at 10X or 20X with transmitted light. The longitudinal and transverse dimensions of each scale and the shortest distance between the anterior margin of the scale and focus were measured. The primary and secondary radii were counted. Mean radii counts, longitudinal-transverse dimension ratios, and focus-longitudinal dimension ratios are based on the values obtained from the lateral scales (Table 2). The means represent from 8 to 16 scales taken from two specimens. Scales from other specimens were examined, but measurements and counts were not included in Table 2.

TABLE 1. SOURCE AREAS OF FISH SCALES REMOVED FOR EXAMINATION

Right side, below the pectoral fin
Left side, below the pectoral fin
Predorsal, anterior to dorsal fin
Postdorsal, posterior to dorsal fin
Right side, caudal peduncle area, above lateral line
Left side, caudal peduncle area, above lateral line
Breast area
Area between pelvic fins
Right side, below dorsal fin origin, above lateral line
Left side, below dorsal fin origin, above lateral line
Right side, above pelvic or anal fin origin, below lateral line
Left side, above pelvic or anal fin origin, below lateral line
Right side, from lateral line

The specimens used are recorded in Appendix A.

TABLE 2. SELECTED CHARACTERISTICS OF LATERAL SCALES OF FISHES FOUND IN INLAND WATERS OF NORTHEASTERN NORTH AMERICA.

	Total Radii	Primary Radii	Focus/Length Ratio (S.D.)	Width/Length Ratio (S.D.)	Lengths (mm)			
					Scale	SL	Scale	SL
Amiidae								
Amia calva			0.75 (0.02)	0.56 (0.03)	0.3	33	15.3	542
Hiodontidae								
Hiodon tergisus	16.8 (3.41)	1.4 (1.41)	0.54 (0.06)	1.07 (0.05)	3.7	108	10.4	305
Elopidae								
Elops saurus	14.0 (1.63)	4.8 (0.96)	0.39 (0.06)	0.90 (0.12)	3.1	270	3.5	290
Anguillidae								
Anguilla rostrata				0.27 (0.03)	0.1	180	1.5	1007
Clupeidae								
Alosa aestivalis	17.0 (2.00)	1.5 (0.93)	0.61 (0.03)	0.95 (0.09)	2.0	62	6.4	238
Alosa mediocris	14.3 (1.75)	1.4 (0.74)	0.68 (0.06)	0.85 (0.12)	3.5	148	7.0	251
Alosa pseudoharengus	18.0 (2.98)	1.4 (0.74)	0.63 (0.04)	0.87 (0.04)	1.8	71	9.0	220
Alosa sapidissima	23.3 (1.98)	0.9 (0.99)	0.64 (0.06)	0.90 (0.05)	1.8	61	9.6	238
Brevoortia tyrannus	4.6 (2.45)	1.3 (0.71)	0.61 (0.04)	1.11 (0.11)	1.4	67	4.8	204
Clupaea harengus harengus	10.4 (4.10)	1.0 (0.53)	0.61 (0.05)	0.82 (0.11)	1.9	67	9.5	300
Dorosoma cepedianum	6.2 (1.56)	1.0 (0.00)	0.66 (0.03)	1.14 (0.10)	2.1	82	6.8	245
Engraulidae								
Anchoa mitchilli	7.7 (1.53)		0.48 (0.01)	1.51 (0.28)	2.6	58	3.0	75
Cyprinidae								
Campostoma anomalum	21.4 (2.20)	7.3 (1.04)	0.18 (0.03)	1.06 (0.06)	0.7	39	2.8	112
Carassius auratus	10.0 (2.67)	8.4 (1.92)	0.53 (0.03)	0.96 (0.11)	3.0	50	16.0	235
Clinostomus elongatus	9.6 (2.23)	3.7 (0.76)	0.20 (0.04)	1.24 (0.13)	0.5	41	1.1	71
Couesius plumbeus	12.2 (1.64)	4.8 (0.84)	0.20 (0.05)	0.80 (0.05)	0.7	45	1.9	100
Ctenopharyngodon idella	41.5 (24.5)	4.2 (3.97)	0.39 (0.07)	0.95 (0.06)	1.5	40	25.5	465
Cyprinella analostana	7.1 (1.46)	4.3 (0.76)	0.19 (0.04)	1.31 (0.12)	1.3	39	2.9	78
Cyprinella spiloptera	9.1 (2.03)	4.6 (1.24)	0.17 (0.03)	1.18 (0.14)	1.4	42	2.6	79
Cyprinus carpio	28.8 (12.7)	10.0 (1.41)	0.42 (0.06)	0.96 (0.15)	3.9	76	37.2	950
Erimystax dissimilis	13.3 (4.15)	5.9 (1.21)	0.15 (0.02)	1.06 (0.10)	0.7	32	1.9	81
Exoglossum laurae	15.0 (2.45)	6.8 (0.75)	0.15 (0.02)	1.05 (0.12)	1.1	45	2.1	101

Exoglossum maxillingua	19.7 (1.80)	6.8 (0.97)	0.13 (0.02)	1.02 (0.02)	1.1	45	2.1	102
Hybognathus hankinsoni	16.5 (3.39)	6.5 (0.84)	0.19 (0.04)	1.24 (0.11)	1.6	48	2.5	78
Hybognathus regius	10.6 (2.07)	5.3 (0.89)	0.15 (0.02)	1.00 (0.04)	1.2	41	2.4	68
Luxilus chrysocephalus	19.9 (4.60)	5.9 (1.21)	0.17 (0.04)	1.11 (0.13)	1.1	40	4.3	128
Luxilus cornutus	26.2 (3.76)	5.2 (0.41)	0.23 (0.06)	1.36 (0.23)	1.2	50	3.3	132
Lythrurus umbratilis	7.5 (3.46)	3.6 (0.74)	0.20 (0.03)	1.40 (0.26)	0.4	27	0.9	52
Macrhybopsis storeriana	16.0 (3.83)	6.0 (1.00)	0.30 (0.02)	1.19 (0.04)	1.4	39	5.4	146
Margariscus margarita	12.7 (1.80)	4.4 (0.79)	0.15 (0.03)	1.03 (0.10)	1.2	67	1.6	95
Nocomis biguttatus	31.7 (5.96)	7.6 (1.52)	0.14 (0.01)	1.21 (0.05)	1.8	60	3.8	110
Nocomis micropogon	35.3 (6.75)	7.7 (1.70)	0.20 (0.02)	1.17 (0.05)	1.4	34	5.9	150
Notemigonus crysoleucas	8.4 (3.50)	4.5 (0.88)	0.35 (0.04)	1.00 (0.05)	0.7	35	7.4	210
Notropis amblops	22.0 (3.74)	5.2 (0.75)	0.22 (0.04)	1.38 (0.17)	1.0	39	1.9	61
Notropis amoenus	5.6 (0.79)	3.1 (0.38)	0.22 (0.07)	1.31 (0.17)	1.4	53	2.2	72
Notropis anogenus	11.4 (2.70)	4.2 (1.64)	0.17 (0.03)	1.09 (0.07)	1.0	32	1.5	40
Notropis atherinoides	8.7 (2.80)	4.5 (0.55)	0.17 (0.06)	1.11 (0.22)	1.0	46	2.5	110
Notropis bifrenatus	9.8 (2.95)	5.4 (1.14)	0.18 (0.02)	1.21 (0.17)	0.7	26	1.4	40
Notropis bucattus	17.0 (2.58)	5.9 (0.69)	0.17 (0.02)	1.24 (0.05)	1.1	32	2.0	70
Notropis chalybaeus	6.0 (0.89)	3.8 (0.41)	0.13 (0.02)	1.10 (0.16)	0.8	28	1.1	35
Notropis dorsalis	10.7 (4.75)	4.8 (0.98)	0.18 (0.05)	1.19 (0.10)	1.1	39	1.5	54
Notropis heterodon	10.3 (2.42)	4.3 (0.52)	0.20 (0.01)	1.25 (0.11)	1.3	37	1.6	59
Notropis heterolepis	9.7 (0.82)	4.2 (0.98)	0.19 (0.04)	1.28 (0.06)	1.1	36	1.4	48
Notropis hudsonius	7.6 (1.92)	4.0 (0.53)	0.21 (0.03)	1.09 (0.09)	0.9	35	3.4	102
Notropis procne	8.7 (2.69)	3.4 (0.90)	0.12 (0.03)	1.30 (0.08)	0.9	41	1.5	53
Notropis rubellus	8.0 (2.16)	3.7 (0.76)	0.18 (0.02)	1.18 (0.10)	1.1	49	2.0	76
Notropis stramineus	8.4 (2.44)	4.4 (0.98)	0.17 (0.03)	1.28 (0.08)	1.3	39	1.6	55
Notropis volucellus	8.8 (2.64)	4.3 (0.52)	0.16 (0.06)	1.16 (0.19)	1.0	33	1.4	48
Phoxinus eos	30.5 (6.86)	13.8 (2.63)	0.30 (0.04)	1.15 (0.11)	0.2	45	0.4	60
Pimephales notatus	21.8 (5.57)	5.0 (0.82)	0.15 (0.06)	1.35 (0.08)	1.2	45	1.6	60
Pimephales promelas	22.1 (5.06)	5.5 (0.76)	0.25 (0.07)	1.32 (0.20)	0.3	18	1.8	52
Rhinichthys atratulus	34.4 (4.72)	23.0 (3.16)	0.16 (0.06)	0.97 (0.03)	0.4	28	0.9	55
Rhinichthys cataractae	32.9 (5.30)	17.3 (2.25)	0.12 (0.03)	0.77 (0.12)	0.4	21	2.6	96
Rhodeus sericeus	20.6 (5.53)	6.5 (1.69)	0.24 (0.04)	1.69 (0.21)	0.7	23	2.3	56
Scardinius erythrophthalmus	11.2 (2.64)	7.8 (1.47)	0.47 (0.04)	1.03 (0.04)	2.7	61	19.3	309
Semotilus atromaculatus	28.9 (3.80)	7.1 (0.83)	0.17 (0.03)	1.12 (0.12)	1.0	36	3.3	158
Semotilus corporalis	18.6 (4.00)	5.8 (1.28)	0.14 (0.03)	0.90 (0.08)	1.8	55	8.9	284
Tinca tinca	53.1 (5.64)	12.7 (2.29)	0.16 (0.00)	0.54 (0.09)	2.7	120	3.4	166
Catostomidae								
Carpiodes carpio	41.7 (11.9)	4.9 (1.05)	0.50 (0.03)	0.99 (0.11)	2.2	43	8.3	178
Carpiodes cyprinus	49.9 (3.94)	7.5 (1.06)	0.50 (0.02)	1.11 (0.07)	1.0	33	13.0	252
Catostomus catostomus	42.1 (8.41)	14.0 (6.71)	0.49 (0.05)	0.70 (0.06)	0.9	61	4.5	272

continued on next page

TABLE 2. — *continued*

	Total Radii	Primary Radii	Focus/Length Ratio (S.D.)	Width/Length Ratio (S.D.)	Lengths (mm)			
					Scale	SL	Scale	SL
Catostomus commersoni	29.9 (3.34)	12.0 (1.83)	0.42 (0.06)	0.80 (0.09)	1.0	53	6.3	289
Cycleptus elongatus	57.7 (4.62)	11.3 (1.53)	0.42 (0.04)	0.73 (0.03)			11.8	415
Erimyzon oblongus	21.7 (6.10)	8.9 (0.69)	0.50 (0.04)	0.58 (0.12)	1.1	48	9.4	247
Erimyzon sucetta	14.3 (5.06)	7.8 (1.58)	0.42 (0.04)	0.77 (0.06)	1.8	38		
Hypentelium nigricans	19.0 (1.55)	12.5 (0.55)	0.49 (0.03)	0.82 (0.06)	1.8	55	10.3	302
Ictiobus cyprinellus	92.5 (21.3)	5.7 (0.52)	0.54 (0.02)	0.92 (0.06)	15.0	310	26.7	540
Moxostoma anisurum	15.0 (2.20)	7.6 (1.04)	0.52 (0.03)	1.05 (0.07)	1.1	35	19.7	455
Moxostoma carinatum	41.4 (19.1)	8.7 (1.25)	0.53 (0.02)	0.92 (0.06)	7.8	157	20.6	455
Moxostoma duquesnei	16.1 (2.27)	10.6 (1.72)	0.42 (0.02)	1.04 (0.03)	1.4	5.2	10.3	266
Moxostoma erythrurum	12.4 (1.30)	8.6 (1.19)	0.50 (0.03)	0.97 (0.11)	2.4	76	10.7	238
Moxostoma hubbsi	48.5 (2.39)	8.1 (0.93)	0.53 (0.02)	0.92 (0.06)			23.6	491
Moxostoma macrolepidotum	14.5 (1.05)	9.2 (0.75)	0.51 (0.03)	1.03 (0.03)	1.7	55	14.2	366
Moxostoma valenciennesi	14.9 (2.41)	9.4 (1.40)	0.51 (0.04)	0.92 (0.04)	3.1	80	13.8	261
Esocidae								
Esox americanus	2.1 (0.75)	2.1 (0.75)	0.64 (0.06)	0.74 (0.09)	0.8	55	3.6	225
Esox lucius	2.3 (0.46)	2.3 (0.46)	0.66 (0.03)	0.82 (0.10)	0.9	74	10.3	910
Esox masquinongy	1.8 (0.41)	1.8 (0.41)	0.57 (0.05)	0.90 (0.03)	0.5	72	8.9	775
Esox niger	2.1 (0.64)	2.1 (0.64)	0.59 (0.04)	0.75 (0.12)	0.3	40	5.2	465
Umbridae								
Umbra limi			0.53 (0.05)	0.89 (0.04)	1.8	42	2.7	75
Umbra pygmaea			0.61 (0.04)	0.78 (0.08)	2.0	43	5.0	79
Osmeridae								
Osmerus mordax			0.23 (0.06)	1.19 (0.09)	1.4	110	2.7	150
Salmonidae								
Coregonus artedi			0.54 (0.03)	1.01 (0.08)	2.0	135	5.0	240
Coregonus clupeaformis			0.58 (0.07)	0.96 (0.06)	1.7	86	9.2	402
Oncorhynchus mykiss			0.60 (0.04)	0.75 (0.11)	0.4	41	4.1	455
Prosopium cylindraceum			0.55 (0.03)	0.97 (0.06)	3.1	163	6.0	266
Salmo salar			0.56 (0.04)	0.63 (0.09)	0.5	64	5.5	530
Salmo trutta			0.55 (0.06)	0.66 (0.01)	0.5	50	5.0	615
Salvelinus alpinus			0.48 (0.06)	0.59 (0.05)	0.9	130	3.7	368
Salvelinus fontinalis			0.53 (0.02)	0.56 (0.06)	0.3	55	1.8	510
Salvelinus namaycush			0.48 (0.05)	0.56 (0.09)	0.3	50	2.6	325

Percopsidae								
Percopsis omiscomaycus			0.75 (0.01)	1.22 (0.16)	1.0	55	1.7	113
Aphredoderidae								
Aphredoderus sayanus	3.3 (1.28)	2.6 (0.74)	0.76 (0.02)	0.68 (0.05)	1.3	34	3.2	74
Gadidae								
Lota lota			0.49 (0.04)	0.95 (0.09)	0.3	89	1.6	532
Microgadus tomcod	45.8 (15.34)		0.35 (0.04)	0.63 (0.09)	1.2	81	3.1	315
Urophycis regia			0.49 (0.02)	0.59 (0.04)	0.9	72	2.7	238
Urophycis tenuis			0.47 (0.03)	0.60 (0.06)	2.1	140	2.8	202
Belonidae								
Strongylura marina			0.50 (0.04)	1.71 (0.14)	0.3	185	3.5	352
Cyprinodontidae								
Cyprinodon variegatus	14.3 (1.50)		0.53 (0.03)	1.14 (0.10)	0.5	14	2.4	43
Fundulus diaphanus	11.2 (2.39)		0.58 (0.04)	1.09 (0.13)	0.8	35	2.3	94
Fundulus heteroclitus	18.5 (2.88)		0.56 (0.06)	0.93 (0.08)	0.8	21	4.3	95
Fundulus luciae	11.8 (1.17)		0.52 (0.04)	0.94 (0.06)	0.7	18	1.5	32
Fundulus majalis	9.6 (0.89)	6.8 (0.84)	0.57 (0.03)	0.83 (0.07)	1.2	36	5.4	112
Lucania parva	14.0 (1.93)		0.46 (0.02)	1.10 (0.41)	0.7	16	1.7	35
Poeciliidae								
Gambusia affinis	13.3 (4.51)		0.61 (0.03)	1.37 (0.13)	0.7	16	1.7	35
Atherinidae								
Labidesthes sicculus	6.7 (0.76)		0.49 (0.04)	1.56 (0.29)	0.4	41	1.0	81
Membras martinica			0.57 (0.03)	1.43 (0.13)	1.5	38	3.1	85
Menidia beryllina	9.1 (0.38)		0.50 (0.03)	1.49 (0.11)	0.9	26	1.7	62
Menidia menidia	9.0 (1.90)		0.43 (0.03)	1.17 (0.12)	1.3	40	3.2	122
Percichthyidae								
Morone americana	11.4 (1.63)	8.6 (0.81)	0.66 (0.03)	1.11 (0.09)	1.1	41	5.8	262
Morone chrysops	11.5 (1.67)	9.1 (1.29)	0.67 (0.03)	1.04 (0.07)	0.7	36	5.0	240
Morone saxatilis	19.3 (2.89)	14.0 (2.20)	0.61 (0.03)	1.06 (0.03)	1.3	72	6.1	320
Serranidae								
Centropristis striata	10(0.00)	10 (0.00)	0.75 (0.01)	1.03 (0.04)	2.4	71	5.1	157
Mycteroperca microlepis	2.8 (0.50)	2.8 (0.50)	0.59 (0.05)	0.53 (0.02)	1.7	79		

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TABLE 2. — *continued*

	Total Radii	Primary Radii	Focus/Length Ratio (S.D.)	Width/Length Ratio (S.D.)	Lengths (mm) Scale	SL	Scale	SL
Centrarchidae								
Acantharchus pomotis	12.0 (1.41)	8.6 (1.19)	0.56 (0.02)	0.99 (0.08)	2.3	48	4.5	98
Ambloplites rupestris	13.0 (0.93)	9.8 (1.67)	0.67 (0.03)	1.00 (0.06)	1.3	39	7.6	175
Enneacanthus gloriosus	13.4 (1.60)	10.6 (0.74)	0.64 (0.01)	1.25 (0.14)	0.5	17	2.8	57
Enneacanthus obesus	11.6 (1.69)	7.8 (2.31)	0.56 (0.02)	0.96 (0.19)	1.2	23	3.0	65
Lepomis auritus	11.3 (1.97)	10.0 (1.15)	0.61 (0.02)	1.06 (0.08)	0.9	45	4.6	133
Lepomis cyanellus	10.3 (1.21)	7.5 (0.55)	0.58 (0.05)	1.07 (0.07)	0.8	40	5.9	200
Lepomis gibbosus	11.5 (1.20)	10.2 (1.24)	0.62 (0.03)	1.15 (0.15)	1.3	50	5.2	152
Lepomis gulosus	9.8 (1.30)	6.4 (1.52)	0.55 (0.04)	1.09 (0.09)	1.4	45	3.1	103
Lepomis macrochirus	12.8 (1.39)	8.4 (1.60)	0.62 (0.03)	1.12 (0.09)	1.7	50	5.4	160
Lepomis megalotus	9.3 (1.71)	8.0 (0.82)	0.61 (0.02)	1.13 (0.06)	1.6	42	3.3	100
Lepomis microlophus	12.9 (1.57)	8.1 (1.36)	0.59 (0.03)	1.08 (0.07)	0.7	33	4.1	102
Micropterus dolomieu	6.3 (1.29)	6.3 (1.29)	0.62 (0.03)	0.98 (0.09)	0.5	31	5.6	284
Micropterus salmoides	7.6 (2.27)	6.3 (1.71)	0.61 (0.08)	0.96 (0.09)	1.8	91	8.5	433
Pomoxis annularis	13.0 (2.14)	8.3 (1.67)	0.55 (0.03)	1.21 (0.14)	1.1	47	5.5	210
Pomoxis nigromaculatus	13.1 (1.86)	12.1 (1.68)	0.55 (0.12)	1.15 (0.10)	1.2	48	5.6	210
Percidae								
Ammocrypta pellucida	3.9 (0.90)		0.44 (0.08)	1.01 (0.90)	0.2	36	0.4	50
Etheostoma blennioides	10.5 (1.76)	6.0 (0.63)	0.62 (0.02)	1.01 (0.03)	0.6	33	1.7	73
Etheostoma caeruleum	13.6 (0.89)	7.2 (0.45)	0.57 (0.04)	1.03 (0.08)	0.9	29	1.4	52
Etheostoma camurum	11.0 (2.00)	5.6 (0.55)	0.62 (0.05)	1.06 (0.25)			1.2	42
Etheostoma chlorobranchium	12.5 (0.58)	8.3 (0.50)	0.67 (0.04)	1.08 (0.26)	1.2	58	1.5	71
Etheostoma exile	12.5 (1.38)	6.5 (1.22)	0.64 (0.06)	1.10 (0.06)	0.6	26	0.7	43
Etheostoma flabellare	13.3 (1.26)	5.5 (0.58)	0.64 (0.06)	1.11 (0.06)	0.8	32	1.2	59
Etheostoma fusiforme	10.1 (1.25)	6.0 (0.53)	0.67 (0.06)	0.98 (0.07)	0.7	26	1.3	43
Etheostoma maculatum	11.4 (0.98)	5.3 (0.76)	0.60 (0.02)	1.02 (0.13)	0.9	36	1.1	57
Etheostoma nigrum	17.7 (0.52)	8.3 (1.37)	0.68 (0.07)	1.40 (0.15)	0.5	23	1.2	53
Etheostoma olmstedi	15.7 (4.22)	7.6 (0.97)	0.68 (0.02)	1.33 (0.14)	0.8	35	1.9	80
Etheostoma tippecanoe	12.2 (1.79)	5.8 (0.45)	0.51 (0.09)	1.41 (0.13)	0.6	26		
Etheostoma variatum	12.9 (2.30)	5.8 (1.38)	0.64 (0.03)	0.97 (0.10)	1.1	41	2.0	78
Etheostoma zonale	12.2 (0.98)	5.8 (0.98)	0.63 (0.02)	1.06 (0.08)	1.1	34	1.5	62
Perca flavescens	6.6 (1.06)	6.5 (0.93)	0.66 (0.05)	1.15 (0.13)	0.6	55	4.0	240
Percina caprodes	9.1 (1.81)	6.4 (0.74)	0.60 (0.05)	0.97 (0.09)	0.7	48	1.6	106
Percina copelandi	11.5 (1.85)	5.9 (0.64)	0.58 (0.03)	1.22 (0.15)	0.9	40	1.2	48
Percina evides	10.0 (1.77)	5.3 (0.89)	0.57 (0.04)	1.08 (0.12)	0.6	41		
Percina macrocephala	10.5 (1.20)	5.6 (0.52)	0.57 (0.05)	1.19 (0.12)	0.6	50	1.0	74
Percina maculata	12.3 (1.89)	7.1 (0.69)	0.62 (0.03)	1.13 (0.06)	0.6	39	1.5	70
Percina peltata	10.0 (0.63)	6.2 (1.17)	0.61 (0.03)	1.03 (0.06)	0.4	25	1.6	69

Percina shumardi	12.1 (3.13)	6.6 (1.27)	0.58 (0.06)	1.07 (0.08)	1.0	45	1.5	70
Stizostedion canadense	6.4 (1.82)	5.2 (0.84)	0.70 (0.03)	1.13 (0.11)	1.0	104	3.4	248
Stizostedion vitreum	6.4 (1.41)	5.9 (0.99)	0.73 (0.03)	1.08 (0.09)	0.3	41	6.5	615
Pomatomidae								
Pomatomus saltatrix	13.3 (4.51)	0.1 (0.25)	0.57 (0.03)	1.37 (0.13)	0.3	71	5.7	402
Carangidae								
Caranx hippos			0.48 (0.06)	1.27 (0.10)	0.3	66	1.2	185
Sparidae								
Archosargus probatocephalus	13.2 (1.79)	6.2 (0.45)	0.72 (0.03)	1.08 (0.04)	3.5	90	3.7	108
Lagodon rhomboides	11.4 (0.74)	7.1 (0.83)	0.75 (0.02)	1.10 (0.06)	0.8	31	2.6	117
Stenotomus chrysops	9.7 (0.95)	7.0 (0.82)	0.59 (0.03)	1.12 (0.12)	0.8	29	15.2	390
Sciaenidae								
Aplodinotus grunniens	11.4 (1.51)	5.6 (0.53)	0.77 (0.02)	1.16 (0.08)	1.2	47	8.3	365
Bairdiella chrysoura	10.9 (1.95)	6.0 (0.82)	0.69 (0.02)	1.17 (0.12)	0.9	38	4.9	169
Cynoscion regalis	16.3 (3.15)	3.1 (0.38)	0.75 (0.04)	1.09 (0.14)	0.9	41	4.1	430
Leiostomus xanthurus	9.4 (0.92)	4.9 (0.83)	0.68 (0.03)	0.99 (0.06)	0.9	52	3.4	138
Sciaenops ocellatus	13.3 (2.73)	6.3 (1.21)	0.79 (0.02)	1.25 (0.08)	4.0	122	20.5	705
Mugilidae								
Mugil cephalus	10.8 (0.71)	7.8 (0.46)	0.57 (0.02)	1.09 (0.05)	1.8	51	9.2	245
Mugil curema	8.1 (0.53)	5.8 (0.90)	0.58 (0.04)	1.07 (0.12)	1.6	66	9.0	258
Eleotridae								
Dormitator maculatus	10.3 (3.77)	5.9 (2.04)	0.92 (0.03)	0.90 (0.08)	1.7	32	2.4	45
Bothidae								
Paralichthys dentatus	31.1 (9.20)	5.4 (1.06)	0.73 (0.02)	0.76 (0.06)	0.5	50	2.5	222
Scophthalmus aquosus	18.3 (4.71)	4.7 (1.60)	0.74 (0.08)	0.83 (0.10)	0.3	45	1.7	198
Pleuronectidae								
Pleuronectes americanus	22.8 (6.07)	7.0 (1.77)	0.77 (0.04)	0.78 (0.08)	0.5	45	2.4	200
Soleidae								
Trinectes maculatus	7.1 (0.83)	4.8 (0.71)	0.57 (0.06)	0.50 (0.03)	0.6	40	2.8	120

Means and standard deviations (in parentheses) are based on counts or measurements from 8-16 lateral scales. The numerator in the focus/length ratio is the longitudinal distance from the focus to the anterior margin. Measurements of scale length and standard length from two specimens is provided to illustrate the relationship between these two variables. The measured scale is a lateral scale taken from the area between the pectoral and dorsal fins above the lateral line.

GLOSSARY

The terms used to describe scale characteristics come from a variety of sources. Early workers were less than careful in applying terms. Consequently, the literature includes many terms that describe a single feature, single terms that describe two or more features, terms that are contradictory, and different spellings of the same term. Some of the terms that have gained wide acceptance are perhaps inappropriate, and other terms would be better. In this volume, no new terms are introduced; instead, the effort has been directed toward consistent use of the terms in existence. Terms associated with the orientation of the scale seem particularly odd. In the way of explanation, many of the terms that have gained acceptance were developed by workers describing a disembodied scale. The scale, lying flat in front of them, was no longer oriented as it would have been on the fish's body. Therefore, terms typically associated with the body no longer defined spatial orientation and were replaced. For example, words such as "dorsal" and "ventral" were replaced by "lateral."

Scale characteristics and measurements are shown in Figures 7 and 8.

Annulus. Pl. annuli. Growth checks or zones that form yearly on scales and other bony structures of fish. See Bagenal and Tesch (1978) for discussion.

Anterior field. Area of the scale, usually wedge-shaped, delineated by the focus, the anterior margin, and lines running from the focus to the antero-lateral corners of the scale. Usually embedded. Synonym: basal field.

Anterior margin. Edge of the scale closest to the head of the fish. Synonym: basal margin.

Bony-ridge scale. Type of scale found on most extant fishes. It is of dermal origin and consists of two layers. Synonym: elasmoid scale.

Border. Imaginary demarcation between adjacent fields.

Circulus. Pl. circuli. See ridge.

Concentric. Having a common center.

Cosmoid scale. Four-layered scale found on certain fossil fishes. The layers comprise two basal layers of bone, a cosmine (non-cellular, dentine-like material) layer, and a thin vitrodentine (enamel-like substance) layer.

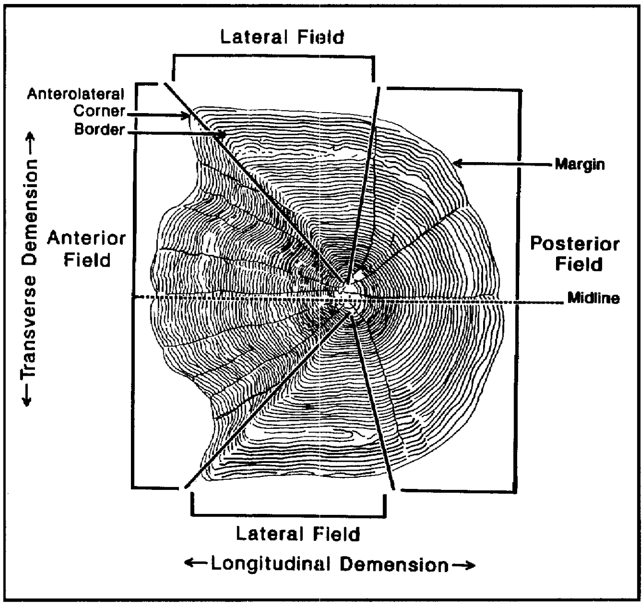


Figure 7. Cycloid scales are one type of bony-ridge scale; they lack ctenii. This scale is from a golden redhorse, *Moxostoma erythrurum* The dimensions referred to throughout the text are identified on this scale.

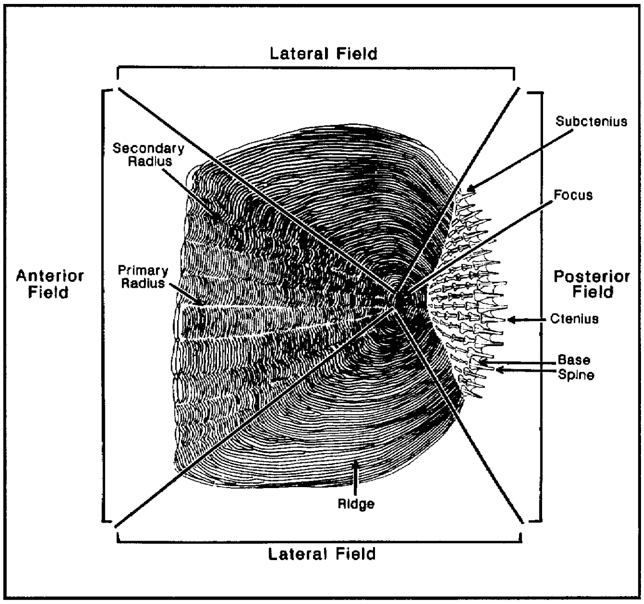


Figure 8. Ctenoid scales are a second type of bony-ridge scale; ctenii are prominent in the posterior field. This scale is from a spot, *Leiostomus xanthurus*. Common surface features are identified on this scale.

Crenate scale. A scale with simple projections and indentations on its posterior margin.

Ctenial base. The proximal part of the ctenius, the part that remains when the distal spine degenerates or is lost.

Ctenial patch. The area on the scale between the posterior margin and the row made up of subctenii and subctenial bases.

Ctenius. Pl. ctenii. [Greek: comb, or the hand with fingers extended.] The individual scalelet found on the posterior field of certain scales. Following Hughes (1981), the ctenius possesses a base and spine. The spelling "ctenus" appears in the literature, but since the term is based on the Greek word "ctenio," the correct root is "cteni," not "cten."

Ctenoid scale. A scale made up of a main body and several scalelets with ctenii in the posterior, exposed field. (Since the Greek root is "cteni," the scale correctly should be called "ctenioid;" thankfully, I have not seen this spelling in the literature.)

Cycloid scale. A scale that is circular, oval, or subquadrate, or with ridges arranged concentrically around a focus or focal, often central, point. In common usage, any scale without spines or ctenii.

Elasmoid scale. See bony-ridge scale.

Embedded. Surrounded by tissue. Scales may be partially or completely embedded.

Focus. Pl. foci. [Latin: hearth.] The point or region from which the scale grows. Ridges are usually concentric about this point, and radii extend from it.

Ganoid scale. A scale composed of three layers common on many relict fishes, such as sturgeons and gars. The three layers consist of basal lamellar bone, a vascularized dentinal layer, and an outer layer of enamel-like ganoine.

Lateral fields. Areas of the scale, usually wedge-shaped, delineated by the focus, the lateral margins and lines running from the focus to the antero-lateral corners and postero-lateral corners of the scale.

Lateral margins. Edges of the scale closest to the dorsal and ventral profiles of the fish.

Longitudinal. Being parallel to the midline of the scale. Length.

Lunula. The exposed, posterior part of the scale.

Midline. The axis of symmetry. An imaginary line running from the midpoint of the anterior margin of the scale, through the focus and terminating at the midpoint of the posterior margin of the scale.

Naked. Without scales.

Peripheral ctenii. Type of ctenii found on scales where a single row of ctenii are found on the posterior margin. There are no proximal, or submarginal, ctenii on scales with peripheral ctenii.

Placoid scale. Type of scale found on cartilagineous fishes (Chondrichthyes). Typically, it consists of a basal plate in the dermis and a spine protruding through to the body surface.

Posterior field. Area of the scale, usually wedge-shaped, delineated by the focus, the posterior margin, and lines running from the focus to the postero-lateral corners of the scale. Usually exposed. Synonym: apical field.

Posterior margin. Edge of the scale closest to the caudal fin. Synonym: apical margin.

Primary radius. Pl. primary radii. [Latin: staff, ray.] A groove, appearing as a line through the circuli, reaching from the scale focus to the scale margin. Synonym: sulcus.

Radius. See primary radius.

Regenerated scale. A scale that has replaced an earlier one. It differs from an original scale in that the center lacks all typical features, such as a focus, ridges, radii or ctenii. Instead, according to Wallin (1957), the center consists of plates of bone that originate simultaneously and grow in all directions. When the plates meet, growth stops. The plates are often separated by grooves which superficially resemble radii (sulci). Scale replacement can be rapid and varies among species.

Rhomboid scale. Ganoid scales that are diamond-shaped. This term refers only to the shape of the scale and not to its structure. Synonyms: rhombic scale, rhombic plate.

Ridge. Concentric, transverse, or longitudinal elevations on scales. Synonyms: stria, circulus.

Scalelet. Subunits found on the bony surface layer of scales separated from each other by radii (sulci). Individual ctenii are usually on scalelets.

Secondary radius. A groove that extends from the scale margin toward, but does not touch, the focus.

Spine. The individual projections extending from the posterior fields of certain scales. Or, the individual projection extending from the ctenial base of scalelets in the posterior fields of certain scales.

Spinoid scale. Scales with spines that project from the posterior (sometimes lateral) margin of the scale. The spines are part of the main body of the scale and do not form on scalelets.

Standard length (SL). The distance from the anteriormost point on the body of the fish (snout or lower jaw) to the bases of the caudal-fin rays (posterior edge of the hypural plate).

Stria. Pl. striae. [Latin: furrow.] See ridge.

Subctenial base. The structure left after the spine of the subctenius deteriorates.

Subctenius. The ctenius at both ends of the row adjacent to the outermost ridge. Unlike the condition in a ctenius, the lobes of the base are noticeably unequal.

Sulcus. Pl. sulci. [Latin: trench.] See radius.

Thickness. The distance between the two flat surfaces of the scale.

Total length (TL). The distance, measured along the midline, between the anteriormost point of a fish to its posteriormost point.

Transforming ctenii. Type of ctenii found on scales where ctenii originate as spines on scalelets at the posterior margin of a scale and then transform into abbreviated ctenii with shortened spines as the scale continues to grow.

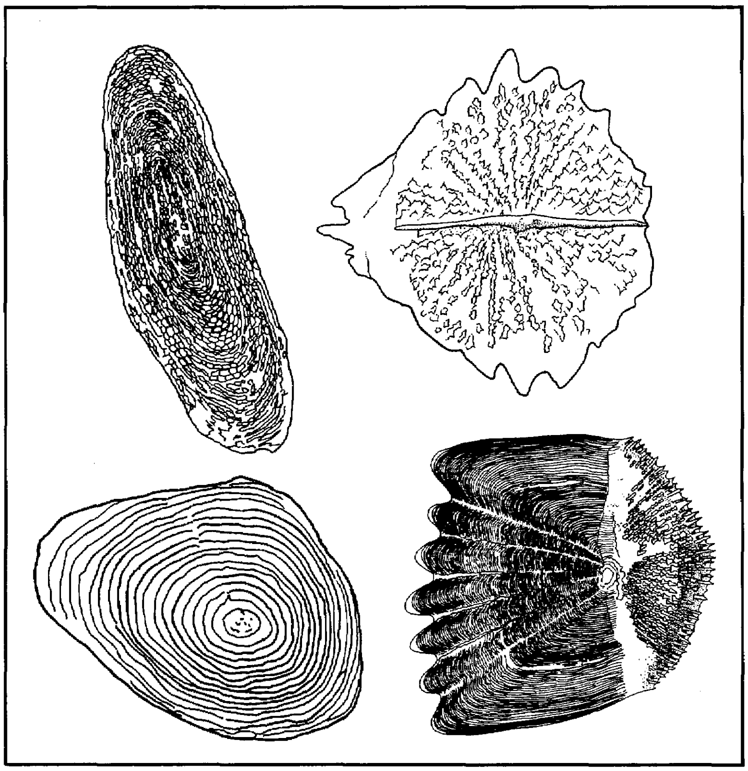
Transverse. Being perpendicular to the midline of the scale on the same plane. Width.

Whole ctenii. Type of ctenii found on scales where the marginal and submarginal ctenii retain spines. This condition is rare.

KEY

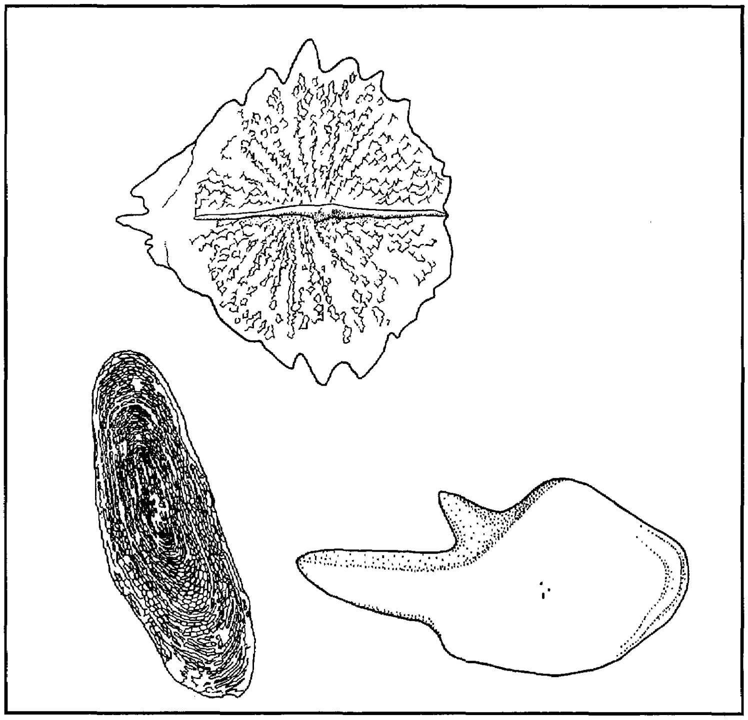
1a. Scale without concentric ridges 2

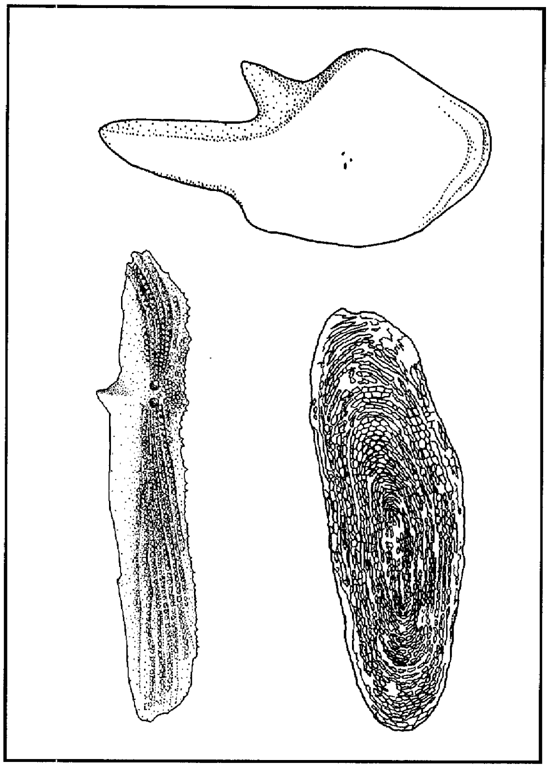
1b. Scale with concentric ridges 5



2a. Scale cap-like, sculptured,
often with a central peak or hook.........
....**Acipenseridae**

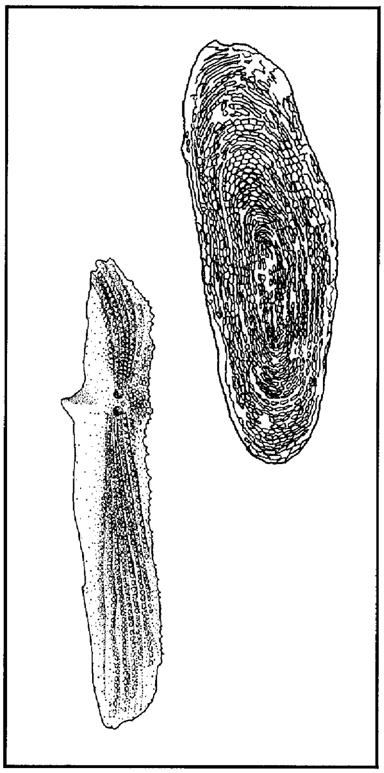
2b. Scale not cap-like.............................3





3a. Scale flat, without surface ornamentation, often with anterior projections, axes about equal............**Lepisosteidae**

3b. Transverse axis more than 4 times longitudinal axis..................................4

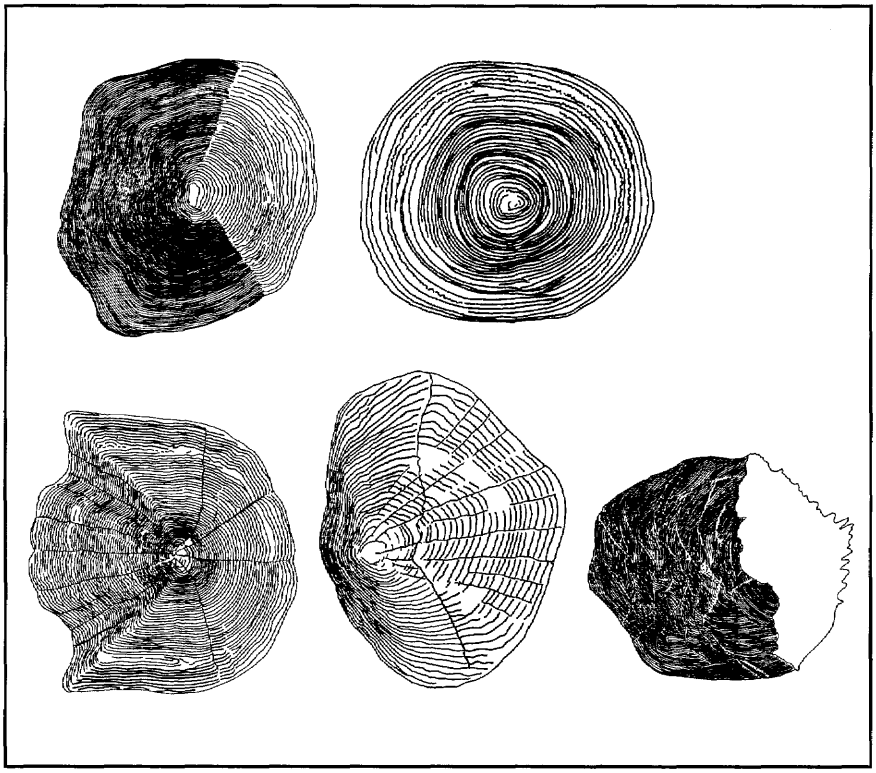


4a. Scale with small, bead-like elements, attached end to end, concentric around focus......................**Anguillidae**

4b. No bead-like elements, surface sculpturing present......**Gasterosteidae**

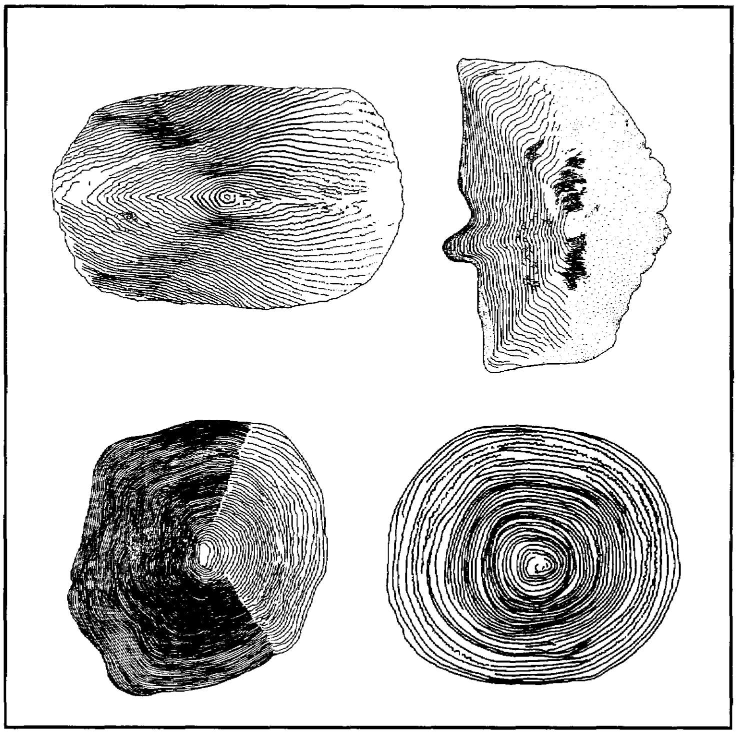
5a. Radii absent......................................6

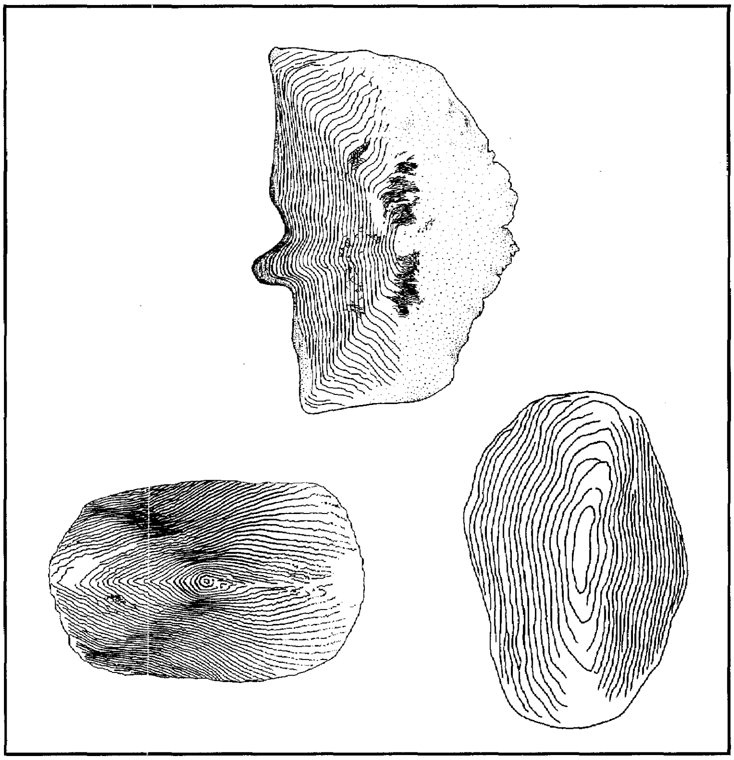
5b. Radii present..................................17



6a. Ridges do not encircle focus..........7

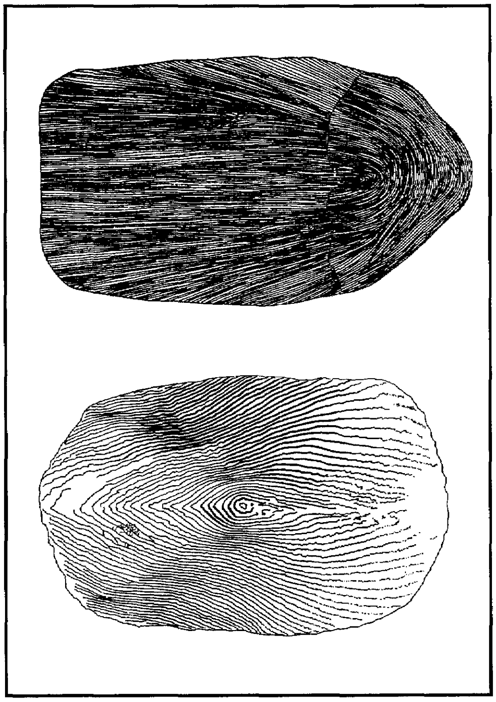
6b. Ridges encircle focus.....................11





7a. Ridges absent from posterior field ....**Atherinidae,** ***Membras***

7b. Ridges present in posterior field....8

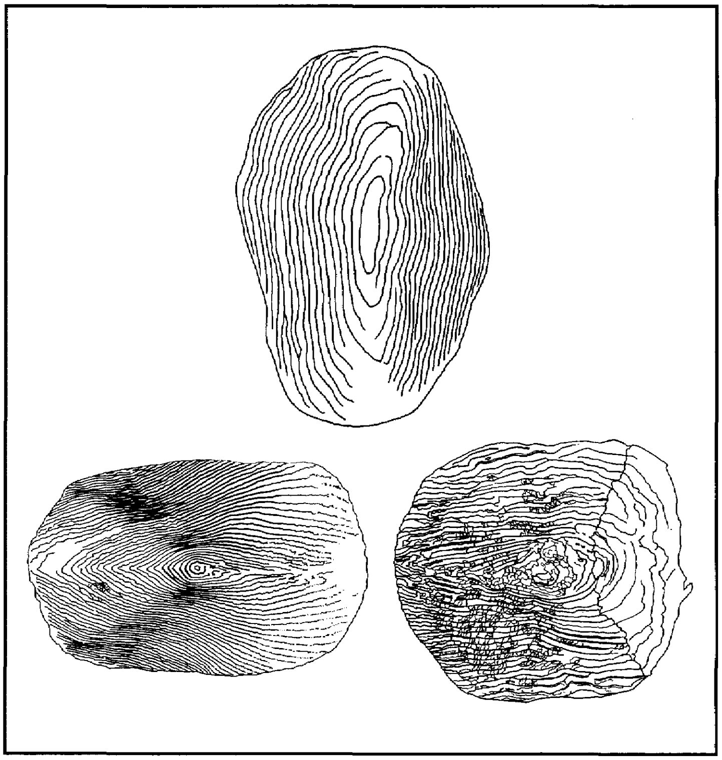


8a. Ridges fan out from focus, then proceed to anterior and posterior margins of scale parallel to lateral margins.....................................**Amiidae**

8b. Ridges not parallel to lateral margins 9

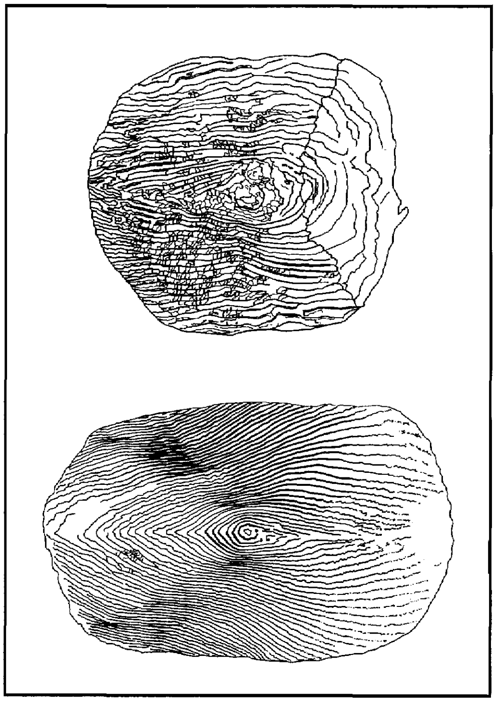
9a. Ridges parallel in anterior and posterior fields, not continuous in lateral fields............................**Belonidae**

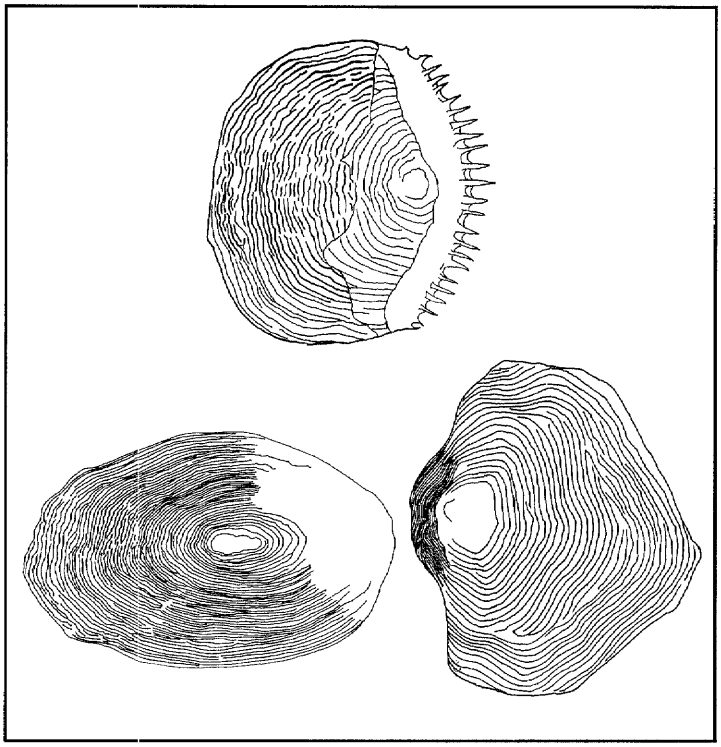
9b. Ridges continuous in lateral........... fields 10



10a. Focus weakly formed, ridges perpendicular to anterior margin of scale ....**Umbridae**

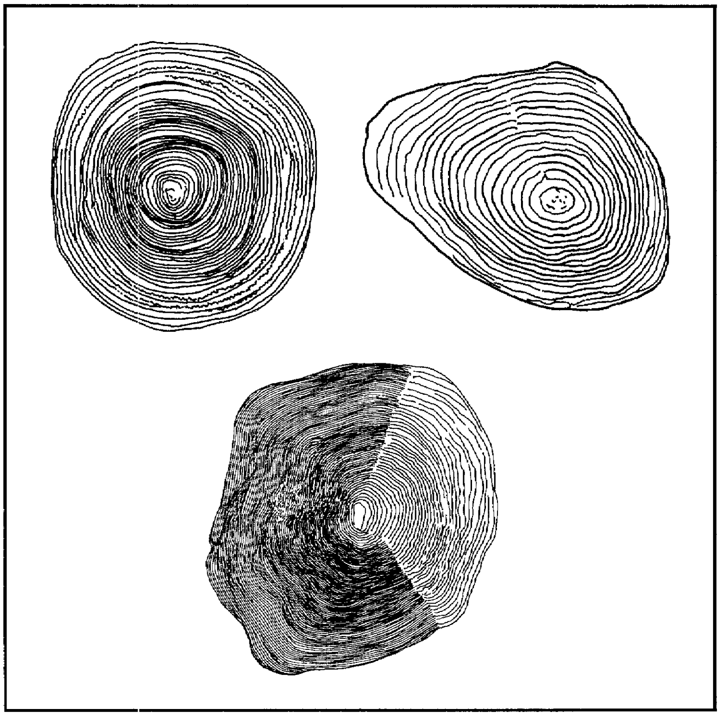
10b. Focus distinct, ridges perpendicular to both anterior and posterior margin...**Gadidae, *Urophycis***





11a. Spines present ....**Percopsidae**

11b. Spines or ctenii absent 12

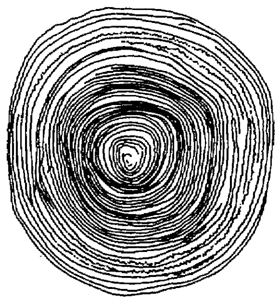


12a. Number of ridges approximately equal in all fields 13

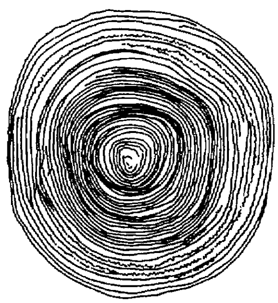
12b. Number of ridges varies among fields 15

13a. Ridges closely packed in anterior field, ridges in lateral or posterior fields widely spaced............**Osmeridae**

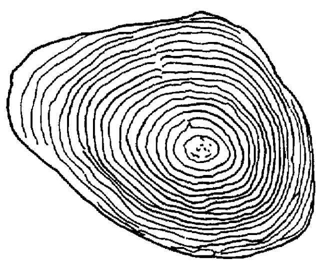
13b. Spaces between ridges approximately equal in all fields....................14

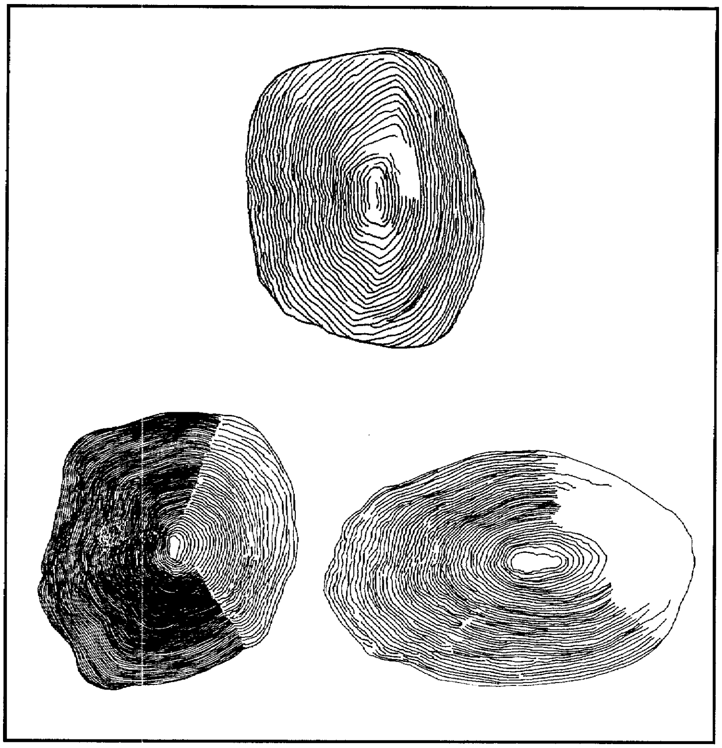


14a. Scale circular, ridges concentric about central focus........**Gadidae, *Lota***



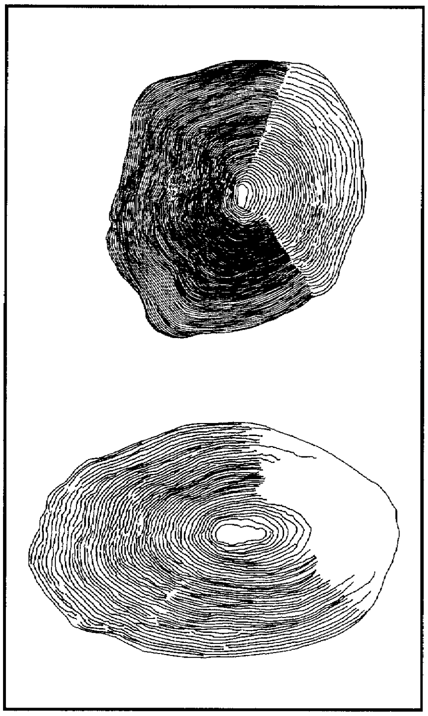
14b. Scale not circular, focus displaced toward posterior margin of scale..........
....**Belonidae**





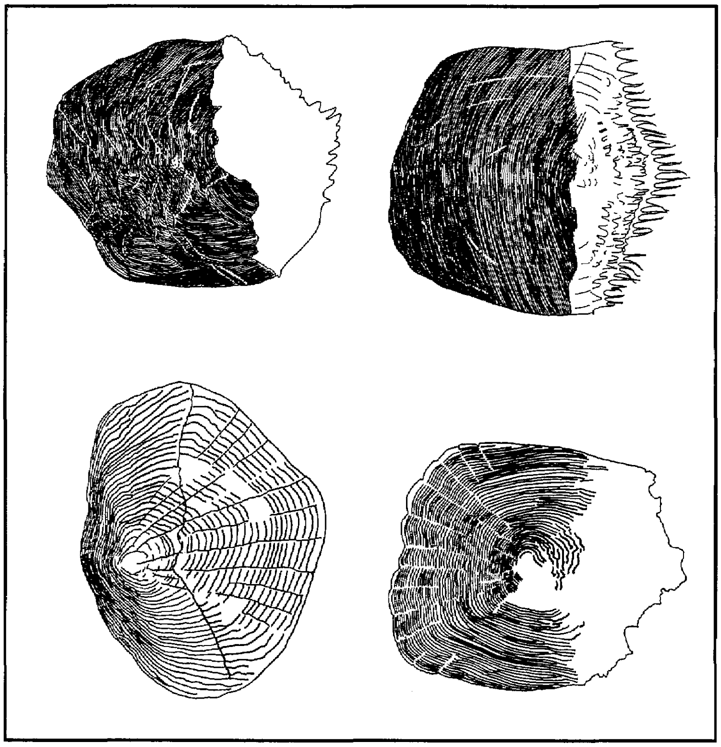
15a. Ridges more numerous in anterior and posterior fields than in lateral fields, scales wider than long ....**Carangidae**

15b. Ridges more numerous in anterior field than in posterior field 16



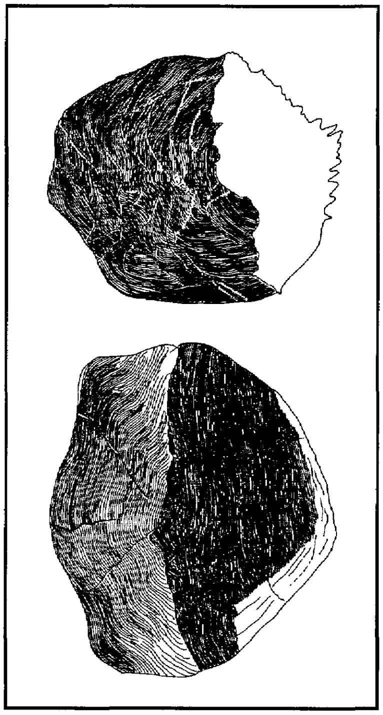
16a. Scale about as long as wide, antero-lateral margins squared ....**Coregoninae**

16b. Scale longer than wide or, if axes equal, outer ridges do not continue into posterior field, antero-lateral corners rounded ....**Salmoninae**



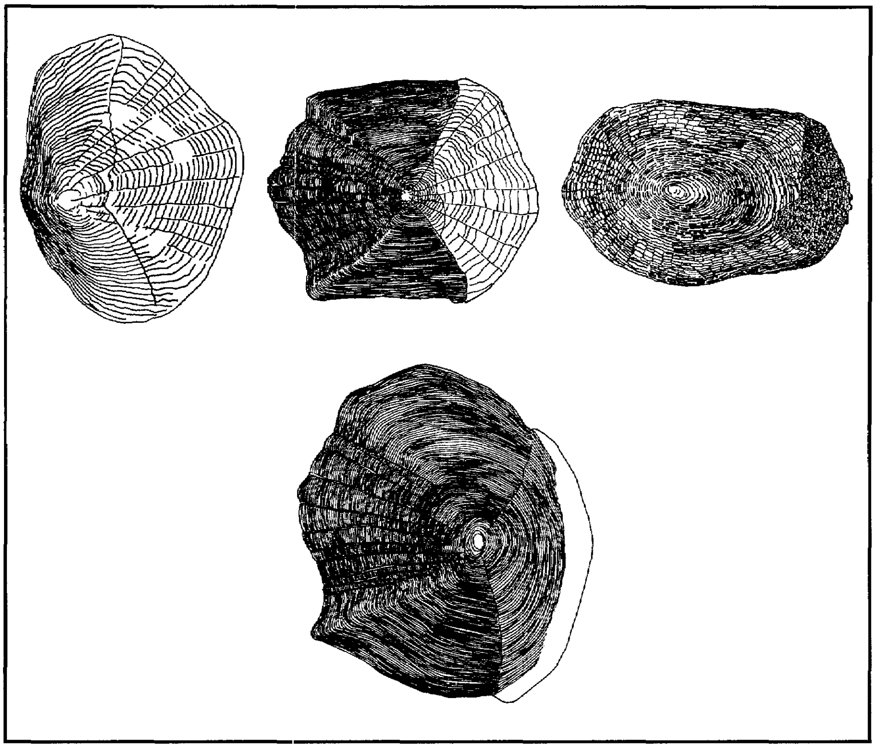
17a. Radii transverse, ridges essentially transverse 18

17b. Radii radiate from focus, or from point near focus 19



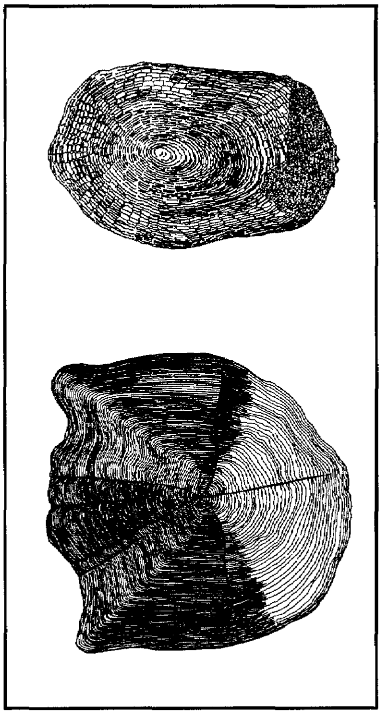
18a. Ridges and radii present in anterior field only....................................**Clupeidae**

18b. Ridges and radii present in anterior and posterior field.................**Engraulidae**



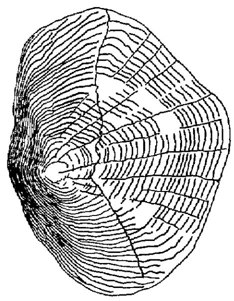
19a. Radii present in posterior field (may also be present in other fields) 20

19b. Radii present in anterior field only 25

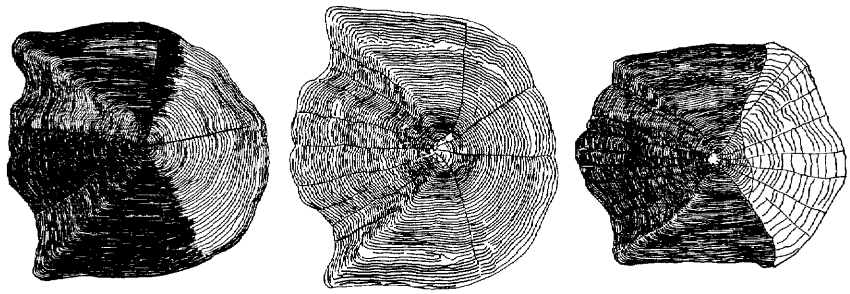


20a. Radii broken, present in all four fields..........**Gadidae, *Microgadus***

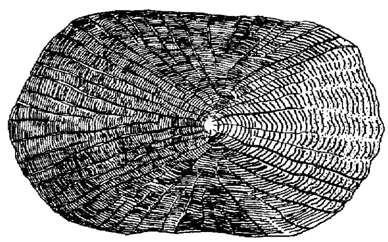
20b. Radii complete..........21



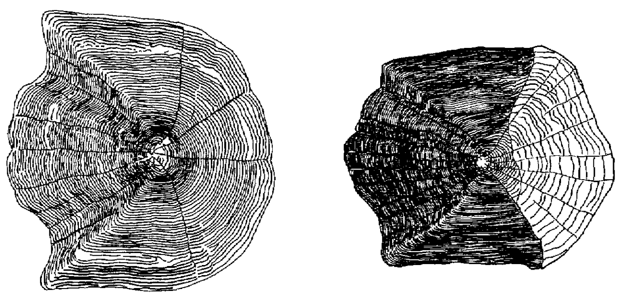
21a. Focus in anterior one-third of scale..........................**Cyprinidae, in part**



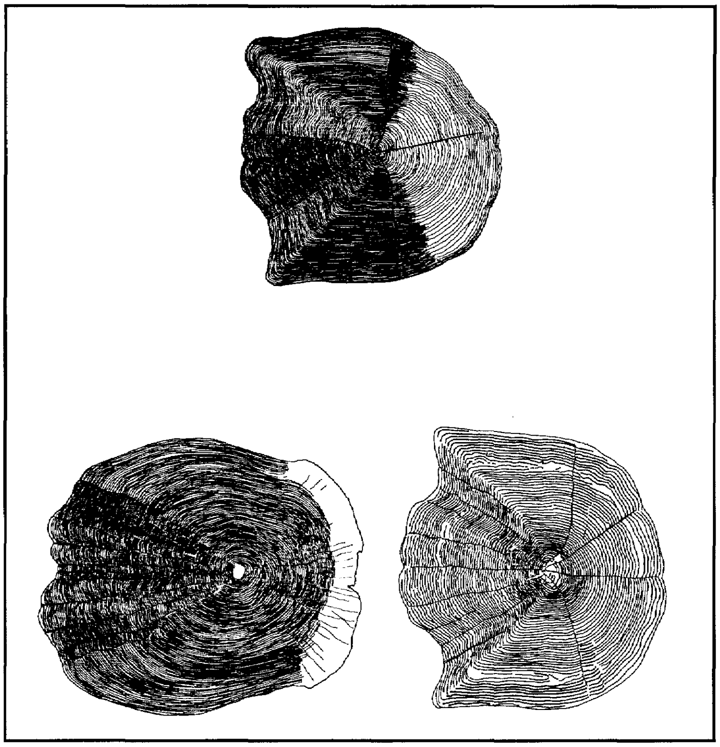
21b. Focus central or subcentral........22



22a. Scales longer than wide.................. ....**Catostomidae, in part**

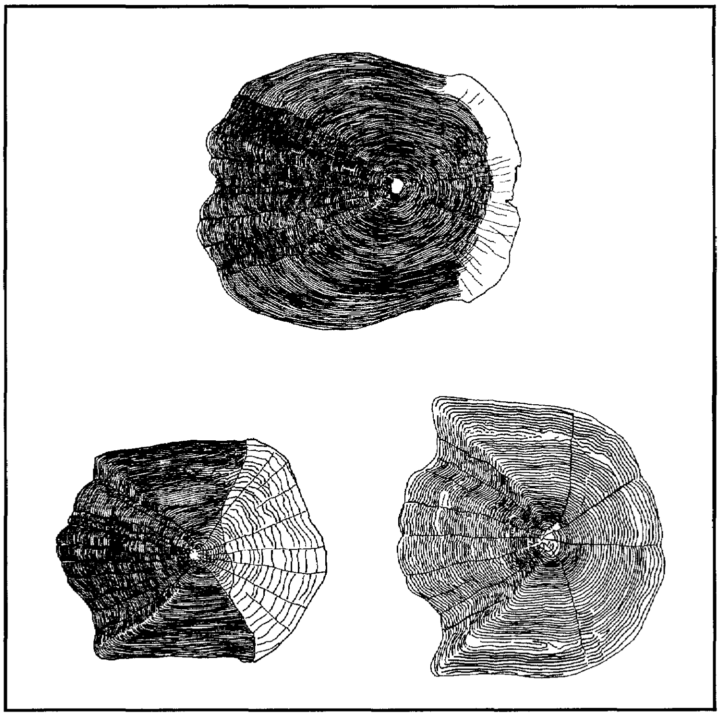


22b. Scales wider than long or axes nearly equal in length..........................23



23a. Ridges more numerous in anterior and lateral fields than in posterior field, ridges weakly formed and less dense in posterior field (may include scales from the sucker genera *Hypentelium* and *Moxostoma*) ....**Cyprinidae, in part**

23b. Number of ridges about equal in all four fields, or if unequal, ridges in posterior field similar in appearance and density to those in other fields.......24

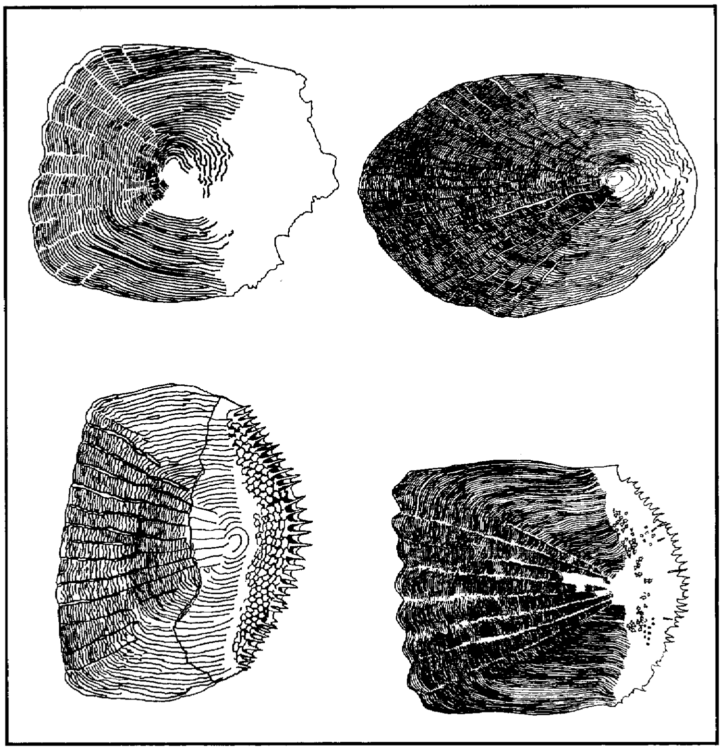


24a. Number of primary radii in anterior field more than twice the number in the posterior field...**Hiodontidae**

24b. Number of primary radii in anterior and posterior fields about equal...................**Catostomidae, in part**

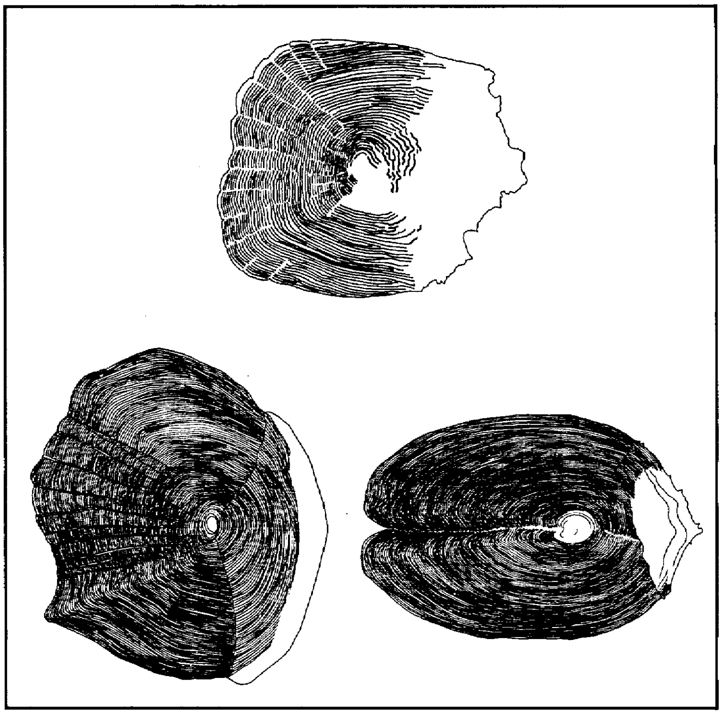
25a. Spines or ctenii absent 26

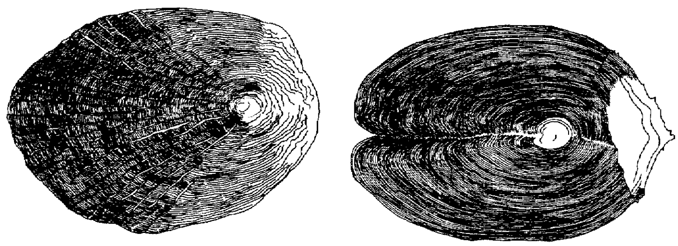
25b. Spines or ctenii present 32



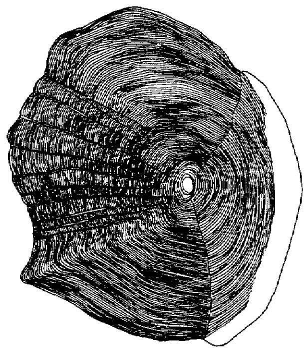
26a. Ridges present in anterior and lateral fields only ....**Elopidae**

26b. Ridges encircle focus...................27

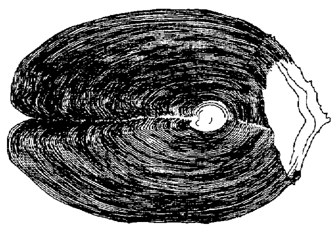




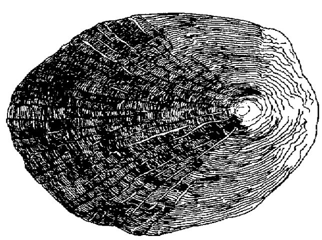
27a. Focus in posterior one-third of scale 28



27b. Focus central 29



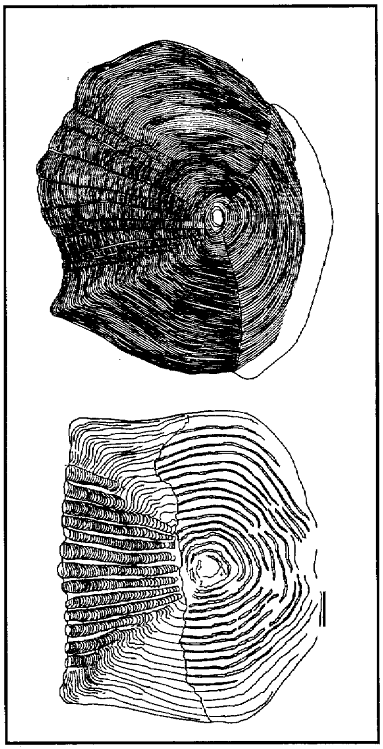
28a. Total radii count < 6 ....**Esocidae**



28b. Total radii count > 15.....**Bothidae, Pleuronectidae**

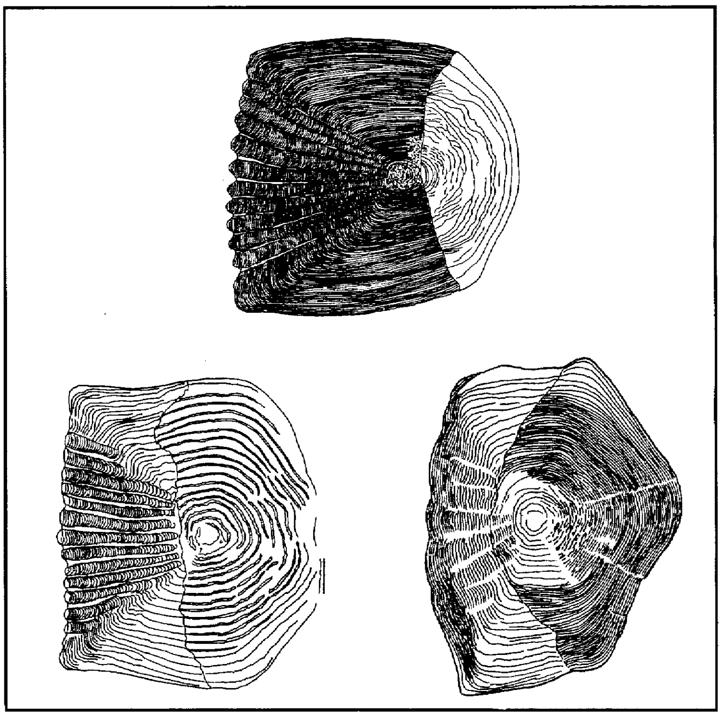
29a. Anterior margin of scale warped or uneven ....**Hiodontidae**

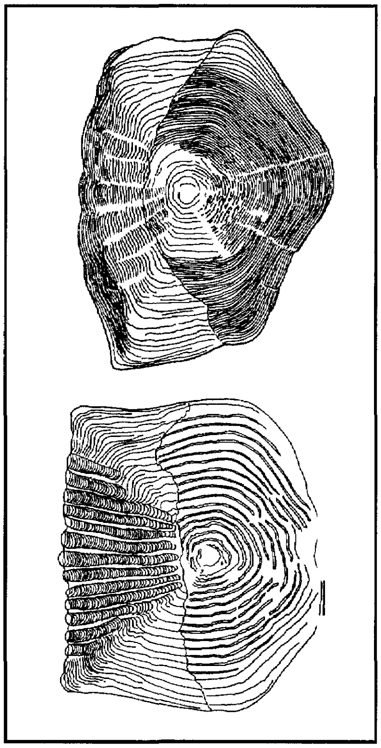
29b. Anterior margin straight or arched 30



30a. Primary radii present ....**Centrarchidae**

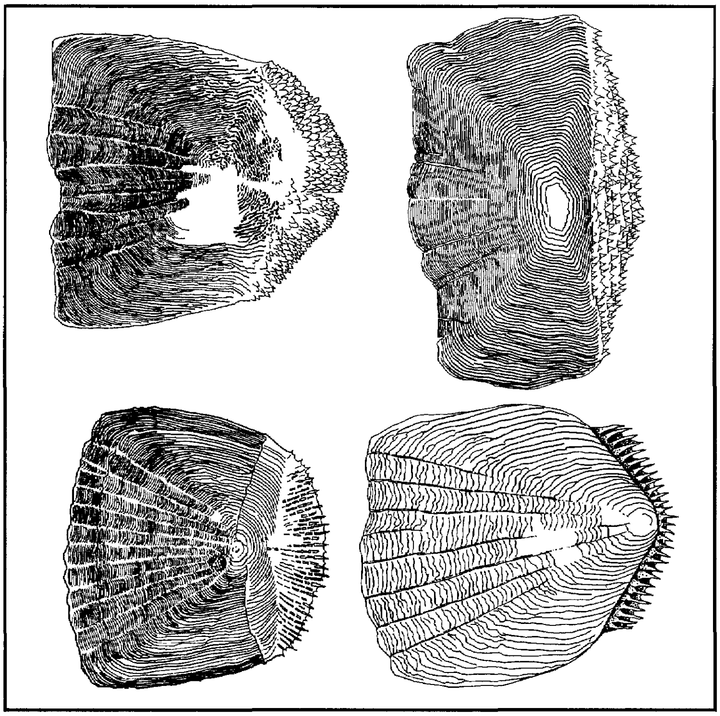
30b. No primary radii 31





31a. Number of ridges in lateral fields smaller than number in anterior or posterior fields .....**Atherinidae, in part**

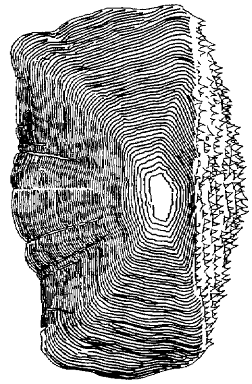
31b. Number of ridges in anterior field greater than number in lateral or posterior fields ....**Cyprinodontidae, Poeciliidae**



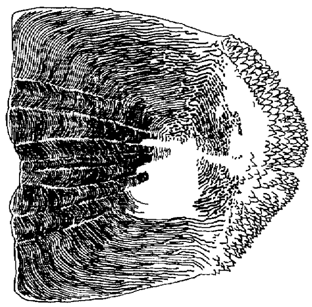
32a. Spines or ctenii weakly developed, spacing without order..............33

32b. Spines or ctenii sharp, ordered in columns and rows 34

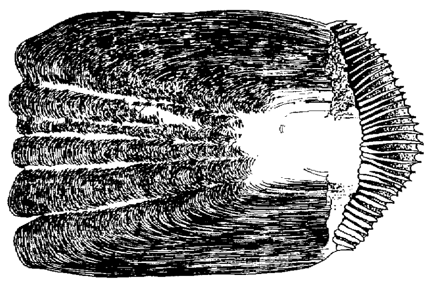
33a. Scale wider than long, spines crenelate, short................**Pomatomidae**



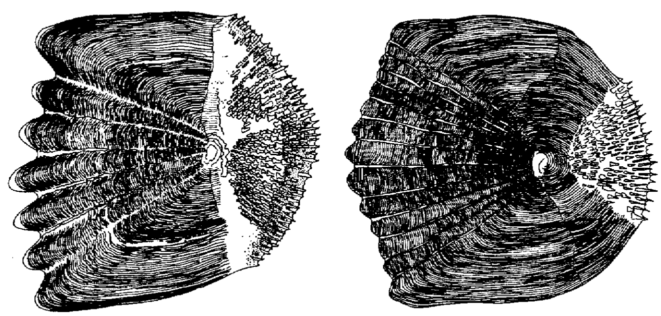
33b. Scale longer than wide, spines form patch ....**Mugilidae**

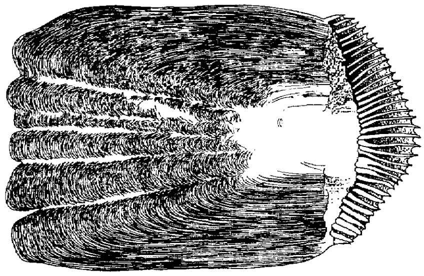


34a. One row of spines or ctenii........35

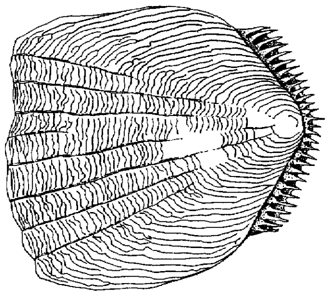


34b. More than one row of ctenii 36

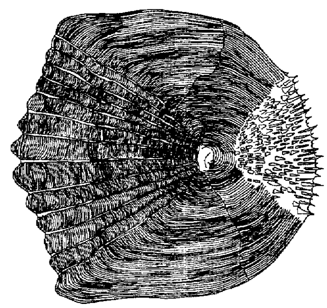




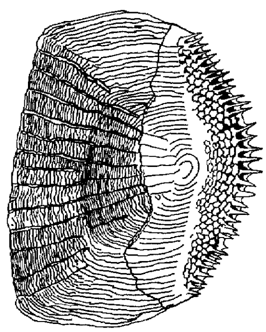
35a. Ridges indistinct, fewer than 7 radii in anterior field, spines long, sharp ....**Aphredoderidae**



35b. Ridges distinct, more than 7 radii in anterior field, ctenii less than 10% of scale length........................**Eleotridae**

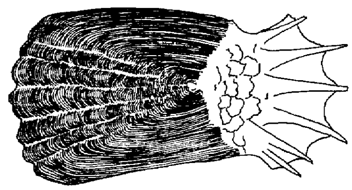


36a. Ctenii present in marginal row and on several proximal rows, ctenii patch diamond shaped ....
....**Centrarchidae**

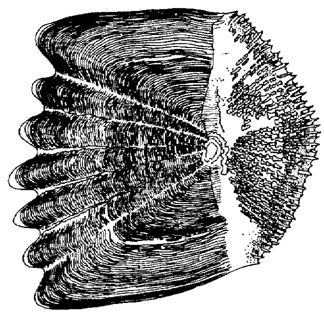


36b. Only marginal row with ctenii, proximal rows made up of ctenial bases...37

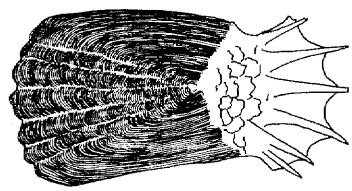
37a. Scale longer than wide 38



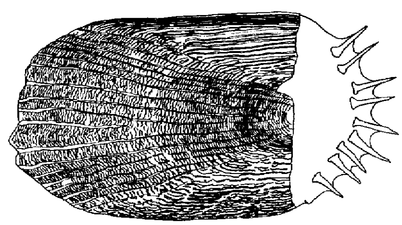
37b. Scale wider than long, or axes of equal length 39

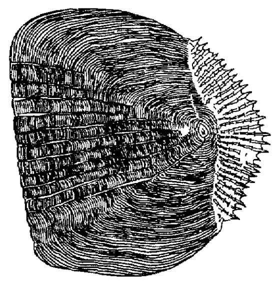


38a. Total radii count fewer than 15 ....**Soleidae**

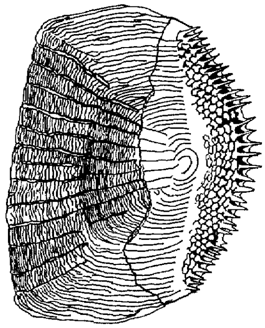


38b. Total radii count more than 15 ....**Pleuronectidae**

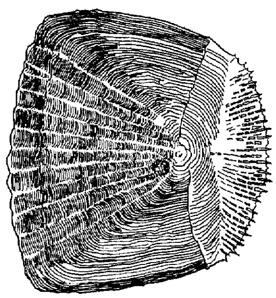




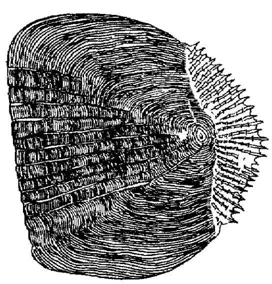
39a. Focus anterior to anterior margin of ctenial patch, 4 or more ridges encircle focus 40



39b. Focus at anterior margin of ctenial patch, fewer than 4 ridges encircle focus..41



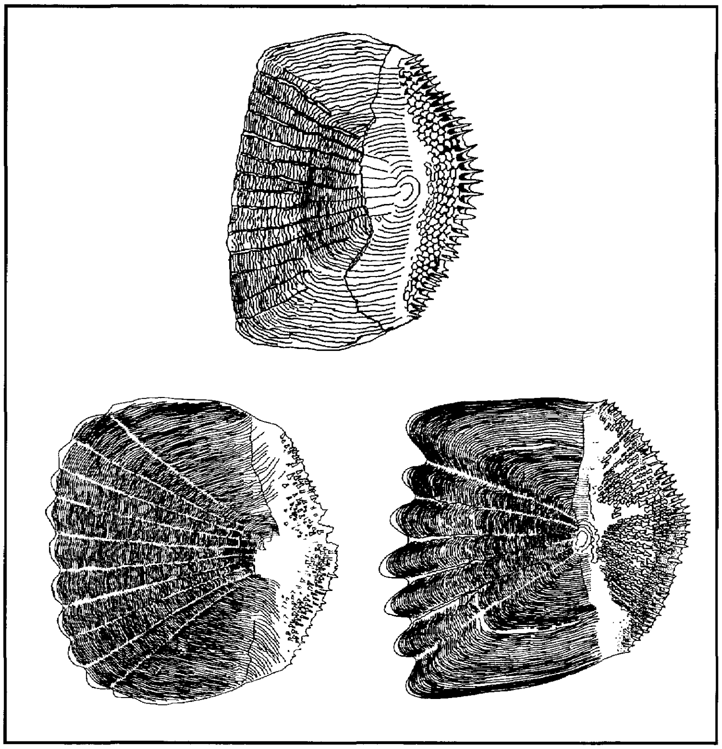
40a. Primary radii more than 8.............
....**Percichthyidae**



40b. Primary radii fewer than 7............
....**Sciaenidae**

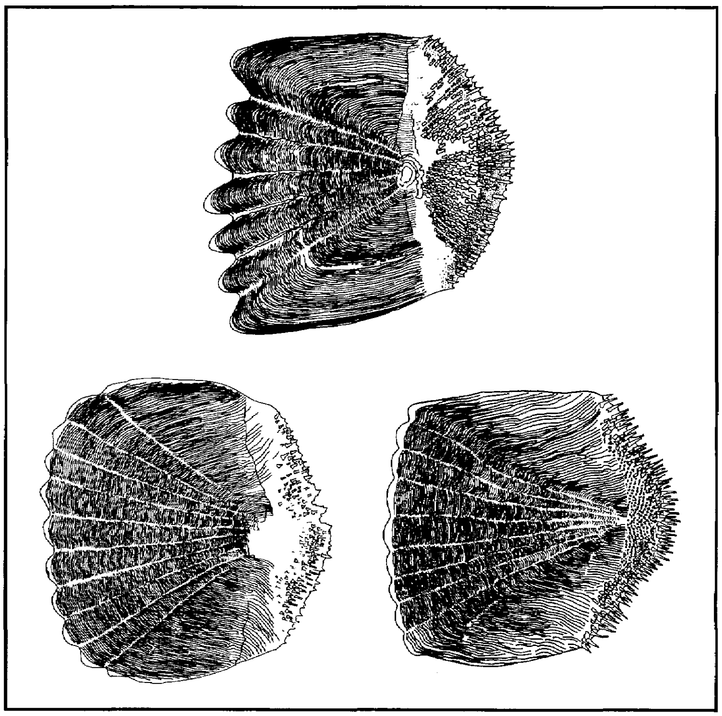
41a. Ctenial bases wider than long ....**Percidae, Etheostomini**

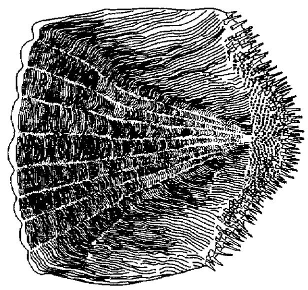
41b. Ctenial bases longer than wide, or axes of equal length.........................42



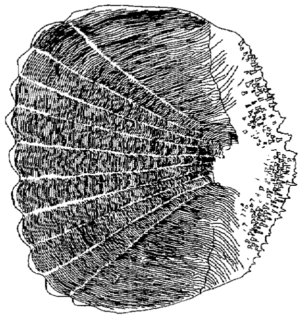
42a. Anterior margin deeply cleft at radii ....**Pericidae, Percini, Luciopercini**

42b. Anterior margin slightly scalloped 43





43a. All radii primary..........**Serranidae**



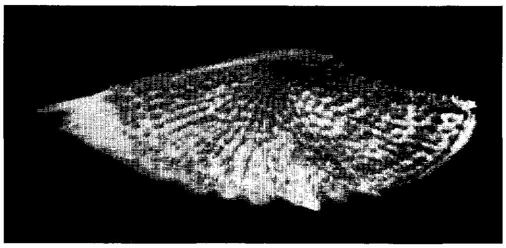
43b. Secondary radii present.................
....**Sparidae**

FAMILY ACCOUNTS

ACIPENSERIDAE, STURGEONS

Sturgeons are members of an ancient family with representatives that lived during the Cretaceous (Vladykov and Greeley 1963). These fishes are found in large bodies of water, and four species are reported from northeastern North America. Sturgeons are among the largest of fresh-water fishes and live longer than most fish species. They were important food fishes in North America before the arrival of Europeans and became commercially important thereafter. During the mid-nineteenth century, sturgeons from the Hudson River were shipped throughout the United States as "Albany beef" (Rostlund 1952).

The shortnose, *Acipenser brevirostrum,* and Atlantic sturgeon, *A. oxyrhynchus,* are anadromous species. The shortnose sturgeon enters the larger river systems from the Delaware to the St. John River. The Atlantic sturgeon is found in more northern rivers as well. Its range extends to Hamilton Inlet, Labrador (Scott and Crossman 1973). Lake sturgeon, *A. fulvescens,* is primarily an inland form found in the Mississippi and St. Lawrence River drainages and in the river systems draining into James and Hudson Bays. It is rarely taken in brackish water, and Vladykov and Greeley (1963) reported no resident populations in salt water. The shovelnose sturgeon, *Scaphirhynchus platorynchus,* was reported by Rafinesque in western Pennsylvania but has not been collected in the area since (Cooper 1983). Sturgeon numbers have declined over the last century. The shovelnose sturgeon was apparently extirpated from the area, and the shortnose and lake sturgeons are protected throughout most of their ranges.



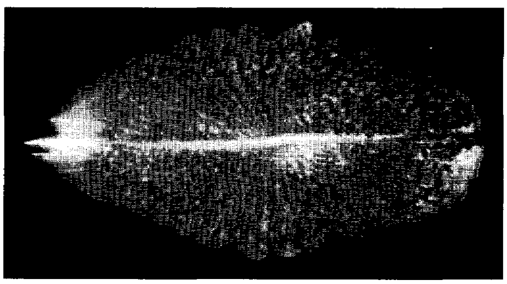


Figure 9 (top). Highly sculptured ganoid scales line sturgeons. Dorsal scute from a 400-mm Atlantic sturgeon, *Acipenser oxyrhynchus,* NYSM 42518, side view. Longitudinal dimension is 29.5 mm.

Figure 10 (bottom). Dorsal scute from an Atlantic sturgeon, *Acipenser oxyrhynchus,* NYSM 42518, dorsal view.

Sturgeons possess five rows of overlapping scutes running along their bodies from the opercular region to caudal peduncle. Between rows of scutes and on the upper lobe of the caudal fin are numerous, small embedded plates with one or more spines projecting through the skin. The head, opercles, and dorsal surface of the caudal fin are also covered with bony plates. The scutes and plates are modified ganoid scales. The shape and size of these bony plates vary with position on body and the age of the fish. Most of the scutes are cap-like (Figure 9). The outline is generally circular or oval (Figure 10). There is a central peak and posteriorly projecting hooks. The outer surfaces of the scutes are rough, since they are covered with numerous small protuberances, while the undersurfaces are smooth. As fish age, surface ornamentation diminishes. The margins of the scutes are often scalloped or possess points. Plates on the head, opercles, and caudal fin have various shapes and are usually flat. The outer surfaces of these plates are rough; the undersides are smooth. The small embedded plates are often rhomboidal. Some scutes may exceed 200 mm and may be even larger on ancient specimens.

LEPISOSTEIDAE, GARS

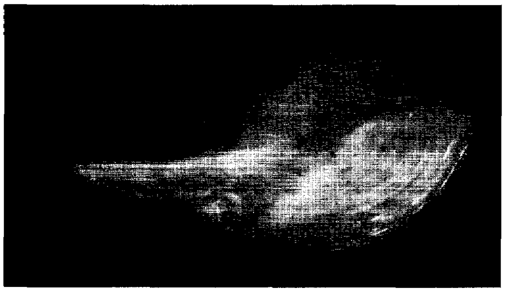


Figure 11. Gars are covered with ganoid scales. Lateral plate from a 1000-mm longnose gar, *Lepisosteus osseus*, NYSM 1628. Maximum dimension is 15.1 mm.

Gars are large, cylindrical fish found in lowland lakes and rivers. The family is an ancient one with fossil representatives from the Upper Cretaceous (Nelson 1984). The longnose, *Lepisosteus osseus*, and spotted gar, *L. oculatus*, occur in the St. Lawrence and upper Mississippi River systems. Longnose gar is also present in the lower Susquehanna and Delaware River systems (Cooper 1983) and has recently been taken in the Hudson River (NYSM 31041). The presence of a third species of gar, *L. platostomus*, has been reported from western New York and Pennsylvania, but there are no documented specimens (Cooper 1983; Smith 1985). Gars are widely distributed but are rarely abundant at any locality. Gars do not appear to have been important food fish prior to European contact (Rostlund 1952) and have not been commercially important since (Smith 1985).

The bodies of gars are covered with a pavement of tightly fitted, diamond-shaped plates. Rhomboid plates are also present on the cheeks. Large, irregularly shaped bony plates cover the head and opercles. All of these plates are ganoid scales. On live fish, the scales appear to be non-overlapping. In fact, two anterior projections on each scale are embedded. Gar scales are flat, without any surface ornamentation, and on any given fish, they are relatively uniform in size and shape (Figure 11). The length of scales from gars greater than 1000 mm total length may exceed 15 mm.

AMIIDAE, BOWFINS

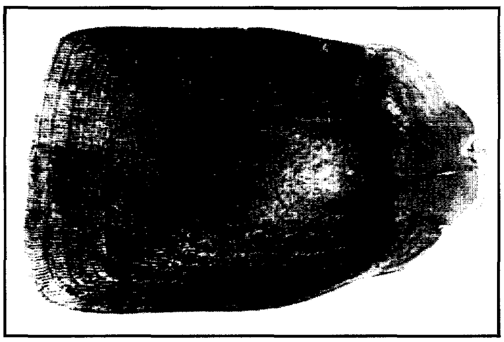


Figure 12. Lateral scale from a 340-mm bowfin, *Amia calva*, NYSM 12245. Longitudinal dimension is 10.5 mm.

Amia calva, the bowfin, is the only extant member of this relict family. Fossil amiids have been found in fresh-water and marine deposits dating to the Jurassic (Nelson 1984). It is the most ancient known fish with bony-ridge scales (Van Oosten 1957). It is typically found in lowland areas in large bodies of water with abundant aquatic vegetation. Although not common in the Northeast, bowfins are present in the St. Lawrence River system, including the Great Lakes, and in the lower reaches of the Susquehanna River system. Introduced populations are reported from Connecticut, New Jersey, and Long Island, New York (Lee et al. 1980 et seq.) and from the Delaware River system.

Bowfins are covered with relatively large imbricating cycloid scales; only the head is naked. The most distinctive feature of bowfin scales, and the characteristic that separates their scales from those of all other northeastern fish, is the position of the ridges. The ridges run longitudinally; they emerge from the focus and proceed toward the anterior and posterior margins parallel to the lateral margins of the scale and perpendicular to the focus or focal line (Figure 12). The scales lack radii and ctenii. The focus is a point or line in the posterior quarter of the scale and in the part of the scale that is exposed. The shape is consistent in scales from different specimens and in those from different areas of the body on a single specimen. All are truncated ovals approximately twice as long as wide. The anterior margin is straight. Lateral-line scales possess an open-ended tube running longitudinally along the midline in the posterior half of the scale.

Hiodontidae, Mooneyes

Fishes in the Osteoglossiformes comprise an ancient group with all but two extant species confined to tropical fresh waters (Berra 1981). The two species found outside the tropics make up the family Hiodontidae and are found in the St. Lawrence, Mississippi, Mackenzie, and Nelson River systems and in several tributaries draining into James Bay. Both species occur in lakes and larger rivers. *Hiodon tergisus,* the mooneye, is not common in the Northeast and now occurs only in tributaries to the lower St. Lawrence River and James Bay and Lake Champlain. Smith (1985) and Trautman (1981) have reported that mooneye is extremely rare in Lakes Erie and Ontario, although it was reported as common in Lake Erie in the past (Greeley 1929). *Hiodon alosoides,* the goldeye, is even rarer in the Northeast. Cooper (1983) mentioned a reported occurrence in western Pennsylvania, and Scott and Crossman (1973) noted several sites in northwestern Quebec.

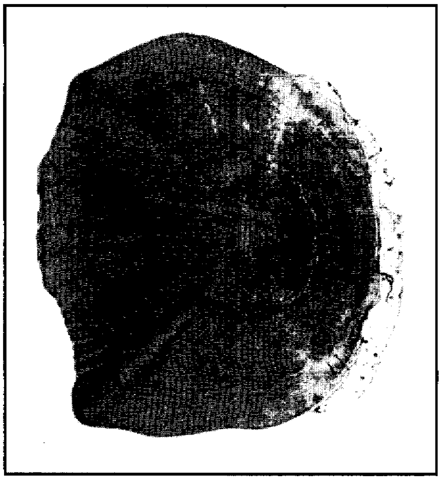


Figure 13. Lateral scale from a 195-mm mooneye, *Hiodon tergisus*, NYSM 24802. Longitudinal dimension is 9.0 mm.

Scales cover the bodies, but heads are scaleless in both species. The scales of *Hiodon* have a characteristic shape. These scales are approximately as wide as they are long. The posterior margin is arched and broadly rounded. The same degree of arc often continues onto the lateral margins but stops abruptly at the antero-lateral corner. The anterior margin is irregular, appearing warped and uneven. The antero-lateral corners are sharp or square, there is a broad concavity next to each corner, and a bulge occurs at the midline (Figure 13). Radii are present in the anterior field of the scale, and in large scales, a few secondary radii may be present in the posterior field as well. In the anterior field, radii are parallel, radial, or exist in some combination of the two. They are usually not equally spaced and may appear crowded in one area of the scale and sparse in another. Most of the radii on the scale are secondary, although each scale usually has a few primary radii as well. The number of ridges is equal in all four fields. The borders of the anterior field are usually well marked by a 70° to 90° bend in the ridges. Non-lateral scales are extremely variable in shape and number of radii present, and they may be difficult to identify using the key. Lateral-line scales are marked by an open-ended tube which sits over the focus on the midline and runs for about a quarter of the length of the scale.

Elopidae, Tarpons

The ladyfish, *Elops saurus,* is the only member of this small family of marine fishes reported to enter fresh water in northeastern North America. Ladyfish is a large predator and powerful swimmer, and it occasionally ascends larger rivers. Smith and Lake (1990) recorded the capture of one specimen off Danskammer Point (river km 106) in the

Hudson River. Other sightings from the Hudson River exist (Smith 1985), but it is not likely that ladyfish is a common upriver migrant. A related fish, the tarpon, *Megalops atlanticus*, has been reported from coastal waters as far north as Nova Scotia (Bigelow and Schroeder 1953; Scott and Scott 1988). Tarpon has not as yet been reported inland, although Hildebrand and Schroeder (1928) noted that in more southern areas this species enters streams in search of food.

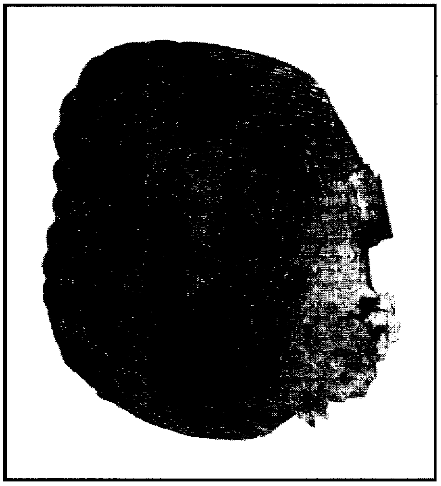
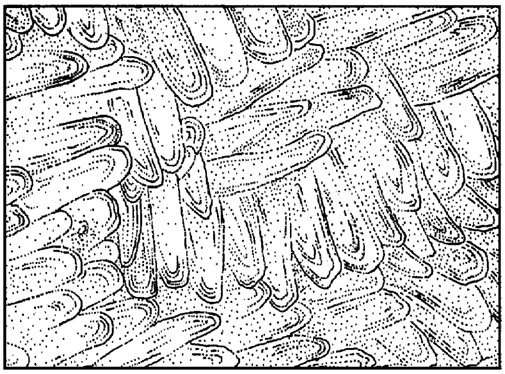


Figure 14. Lateral scale from a 290-mm ladyfish, *Elops saurus*, NYSM 49. Longitudinal dimension is 2.9 mm.

The bodies of ladyfish are covered with scales, and their heads are naked. Ladyfish scales lack ctenii and traditionally have been regarded as cycloid. Roberts (1993) has labeled them crenate, since the posterior margin is not entire. All of the posterior part of the scale is poorly formed, lacks ridges, and usually has a frayed posterior margin (Figure 14). Scales have radii in the anterior field with a total (i.e., primary plus secondary radii) count between 12 and 17. Most radii do not reach the focus. Two secondary radii occur in each lateral field on the interpelvic scale. A few ridges surround the focus, but most are semicircular and do not continue into the posterior field. There are about the same number of ridges in the lateral and anterior fields. The focus is in the anterior half of the scale. Lateral scales are rectangular with all four corners squared; others scales may be ellipsoidal with slightly rounded corners. A tube is centrally situated on the lateral-line scale.

Anguillidae, Freshwater Eels

Anguilla rostrata, the American eel, is a catadromous fish that enters all major river systems and coastal streams in northeastern North America from the Susquehanna River to the Hamilton Inlet. From these coastal rivers, individuals, primarily female, ascend to headwater tributaries where they reside for several years before returning to the sea. When these large females return to the ocean, they are often over 1 m long and provide more calories per pound that any other fresh-water fish (Rostlund 1952). Large size, high caloric value, and migratory behavior help explain the immense popularity of this fish as food in Native American settlements throughout the area (Junker-Andersen 1988).



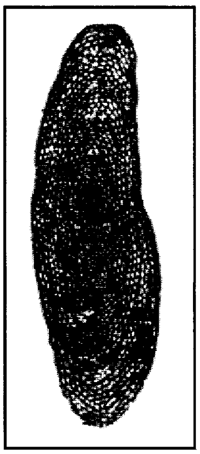


Figure 15 (top). In contrast to those of most other fishes, scales of the American eel, *Anguilla rostrata*, are embedded and are laid down in a mosaic.

Figure 16 (left). Lateral scale from a 605-mm American eel, *Anguilla rostrata*, NYSM 10948. Longitudinal dimension is 0.7 mm.

American eel appears to lack scales; however, embedded scales cover the body entirely (Figure 15). The scale of the American eel is unlike that of any other fish occurring in the Northeast. It lacks radii, ctenii, and in the typical sense, ridges (Figure 16). The central focus is an oval structure surrounded by additional oval structures arranged end-to-end. The appearance is that of several concentric strings of beads. The scale is ellipsoidal and much wider than long. The longitudinal dimension ranges from 20% to 30% of the transverse one. The anterior and posterior margins are parallel to each other, and the lateral margins are rounded.

Clupeidae, Herrings

Nine members of this large, commercially important family have been taken from inland waters in northeastern North America. Three species–blueback herring, *Alosa aestivalis;* alewife, *A. pseudoharengus;* and American shad, *A. sapidissima*– are anadromous forms that ascend rivers in the spring to spawn in the stream or in lowland tributaries. Two species–skipjack herring, *A. chrysochloris,* and gizzard shad, *Dorosoma cepedianum*–are fresh-water forms. Four species–Atlantic menhaden, *Brevoortia tyrannus;* Atlantic herring, *Clupaea harengus harengus;* hickory shad, *A. mediocris;* and round herring, *Etrumeus teres*–are marine forms that stray into coastal streams and large estuaries. The blueback herring is currently found in coastal streams from the Delaware River north to tributaries of the Gulf of St. Lawrence. It is not common in Canada (Scott and Crossman 1973), but it becomes more abundant with decreasing latitude. There are no historical records of landlocked populations of this fish, although populations are now present in the Mohawk River and Lake Champlain (Plosila and LaBar 1981). Smith (1985) has attributed the presence of these new populations to the ease with which blueback herring can travel through canal locks. The alewife and American shad were historically present in most coastal rivers from Labrador south to the Delaware River and beyond. Both species have gained access to other systems during the last century. Alewives expanded their range into the Great Lakes from Lake Ontario. The method used by this species to gain access into Lake Ontario is not known. Miller (1957) reviewed the literature and concluded that it was accidentally introduced, but Smith (1968) suggested that it migrated into the lake through the Erie Canal. The America shad, which migrates farther upstream than the other *Alosa,* may also be present in Lake Ontario as a result of recent successful introductions (Smith 1985). American shad has been stocked into Lake Ontario several times during the past (Miller 1957). Both alewife and American shad have been stocked into other inland waters in most of the states and provinces in the Northeast.

The skipjack herring is a Mississippi drainage fish that may occur in the Ohio River system in western New York and Pennsylvania. There are no reports of this fish from New York, and Cooper (1983) noted that it is extirpated from Pennsylvania. The gizzard shad is widely distributed throughout eastern North America. Its native range is difficult to delineate (see discussion in Scott and Crossman 1973). Canals and introductions may have greatly facilitated its dispersal. The four remaining species are uncommon in inland waters. The hickory shad may be anadromous, but too little information about the life history of this species is known. It ranges north from the Delaware River to the Gulf of Maine, but its center of distribution is off the coast of Virginia and the Carolinas. The Atlantic menhaden, Atlantic herring, and round herring occur in coastal streams and the tidal portions of several of the larger rivers in the Northeast. All four species have been taken in the Hudson River (Smith and Lake 1990).

In general, herrings and shads are big-water fishes. They are found in lakes, estuaries, and the main channels and back-waters of larger rivers. Most of the species spend the greatest proportion of their lives in the ocean. Even the fresh-water forms, like the gizzard shad, are tolerant of brackish and sea water and can use a marine route for dispersal. For example, gizzard shads, which were not collected in the Hudson River during a synoptic survey conducted in 1936 (Greeley 1937), have become more abundant in the river during the last two decades. Smith and Lake (1990) have pointed out that these fish may have entered the lower Hudson River by moving downstream from the Mohawk River

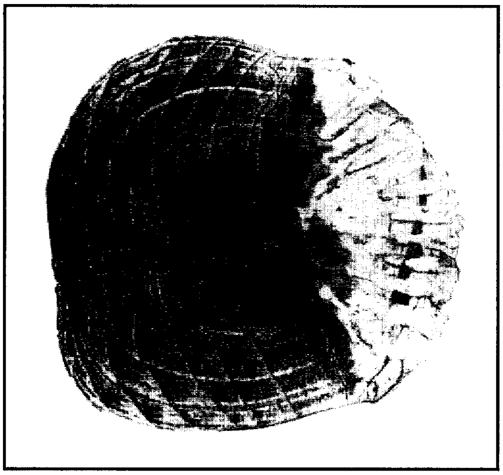


Figure 17. Lateral scale from a 250-mm American shad, *Alosa sapidissima*, NYSM 21166. Longitudinal dimension is 9.5 mm.

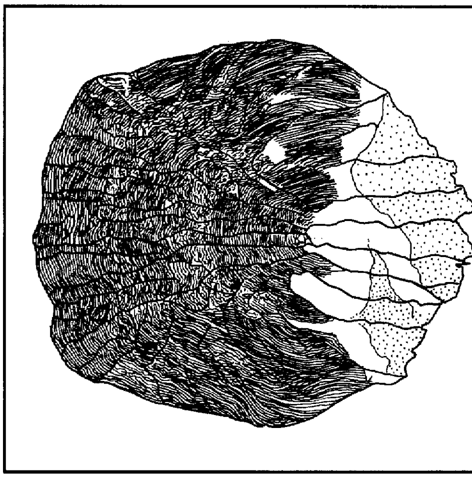


Figure 18. The regenerated scales of shads and herrings lack the transverse radii and ridges present in original scales. Instead, the scale appears as a patchwork of irregular cells. Regenerated scale from an American shad, *Alosa sapidissima*. Longitudinal dimension is 8.5 mm.

or upstream from New York Harbor and the Atlantic coastal plain. Herrings typically exceed 50 cm in length as adults, and the anadromous forms can be caught in large numbers during their spawning migrations. Although the fresh-water species appear not to have been particularly important to Native Americans, the anadromous forms were an extremely important supplement to the diets of most coastal populations (Rostlund 1952).

Members of this family possess scales over their bodies. They lack specialized lateral-line scales, but modified scales, called scutes, are found on the ventral edge of the body in most species. Herring scales possess transverse radii and ridges (Figure 17). These features are shared only with a closely related family, the anchovies. However, herring scales can be distinguished from those of the anchovy by the lack of ridges and radii in the posterior field and a focus in the posterior one-third of the scale. All herring scales are cycloid and thin, although those of the menhaden are termed crenate in Roberts' (1993) classification. These scales easily dissociate from the body, and this type of scale is termed deciduous or caducous. Because the morphology of these scales is different, some of the terms used to describe features on the scales of other fishes make little sense. For example, on these scales, radii do not radiate from a focus; in addition, there is no point that can be identified as a focus. Standard terms are nevertheless used in this work for consistency even though more appropriate terms can be found in the glossary. The latter are rarely used in the literature. Cockerell (1910b) reported the unusual character of clupeid scales and provided a detailed description of several. All herring scales share many characteristics; however, within the family, lateral scales of the genera can be differentiated from each other in some cases.

Shared traits include aspects of shape and structure. On any individual, the shapes of scales vary. Lateral scales are round, subquadrate, or oblong. If present, scales from the dorsum and ventral edge of the fish are elongate, tear-shaped, triangular, or some other irregular shape. A complete radius runs transversely across the scale. This radius separates the anterior and posterior fields; there is no practical reason to identify lateral fields on clupeid scales. In most scales, a few ridges are present posterior to this complete radius, but, except for these few, the posterior field lacks any other ridges or radii. Anterior to this radius, ridges run transversely across the scale roughly parallel to the complete radius and meet the lateral margins perpendicularly or at oblique angles. Also in the anterior field, partial radii extend from the lateral margin to the midline of the scale. These partial radii are usually paired and rarely touch at the midline. The posterior field has some structure which is more apparent in larger scales. Very fine lines follow the contour of the posterior margin and encircle an indistinct focus. These fine lines continue into the anterior field and are visible under the more obvious transverse ridges and radii. Also, radiating from the focus toward the posterior margin are many thin grooves.

Cockerell (1910b) used terms to describe the fine lines and grooves found on herring scales; unfortunately, his terms are used interchangeably with terms found in the literature denoting ridges and radii. The fine lines and grooves found on herring scales are not commensurate with the usage of these two terms. Description without applying specific terms should permit identification of these scales. Since herrings easily loose their scales, regenerated scales are often more numerous than original scales on a particular fish. Regenerated scales can be identified by the anastomosing grooves in the anterior and occasionally in the posterior field (Figure 18).

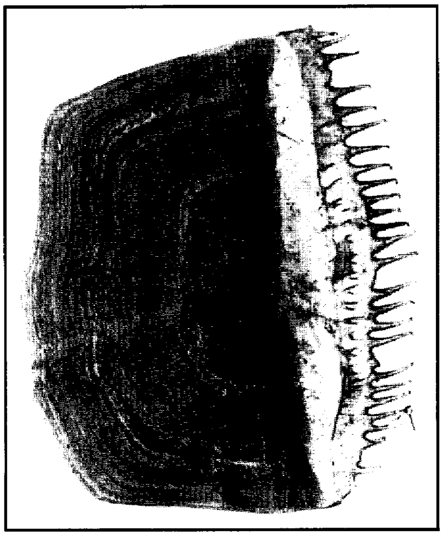


Figure 19. Lateral scale from a 190-mm Atlantic menhaden, *Brevoortia tyrannus*, NYSM 23808. Longitudinal dimension is 5.5 mm.

Lateral scales of the species in *Alosa* are round to oblong. If oblong, the longitudinal axis is longer than the transverse. On larger fishes, lateral scales are often subquadrate with squared antero-lateral and postero-lateral corners. There are from 10 to 25 transverse radii in the anterior field. The paired radii extend from the lateral margin of the scale to the midline, but they rarely meet. Instead, they cross over the midline and remain separated but parallel to each other. The posterior margin is scalloped due to small indentations at each groove. Between the grooves, the fine lines bow out toward the posterior margin.

Atlantic menhaden scales are the most distinctive in the family (Figure 19). Instead of the slightly scalloped posterior margin found in *Alosa,* menhaden scales have long pointed extensions, or a pectinate margin. These fine extensions may represent from 8% to 15% of the length of the scale. Menhaden scales also have relatively few radii (i.e., from 3 to 6) that rarely extend to the scale midline. Finally, lateral scales tend to be wider than long. Gizzard shad scales are also easily separated from those of other herrings. These scales are rounded and slightly wider than long. They possess few radii, usually fewer than 10, and the radii do not extend to the midline of the scale.

Atlantic and round herring scales are similar to those of *Alosa* and may be difficult to separate. Scales tend to be rounder and lack squared corners. Paired radii often do not reach the scale midline, and ridges often meet the lateral margins obliquely.

ENGRAULIDAE, ANCHOVIES

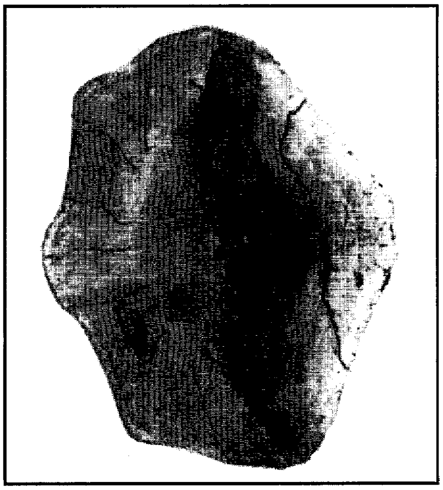


Figure 20. Lateral scale from a 75-mm bay anchovy, *Anchoa mitchilli*, NYSM 7294. Longitudinal dimension is 3.0 mm.

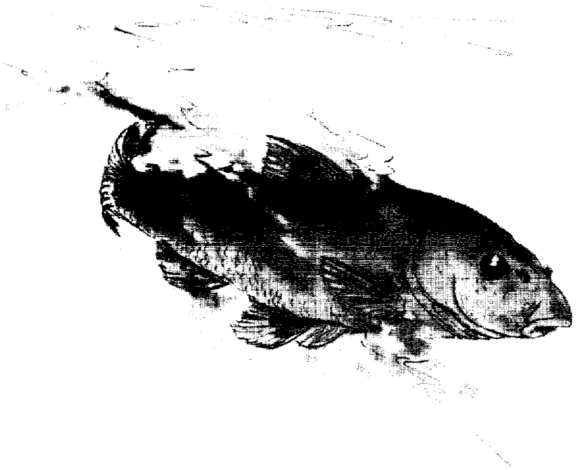
Anchovies are small schooling fish. Only two species, bay anchovy and striped anchovy, have been reported from northeastern inland waters south of the Gulf of Maine. Of these two, only the bay anchovy, *Anchoa mitchilli,* is common. Schmidt (1989) estimated that this may be the most abundant fish in tidal rivers along the Atlantic coast. Bay anchovies reach 80 mm standard length.

Anchovies have thin scales over most of their body. Anchovy scales, like those of the herrings, are cycloid, thin, and deciduous. Also like herring scales, anchovy scales possess transverse ridges and radii. They differ from herring scales in that anchovy scales have a central focus and are much wider than they are long (Figure 20). Also in contrast to herring scales, ridges and radii are visible in the posterior field as well as the anterior field. In an original scale, the radii in the anterior field number 2 or 3, are short, and run from the margin toward the focus. There are from 5 to 7 transverse radii in the posterior field that are roughly parallel to each other and the ridges. The

Figure 21. Axillary scale from a 75-mm bay anchovy, *Anchoa mitchilli*, NYSM 677. Longitudinal dimension is 7.7 mm.

ridges are also transverse in both the anterior and posterior fields and meet along a line slightly anterior to the middle of the scale. Because they are so easily lost and replaced, most of the scales on an individual fish are regenerated. In these scales, ridges are usually present in both anterior and posterior fields. Grooves develop as an anastomosing network of lines forming cells or dendritic patterns. Original scales are wider than long with rounded anterior margins and broadly rounded posterior margins. The shapes of non-lateral scales vary considerably. For example, anchovies possess an axillary scale, an elongated scale just above each pectoral and pelvic fin (Figure 21). This scale is three to four times larger than any other scale on the fish. It is broadly rounded anteriorly and tapers to a point posteriorly.

Cyprinidae, Carps and Minnows



This family dominates the continental ichthyofauna of North America, Europe, and Asia. There are 53 species reported from the states and provinces in northeastern North America (Table 3). The North American representatives of this family, most of which are in the Subfamily Leuciscinae, comprise a morphologically and ecologically diverse group which runs the spectrum from small, stream-dwelling fishes to large lacustrine and riverine forms. In addition to the native species, six Eurasian species have been introduced into the Northeast. Most of these exotic species became established during the last 100 years. Introductions of native fishes from one drainage to another have also occurred, and most of these extra-basin transfers have not been documented. The ancestral ranges of most of the fishes in this family in eastern North America are speculative.

Examples of how fishes have gained access to new drainages will illustrate some of the dispersal mechanisms used. Clearly, the Eurasian minnows were introduced into North America, but the reason for each introduction varies. The goldfish, *Carassius auritus,* was introduced into North America as an "ornament" in the seventeenth century. Common carp, *Cyprinus carpio,* was introduced first by a private individual in 1831 (DeKay 1842) and was later successfully introduced by the United States Fish Commission in 1876 (State Board of Fisheries and Game Lake and Pond Survey Unit 1941). Common carp, in particular, was introduced into North America due to its popularity as a food fish in the "Old Country" (Moyle 1976). Bitterling, *Rhodeus serceus,* was reported first from the Sawmill River by Dence (1925). Its introduction was probably accidental. Grass carp, *Ctenopharyngodon idella,* has been introduced during the past decade in the belief that it will serve as a control agent for undesirable aquatic plants. Many of the native minnows have expanded their ranges as "bait-bucket" introductions. The intentional release of bait at the end of a day of fishing may account for the ubiquity of the fathead minnow, *Pimephales promelas,* for example (Hartel 1992). George (1981) has credited this method with the widespread distribution of golden shiner, *Notemigonus crysoleucas,* in upland Adirondack lakes and ponds.

Migration through canals has been suggested as the mode used by other minnows. For example, Snelson (1968) suggested that the presence of comely shiners, *Notropis amoenus,* in Seneca Lake resulted from a migration through the short-lived Chemung Canal in the

TABLE 3. DISTRIBUTION OF MINNOWS, FAMILY CYPRINIDAE, IN NORTHEASTERN NORTH AMERICA.

Species	Ohio	Potomac	Susquehanna	Delaware	New Jersey Coast	Hudson	Long Island	Housatonic	Connecticut	Thames	Taunton	Massachusetts Coast	Merrimack	Kennebec	Penobscot	St. Croix	St. John	Nova Scotia Coast	Mirimichi	Restigouche	St. Lawrence	Newfoundland Coast	Labrador Coast	James/Hudson Bay
	Drainage																							
Campostoma anomalum	N	N	N	R	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Carassius auratus	I	I	I	I	I	I	I	I	I	I	I	I	I	—	—	—	—	—	—	—	I	—	—	—
Clinostomus elongatus	N	—	N	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Couesius plumbeus	—	—	—	N	—	N	—	—	N	—	—	—	N	N	N	N	N	N	N	N	N	—	N	N
Ctenopharyngodon idella	—	—	—	I	—	I	I	IE	—	—	—	—	—	I	—	—	—	—	—	—	I	—	—	—
Cyprinella analostana	—	N	N	N	—	N	—	—	—	—	—	IE	—	—	—	—	—	—	—	—	N?	—	—	—
Cyprinella spiloptera	N	N	N	N	N	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Cyprinus carpio	I	—	I	I	I	I	I	I	I	I	I	—	I	I?	I	—	—	—	—	—	I	—	—	—
Erimystax dissimilis	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Erimystax x-punctatus	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Exoglossum laurae	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Exoglossum maxillingua	—	N	N	N	N	N	—	N	N	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Hybognathus hankinsoni	R	—	I?	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Hybognathus regius	—	—	N	N	N	N	—	N	N	—	—	—	N	—	—	—	—	—	—	—	N	—	—	—
Luxilus chrysocephalus	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Luxilus cornutus	N	N	N	N	N	N	—	N	N	N	N	N	N	N	N	N	N	N	N	—	N	—	—	—
Lythrurus umbratilis	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Macrhybopsis storeriana	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Margariscus margarita	N	N	N	N	—	N	—	—	—	—	—	—	—	N	N	N	N	N	N	N	N	—	N	N
Nocomis bigutatus	N	—	I?	—	—	I?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Nocomis micropogon	N	N	N	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notemigonus crysoleucas	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	—	—	N	—	—	N
Notropis amblops	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis amoenus	—	N	N	N	—	N?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notropis anogenus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis ariommus	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notropis atherinoides	N	—	I?	—	—	N	—	I	I	—	—	—	—	I?	I	—	—	—	—	—	N	—	—	N
Notropis bifrenatus	—	—	N	N	—	N	N	N	N	N	N	N	N	N	N	—	—	—	—	—	N	—	—	—
Notropis blennius	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notropis buchanani	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

continued on next page

TABLE 3. — *continued*

Species	Ohio	Potomac	Susquehanna	Delaware	New Jersey Coast	Hudson	Long Island	Housatonic	Connecticut	Thames	Taunton	Massachusetts Coast	Merrimack	Kennebec	Penobscot	St. Croix	St. John	Nova Scotia Coast	Mirimichi	Restigouche	St. Lawrence	Newfoundland Coast	Labrador Coast	James/Hudson Bay
	Drainage																							
Notropis bucattus	N	N	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notropis chalybaeus	—	—	—	N	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notropis dorsalis	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis heterodon	N	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis heterolepis	N	—	N	—	—	N	—	—	—	—	—	—	—	N	—	—	N	N	—	—	N	—	—	N
Notropis hudsonius	I	N	N	N	N	N	—	N	N	N	N	N	N	—	—	—	—	—	—	—	N	—	—	N
Notropis photogenis	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis procne	—	—	N	N	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notropis rubellus	N	N	N	R	—	N	—	—	I	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis stramineus	N	—	—	—	—	I?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Notropis volucellus	N	—	R	—	—	—	—	—	I	—	—	—	I	—	—	—	—	—	—	—	N	—	—	—
Phoxinus eos	—	—	E	—	—	N	—	—	N	—	—	—	—	N	N	N	N	N	N	—	N	—	—	N
Phoxinus ethryogaster	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phoxinus neogaeus	E	—	—	—	—	E	—	—	N	—	—	—	N	—	N	N	N	—	—	—	N	—	—	N
Pimephales notatus	N	N	N	N	—	N	—	I	I	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Pimephales promelas	N		N	I	I	I	—	I	I	—	—	—	I	I	—	—	I	—	—	—	N	—	—	—
Rhinichthys atratulus	N	N	N	N	N	N	—	N	N	N	—	—	N	N	N	N	N	N	N	N	N	—	—	—
Rhinichthys cataractae	N	N	N	N	—	N	—	N	N	N	NE	—	N	—	—	—	—	—	—	—	N	N	—	N
Rhodeus sericeus	—	—	—	—	—	I	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scardinius erythrophthalmus	—	—	I	—	—	I	—	—	—	—	—	I	—	I	—	—	—	—	—	—	I	—	—	—
Semotilus atromaculatus	N	N	N	N	N	N	—	N	N	N	—	—	—	N	N	N	N	N	N	N	N	—	—	—
Semotilus corporalis	—	N	N	N	N	N	—	N	N	N	N	NE	N	N	N	N	N	—	N	—	N	—	—	N
Tinca tinca	—	—	—	—	—	—	IE	—	—	IE	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Information taken from Cooper (1939a, 1939b, 1940, 1941, 1942), Scott and Crossman (1973), Lee et al. (1980 et seq.), Cooper (1983), Halliwell (1984), Smith (1985), Schmidt (1986), Underhill (1986), and Scott and Scott (1988). The Great Lakes, Finger Lakes, and Lake Champlain are included in the St. Lawrence River system. N = native; E = extirpated; I = introduced; R = recent arrival, maybe introduced; ? = status uncertain.

TABLE 4. ADULT SIZE RANGE AND HABITAT CHARACTERISTICS OF SPECIES OF MINNOWS AND CARPS INHABITING INLAND WATERS OF NORTHEASTERN NORTH AMERICA.

Species	Size Range (mm SL)	Macrohabitat Lake	Macrohabitat Stream	Habitat Characteristics	Abundance when Present
Campostoma anomalum	70-230		x	tributary streams, pool and riffle, tolerant	common, expanding
Carassius auratus	200-300	x		large rivers, lakes, thick vegetation, tolerant	rare to common
Clinostomus elongatus	50-80		x	pools of small streams, cool, clear water	rare to abundant
Couesius plumbeus	60-200	x	x	usually in streams, cool, clear water	rare to common
Ctenopharyngodon idella	750-1250	x		large rivers, ponds, lakes	rare
Cyprinella analostana	45-90		x	streams with moderate to high flow, clean	rare to common
Cyprinella spiloptera	50-80		x	mid-elevation, flowing streams	common
Cyprinus carpio	200-1200	x	x	large rivers, ponds, lakes, mid-size streams	common
Erimystax dissimilis	60-100		x	mid-sized streams, flowing water, clear	rare, declining
Erimystax x-punctatus	60-90		x	mid-sized flowing streams, gravel bottoms	rare, endangered
Exoglossum laurae	65-135		x	pools or runs in middle gradient streams	rare
Exoglossum maxillingua	95-140		x	pools or runs in flowing streams, bottom form	rare to common
Hybognathus hankinsoni	55-100		x	sluggish, weedy streams; occasionally in bogs	rare to common
Hybognathus regius	55-120		x	slow-moving rivers, backwaters, pools	common
Luxilus chrysocephalus	65-100		x	mid-sized streams, column dweller	abundant
Luxilus cornutus	65-100		x	ponds, pools of mid-sized streams, column	abundant
Lythrurus umbratilis	50-70		x	streams, tolerant of slow to high flow	rare, declining
Macrhybopsis storeriana	150-200	x		lakes or large, turbid rivers	rare, declining
Margariscus margarita	70-110		x	small, clear creeks, bogs, darkly-stained ponds	common
Nocomis bigutatus	80-140		x	pools or slow-moving runs, rarely in lakes	common, expanding
Nocomis micropogon	90-200		x	pools to swift streams, bottom-dweller	common
Notemigonus crysoleucas	70-200	x		slow-moving or standing water, vegetation	abundant
Notropis amblops	50-75		x	quiet water, near riffles, vegetation	rare, declining
Notropis amoenus	50-75		x	large streams, rivers, slow to fast water	common
Notropis anogenus	35-45		x	slow or standing water, dense vegetation	rare, endangered
Notropis ariommus	45-75		x	flowing streams, clear, clean water	rare, extirpated
Notropis atherinoides	60-200	x	x	lakes, large rivers, open water, turbid	abundant
Notropis bifrenatus	25-50		x	ponds, slow, small streams, mud, detritus	common to abundant
Notropis blennius	75-100	x		main stem of large rivers, deep water	rare, extirpated
Notropis buchanani	30-60		x	pools, backwaters of large rivers	rare, extirpated
Notropis bucattus	30-50		x	associated with sand in flowing streams	common
Notropis chalybaeus	40-55		x	small, low-gradient streams, bogs, surface	rare to common
Notropis dorsalis	40-70		x	small, low-gradient streams, mud	common
Notropis heterodon	40-50		x	small, cool, clear ponds and streams, vegetation	rare, declining

continued on next page

TABLE 4. — *continued*

Species	Size Range	Macrohabitat		Habitat Characteristics	Abundance
	(mm SL)	Lake	Stream		when Present
Notropis heterolepis	50-90		x	small lakes and streams, vegetation	common
Notropis hudsonius	75-100	x		large rivers and lakes	abundant
Notropis photogenis	75-115		x	medium to large streams, clear, flowing water	common
Notropis procne	30-60		x	small, low-gradient, warm, turbid streams	rare to common
Notropis rubellus	50-75		x	mid-sized, flowing streams, clear, near riffles	common
Notropis stramineus	40-60		x	flowing, mid- to low elevation streams, sand	common
Notropis volucellus	40-60		x	near riffles in mid-sized streams	common
Phoxinus eos	40-55		x	slow-moving creeks or backwaters, vegetation	rare to abundant
Phoxinus ethryogaster	55-65		x	small, clear, cold streams	rare to common
Phoxinus neogaeus	55-70		x	slow-moving, swampy streams, ponds, vegetation	rare to common
Pimephales notatus	40-70		x	tolerant of a variety of stream habitats	abundant
Pimephales promelas	50-90	x	x	tolerant of a variety of habitats, stream, pond	abundant
Rhinichthys atratulus	40-60		x	small to mid-sized cool streams, runs, riffles	abundant
Rhinichthys cataractae	60-100		x	small to large streams, riffles	abundant
Rhodeus sericeus	75-90		x	low-gradient streams, requires freshwater mussel	rare
Scardinius erythrophthalmus	200-335	x		still or slow-moving water	rare to common
Semotilus atromaculatus	100-250		x	pools of small to mid-sized streams	abundant
Semotilus corporalis	100-400		x	mid-sized to large streams, cool lakes	abundant
Tinca tinca	400-600	x		ponds, sloughs, warm quiet water	rare

Information taken from Scott and Crossman (1973), Moyle (1976), Trautman (1981), and Smith (1985).

mid-nineteenth century. Other minnows have been accidentally introduced in conjunction with the intentional introduction of other fishes, such as the spottail shiner, *N. hudsonius,* into Allegheny Reservoir (Cooper 1983). Minnows, in general, have been substantially aided in their range expansions by human activity. However, many species of minnows have qualities that make them formidable migrators in their own right, which accounts for their wide distribution. One characteristic that limits their ability to disperse is that, with a few exceptions, minnows are intolerant of salt water and must move along established fresh-water routes. This may account for the absence of most species from Long Island, Newfoundland, and Prince Edward Island. This limitation renders minnows especially useful to zoogeographers in that their current distributions provide clues to past stream connections and to locations of ice age refugia.

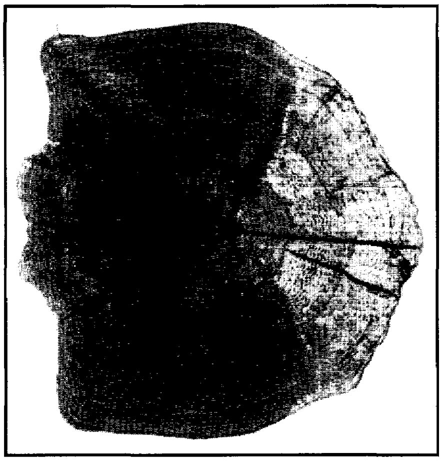


Figure 22. Lateral scale from a 182-mm rudd, *Scardinius erythrophthalmus,* NYSM 42040. Longitudinal dimension is 9.5 mm.

In North America at present, minnows support no major commercial fishery. This group does not appear to have been important to northeastern Native Americans either, although some minnows, primarily the larger western forms, were consumed in abundance by Native Americans (Gobalet 1989, 1990b, 1993; Schultz 1979; Schultz and Simons 1973). Native North American minnows in the Northeast tend to be small stream-dwelling fishes (Table 4) and apparently not prized food fishes. However, their apparent lack of importance in the diets of northeastern Native Americans may more accurately reflect the inability of modern researchers to find traces of their use, either because small minnows do not preserve well (Hopkirk 1988) or because sampling is inadequate. In general, fish are attractive as food if minimal effort is expended in obtaining a meal, either because the fish is large or because small ones are plentiful. There are minnows in the Northeast that are large. The stream-dwelling fallfish, *Semotilus corporalis,* attains lengths in excess of 40 cm. Certain lake fishes, like the golden shiner and silver chub, *Macrhybopsis storeriana,* grow to 25 cm. The smaller fishes may have been used since they are often locally or regionally abundant (Gobalet 1989).

The scales of all minnow species share certain features. They are cycloid, and they have primary and secondary radii in the posterior field. However, based on other scale characteristics, minnows can be divided into three broadly defined groups. The first group comprises four of the Eurasian carps introduced into North American waters. In these species, scales are quadrate, the focus is central, or at least in the middle one-third of the scale; there are fewer ridges in the posterior field; these ridges are weakly formed; and radii occur in both the anterior and posterior field. The second group includes two North American genera and the European tench, *Tinca tinca.* These fish have scales with radii in all four fields. The third group includes all the remaining native species and the bitterling. These fish possess scales with a focus in the anterior one-third of the scale and an absence of radii in the anterior field. Cockerell and Allison (1909) described the scales of several species found in the Northeast and provided a key to help identify the scales of some forms.

The fishes in the first group are four introduced carps. In general, the scales of these fishes are square, have a focus in the middle one-third of the scale, and have radii in the posterior and anterior field (Figure 22). These scales are also relatively thick and can be quite large (up to 5 cm). The scales of fishes in this group are similar in appearance stoneroller (*Campostoma anomalum*); members in the genera *Exoglossum, Luxilus, Nocomis, Pimephales,* and *Semotilus;* and bigeye chub (*Notropis amblops*). The two species that are primarily inhabitants of lakes or ponds–the silver shiner, *Macrhybopsis storeriana,* and golden shiner, *Notemigonus crysoleucas*–have scales in which the focus sits along the scale midline from 30% to 40% from the anterior margin (Figure 25). The lake chub, *Couesius plumbeus,* and fallfish, *Semotilus corporalis,* have scales that are typically longer than wide (Figure 26). The cutlips minnow, *Exoglossum maxillingua,* has scales where secondary radii spill over into the two lateral fields. The scales of the fishes in the remaining genera are similar to each other, although slight differences in the radii count and the width-length ratio may aid in identification (Table 2).

Catostomidae, Suckers

Suckers are primarily North American fresh-water fishes. They are found in both rivers and lakes throughout the Northeast, and one species, the white sucker, *Catostomus commersoni,* is probably the widest ranging fish in the area. Nineteen species of suckers have been reported from systems draining the northeastern states and provinces. Of these, six are, or were, recorded only from the Ohio River or Lake Erie drainages in western Pennsylvania and Ontario (Table 5). Suckers are not popular game or bait fishes, so the likelihood that extant populations resulted from introductions is low. Suckers are relatively large fish, and many migrate into small tributaries for spawning (Table 6). Large size and a seasonal increase in density related to spawning migrations make these fishes an attractive food source, and they were important food fishes for several Native American tribes in this area (Rostlund 1952) and throughout northern North America (Follett 1982; Gobalet and Fenenga 1993; Miller 1955).

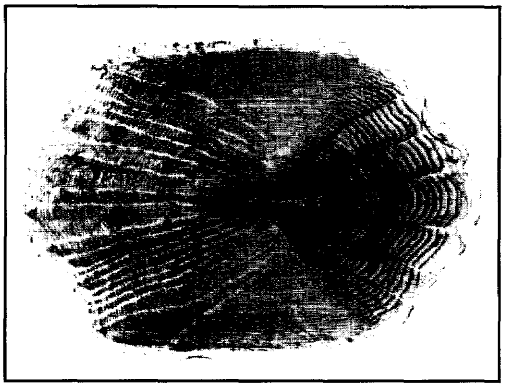


Figure 27. Lateral scale from a 271-mm white sucker, *Catstomus commersoni,* NYSM 38340. Longitudinal dimension is 6 mm.

The bodies of suckers are entirely covered with scales, and their heads are entirely naked. Sucker scales are cycloid, have a central or subcentral focus, and possess primary and secondary radii in both the anterior and posterior fields. The number of secondary radii increases with increasing size of the scale. Ridges encircle the focus. The scales of the different genera in the Catostomidae fall into two groups based on the width-length ratio. Species in *Catostomus, Cycleptus,* and *Erimyzon* have lateral scales that are longer than they are wide. These fishes have scales that are generally less than 1 cm long. In general, the lateral scales in *Carpiodes, Hypentelium, Ictiobus,* and *Moxostoma* have axes about equal in length or are wider than long. The scales of large adults in these genera can exceed 4 cm.

Longnose (*Catostomus catostomus*) and white suckers have scales with from 8 to 20 primary radii that fan out from the focus in anterior and posterior fields (Figure 27). There are usually more primary radii in the anterior field. Secondary radii are interspersed among the primaries in both fields and are present in the lateral fields. This is the only sucker genus in the Northeast whose members' scales have more than three secondary radii in the lateral fields. The presence of radii in the lateral fields of scales of the longnose sucker is common; the condition is rarer in white sucker scales. The focus is central or slightly anterior to the center of the scale. Ridges surround the focus and are

TABLE 5. DISTRIBUTION OF SUCKERS, FAMILY CATOSTOMIDAE, IN NORTHEASTERN NORTH AMERICA.

Species	Drainage: Ohio	Potomac	Susquehanna	Delaware	New Jersey Coast	Hudson	Long Island	Housatonic	Connecticut	Thames	Taunton	Massachusetts Coast	Merrimack	Kennebec	Penobscot	St. Croix	St. John	Nova Scotia Coast	Mirimichi	Restigouche	St. Lawrence	Newfoundland Coast	Labrador Coast	James/Hudson Bay
Carpiodes carpio	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carpiodes cyprinus	N	—	N	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Capriodes velifer	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Catostomus catostomus	N	—	N	—	—	N	—	—	N	N	—	—	N	N	N	N	N	—	N	N	N	—	N	N
Catostomus commersoni	N	N	N	N	N	N	—	N	N	N	N	N	N	N	N	N	N	N	N	—	N	—	N	N
Cycleptus elongatus	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Erimyzon oblongus	—	—	N	N	N	N	N	N	N	N	N	N	N		—	—	—	—	—	—	N	—	—	—
Erimyzon sucetta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Hypentelium nigricans	N	N	N	N	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Ictiobus bubalus	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	E	—	—	—
Ictiobus cyprinellus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Minytrema melanops	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Moxostoma anisurum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Moxostoma carinatum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Moxostoma duquesnei	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Moxostoma erythrurum	N	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Moxostoma hubbsi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Moxostoma macrolepidotum	N	—	N	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	N
Moxostoma valenciennesi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—

Information taken from Cooper (1939a, 1939b, 1940, 1941, 1942), Scott and Crossman (1973), Lee et al. (1980 et seq.), Cooper (1983), Halliwell (1984), Smith (1985), Schmidt (1986), Underhill (1986), and Scott and Scott (1988). The Great Lakes, Finger Lakes, and Lake Champlain are included in the St. Lawrence River system. N= native; E = extirpated.

TABLE 6. ADULT SIZE RANGE AND HABITAT CHARACTERISTICS OF SPECIES OF SUCKERS INHABITING INLAND WATERS OF NORTHEASTERN NORTH AMERICA.

Species	Size Range (mm SL)	Macrohabitat Lake	Stream	Habitat Characteristics	Abundance when Present
Carpiodes carpio	300-350	x		large rivers, pools, fine substrates	extirpated
Carpiodes cyprinus	400-650	x		large low-gradient rivers, lakes	common
Carpiodes velifer	200-275	x		rivers, lakes, clear water, hard substrates	rare
Catostomus catostomus	150-600	x	x	clear, cold flowing water, deep lakes	common
Catostomus commersoni	250-450	x	x	found in most habitats	abundant
Cycleptus elongatus	400-900	x		large river channels, pools, usually clear water	extirpated
Erimyzon oblongus	130-280	x	x	small streams with variety of bottoms, flows	common
Erimyzon sucetta	130-380	x		areas of low flow, ponds, pools, backwaters	rare
Hypentelium nigricans	100-300		x	riffles, pools in smaller creeks, gravel, rubble	common
Ictiobus bubalus	400-730	x		clear, flowing rivers	rare
Ictiobus cyprinellus	250-800	x		shallows, large slow rivers, lakes	rare
Minytrema melanops	150-450	x		low-gradient waters, aquatic vegetation	rare
Moxostoma anisurum	250-400	x		pools of large and mid-size rivers, lakes	rare to common
Moxostoma carinatum	360-600	x		mid-size and large rivers, clear, flowing water	rare
Moxostoma duquesnei	170-400	x		mid-size and large rivers, rocky pools, flow	rare to common
Moxostoma erythrurum	180-300	x		pools, mid-size and large rivers, moderate flow	common
Moxostoma hubbsi	380-570	x		high flow, large rivers	rare
Moxostoma macrolepidotum	215-450	x		large rivers, lakes	common
Moxostoma valenciennesi	400-650	x		large rivers, lakes, clear, moderate flow	rare

Information taken from Scott and Crossman (1973), Trautman (1981), and Smith (1985).

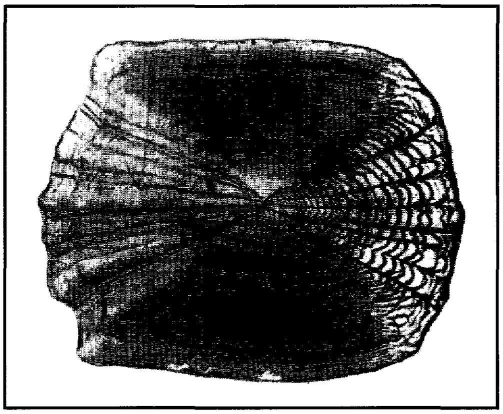
more numerous and denser in the anterior and lateral fields than in the posterior field. In the posterior field, ridges are widely spaced, with the space about 3 to 5 times the width of the ridge. Lateral scales are oblong with broadly rounded anterior and posterior profiles. On some scales, small notches are present near the antero-lateral corners. Lateral margins are roughly parallel to each other. Non-lateral scales, although usually smaller, are similar in appearance to lateral scales. Lateral-line scales possess a tube on the scale midline that opens just posterior to the focus and runs back almost to the posterior margin.

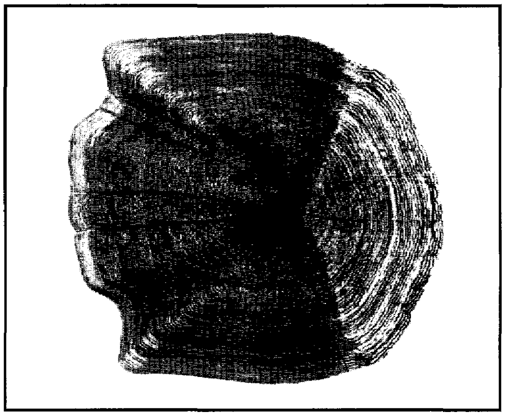
Scales of the blue sucker, *Cycleptus elongatus,* differ from those of *Catostomus* in shape and the density of the ridges in the posterior field. Lateral scales are rough ellipses. The anterior profile is irregular, and the posterior profile rounded. The antero-lateral corners are squared slightly. Non-lateral scales vary in size and shape. Ridges in the posterior field are as dense as those in the other fields, although they are fewer in number. The tube on the lateral-line scale begins just anterior to the focus and runs along the scale midline toward the posterior margin.

The creek (*Erimyzon oblongus*) and lake chubsuckers (*E. sucetta*) have scales that possess relatively few (from 6 to 10) primary radii (Figure 28). Radii are more numerous in the anterior field, and often there are no secondary radii in the posterior field. As is true for *Catostomus,* the ridges in the posterior field of chubsucker scales are less numerous and much less dense than those in the lateral or anterior fields. The shape of the lateral scales is also oblong, but the antero-lateral corners are square, and the anterior profile is jagged. The lateral margins are parallel to each other, and the posterior profile is rounded. Non-lateral scales are irregularly shaped and vary considerably in size. There is no modified lateral-line scale in this genus.

The scales of the redhorses (*Moxostoma* spp.) are about as long as they are wide, have a central focus, and have ridges in all four fields, but the ridges in the posterior field are less abundant and less dense than in the other fields (Figure 29). Similar to the scales of the Eurasian carps and to some of the scales of the northern hog sucker, scales of the redhorses are difficult to differentiate. For most species, there are from 7 to 10 primary radii on each scale, although there are from 10 to 15 on black redhorse, *M. duquesnei,* scales. There are 4 to over 50 secondary radii, depending on the size and age of the scale. Usually there are more radii in the posterior field, but these radii are weaker. The radii fan out from the central focus, and primary and secondary radii are interspersed. Secondary radii often parallel and are closely associated with the primary radii. There were no radii in the lateral fields of the species examined, although Jenkins (1970) noted that secondary radii may be present on occasion. Ridges surround the focus. On smaller (younger) scales the ridges are more poorly developed in the posterior field. As the fish and scale grow, the ridges in the posterior field become denser and similar in appearance to those in the other fields. Lateral scales would be almost circular except that the antero-lateral corners are squared and cause an indentation of the anterior margin at both corners. Non-lateral scales are similar, but the anterior margin is very irregular. The tube on the lateral-line scales runs back from the focus almost to the posterior margin.

Northern hog sucker (*Hypentelium nigricans*) scales are extremely variable and may thus be difficult to distinguish from those of other suckers and the introduced Eurasian carps. Lateral scales from the caudal peduncle and below the lateral line are similar to other sucker scales in





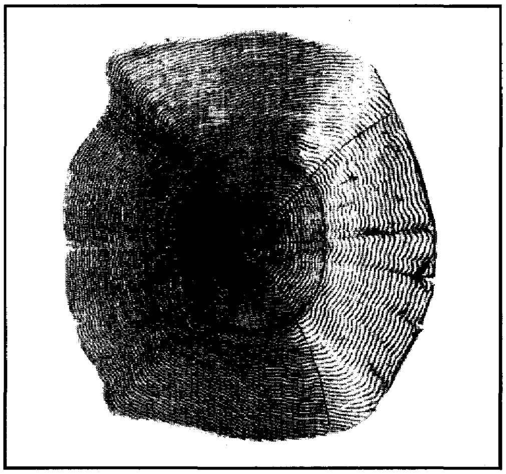


Figure 28 (top). Lateral scale from a 249-mm creek chubsucker, *Erimyzon oblongus,* NYSM 13881. Longitudinal dimension is 9.5 mm.

Figure 29 (center). Lateral scale from a 215-mm golden redhorse, *Moxostoma erythrurum,* NYSM 40471. Longitudinal dimension is 11.0 mm.

Figure 30 (bottom). Lateral scale from a 173-mm quillback, *Carpiodes cyprinus,* NYSM 13142. Longitudinal dimension is 7.5 mm.

that they are longer than wide. They also have fewer ridges in the posterior field, which makes these scales difficult to distinguish from *Catostomus* and *Erimyzon* scales. The transverse axis in scales above the lateral line and on the anterior part of the body is only slightly shorter than the longitudinal axis. These scales are similar in shape and appearance to those of *Moxostoma* and related sucker genera and the Eurasian carps. The primary radii count can provide some clue to the identity of the scale, since northern hog sucker scales have slightly more radii (from 11 to 14) than other species in this group. The other sucker genera typically have from 7 to 10 radii, and the carps have from 6 to 11, although occasionally scales from both groups have radii counts as high as 13. The secondary radii count is even less useful because the number varies with scale size or age of fish. Characteristics associated with the focus, ridges, and scale shape are similar to those of *Moxostoma.*

Quillback (*Carpiodes cyprinus*), river carpsucker (*C. carpio*), and smallmouth buffalo (*Ictiobus cyprinellus*) have scales that are roughly similar to those of the redhorses. However, in contrast to *Moxostoma* scales, the secondary radii count in the anterior field of these scales greatly exceeds that in the posterior field (Figure 30). Radii counts, focus position, and shape are not substantially different. In these scales, the ridges in the posterior field are as dense and as distinct as those present in the other fields.

Esocidae, Pikes

Four members of this north temperate, circumpolar family inhabit lakes and streams of northeastern North America. Fossil esocids have been found in Paleocene deposits in western Canada (Wilson 1980). These fish grow to relatively large sizes, and their presence in archeological sites attests to their long-term importance as popular food and game fishes (Rostlund 1952). These fishes are typically found throughout the area in low-velocity waters such as ponds, lakes, backwaters of streams, and the main channels of larger rivers. Although each species is native to certain drainages within northeastern North America, the range of each has been widely expanded within the Northeast by the activities of humans (Crossman 1978). The majority of new populations began as intentional introductions into suitable waters outside their native ranges within the last 150 years, although some may have resulted from out-migrations through canal systems (Smith 1985). *Esox americanus* is the smallest member of the family and rarely grows beyond 350 mm. The distribution of this species encircles the Appalachian Mountains with one subspecies, redfin pickerel (*E. a. americanus*), inhabiting the Atlantic coastal plain, including Lake Champlain and the lower St. Lawrence River, and a second, grass pickerel (*E. a. vermiculatus*), in the upper St. Lawrence and Mississippi River drainages.

In the Northeast, the chain pickerel, *E. niger*, grows to 600 mm. The historical range for this fish was along the Atlantic coastal plain from Maine south. Populations in Nova Scotia, New Brunswick, Quebec, and western New York and Pennsylvania are probably introduced (Lee et al. 1980 et seq.). Muskellunge, *E. masquinongy*, is the largest of the esocids and often grow well beyond 1 m in length. This species is

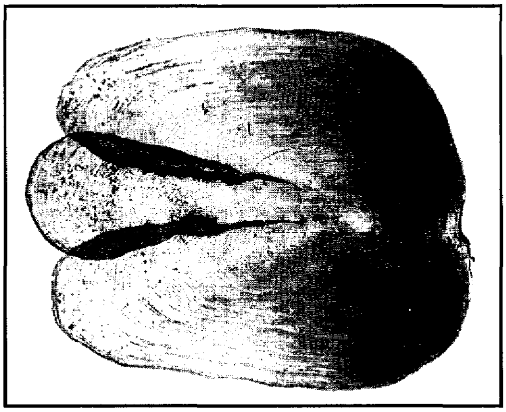


Figure 31. Lateral scale from a 775-mm muskellunge, *Esox masquinongy*, NYSM 13254. Longitudinal dimension is 8.9 mm.

native to the upper Mississippi and St. Lawrence River systems west of the Appalachian Mountains. *Esox lucius*, the northern pike, also grows to 1 m and is widely distributed in North America, Europe, and Asia. In northeastern North America, it is native to the St. Lawrence and upper Hudson and Mississippi River drainages, and it has been introduced widely into other river systems. For example, Crossman (1978) noted the introduction of pikes into the Connecticut River prior to 1850.

The bodies of esocids are covered with scales. Heads are free of scales except for varying numbers on the cheeks and opercles. Pike and pickerel scales are cycloid and have from 1 to 4 primary radii in the anterior field. Secondary radii are rare. The very fine ridges that encircle the focus are arcuate between radii. The focus lies on the midline about 60% of the length from the anterior margin of the scale (Figure 31). Scales are circular or, more commonly, ovoid with the longitudinal axis longer. The anterior margin of the scale is deeply cleft at each radius. On many scales, particularly lateral-line scales and scales on the venter, there is also a deep notch on the posterior margin; these scales are termed cardioid scales, and Roberts (1993) has labeled them crenate. The transverse axis on the scales of the pickerels and pikes is about 75% of the longitudinal axis. The scales of muskellunge are more nearly circular, with the transverse axis only slightly smaller than the longitudinal one.

Differences in scale shape and structure among northern pike, muskellunge, and their hybrids have been detailed by Casselman et al. (1986). These authors noted significant differences in the focus and annulus and in the pattern of regenerated scales. The focus in muskellunge scales is relatively clear with few, thin scattered ridges. In northern pike, the focus has many fine, closely spaced ridges that often give the appearance of paired foci. The ridges in the focus of hybrids are thick and widely spaced and form several cells with irregular shapes. The ridges of regenerated scales of muskellunge are thick, short, curved, and often branched. In northern pike, the ridges on regenerated scales are interconnected, thin, and long (i.e., characteristics similar to the ridges in the focus of an original scale). In hybrids, the ridges are thick and interconnected.

Umbridae, Mudminnows

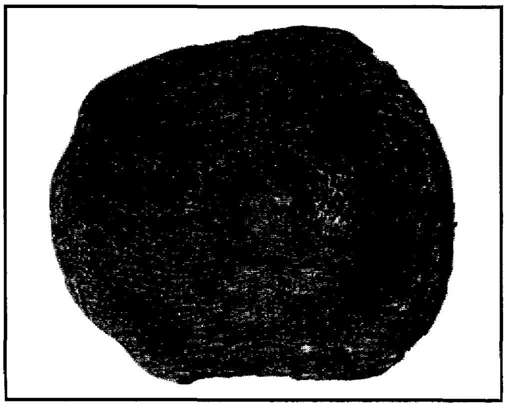


Figure 32. Lateral scale from a 91-mm central mudminnow, *Umbra limi*, NYSM 1350. Longitudinal dimension is 3.8 mm.

Two species of this small, north temperate family occur in the Northeast. The eastern mudminnow, *Umbra pygmaea*, is found in coastal streams on Long Island, southern New York, New Jersey, and Pennsylvania and in the lower Delaware River system. The central mudminnow, *U. limi*, is native to the St. Lawrence and Allegheny River systems and has recently been taken with increasing frequency in the Mohawk and Hudson River systems. Smith (1985) notes that the ability of this fish to extend its range into the Hudson River may have been facilitated by the presence of the Erie Canal. *Umbra limi* has also been introduced into the Connecticut River system in recent years (Halliwell 1984). Both species are small, cryptic fishes that typically inhabit shallow, low-velocity streams with dense aquatic vegetation and debris.

The body, top of head, cheeks and opercles of both species are scaled; snout and chin lack scales. *Umbra* scales are cycloid (Figure 32). They lack radii, the focus is diffuse, and the ridges are not concentric.

Instead, the ridges are roughly parallel to the lateral margins. In the anterior field, the outer ridges meet the anterior margin perpendicularly, and the inner ridges meet at an acute angle along a crooked line which roughly corresponds to the midline of the scale. In the posterior field, the ridges bend at the postero-lateral border and follow the profile of the posterior margin. The scales are subquadrate or ovoid with rounded corners. They are sightly longer than wide. The ridge pattern and focus in non-lateral scales are similar to those of lateral scales, but these scales are irregularly shaped and tend to be smaller.

Osmeridae, Smelts

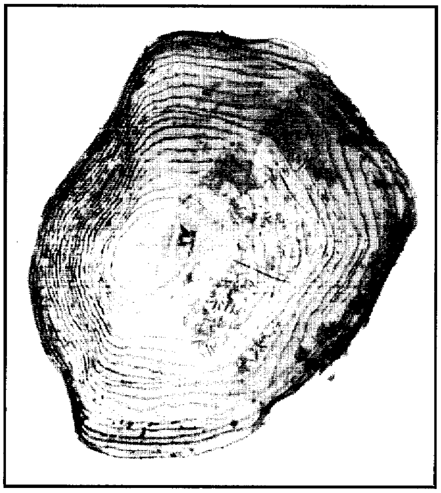


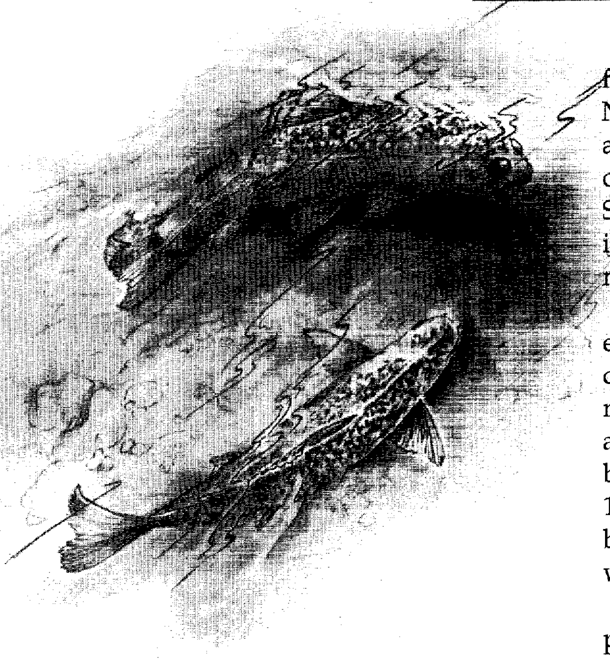
Figure 33. Lateral scale from a 113-mm rainbow smelt, *Osmerus mordax*, NYSM 23059. Longitudinal dimension is 1.6 mm.

Smelts make up a small family of north-latitude marine, anadromous, or fresh-water fishes. Only the rainbow smelt, *Osmerus mordax*, frequents inland waters in the Northeast. This species is an anadromous fish that is found in inlets, estuaries, and coastal streams from Labrador to the Hudson River. There are several landlocked populations as well, found in lakes from Newfoundland to New Hampshire and Quebec (Scott and Crossman 1973). Often these populations are so unstable that the species becomes locally extinct. Other landlocked populations have been introduced. Cooper (1983) reported that the Pennsylvania Fish Commission stocked rainbow smelt into inland lakes in the Susquehanna River drainage. Rainbow smelt in Adirondack lakes have resulted from accidental or intentional stockings (George 1981). The most dramatically successful introduction is the population that has spread throughout the Great Lakes. The parental stock arrived in Lake Michigan from a stocked population in a Michigan pond (see Smith 1985 for additional details).

Rainbow smelt are relatively small fish; adult males typically range from 180 to 200 mm, although ocean-run fishes can be bigger. However, these small fish can become phenomenally abundant during spawning runs up small, shallow tributary streams in late winter. The fact that these fish form dense congregations in small streams in late winter, when other fishes are less available, made them an important and highly prized component of the diets of Native Americans and early European settlers (Rostlund 1952).

The bodies of rainbow smelt are completely scaled and their heads are naked. The scales of rainbow smelt are cycloid, deciduous, and very thin (Figure 33). They lack radii, and the focus is weakly formed and sits near the anterior margin. The ridges encircle the focus and are very narrow. They are about equal in number in all fields; however, since the anterior field is so narrow, the ridges in this field are extremely crowded. Lateral scales are wider than long. The lateral margins are roughly parallel to each other. The posterior margin is broadly rounded, and the posterior field accounts for approximately 70% of the surface of the scale. The profile of the anterior margin varies. Non-lateral scales are more similar in appearance to the lateral scales of this species than they are in most species. The breast and interpelvic scales tend to be longer than wide. The lateral-line scales have only a small pore to distinguish them from other lateral scales.

SALMONIDAE, TROUTS



The salmons, trouts, charrs, and whitefishes are holarctic fishes found in cool and cold waters in North America, Europe, Asia, and North Africa (Berra 1981). Several species have been introduced into all parts of the world during the last century, however. Representatives of two subfamilies are common in northeastern North America. The Salmoninae include the native charrs and Atlantic salmon and the introduced salmon and European trout. The Coregoninae include the native whitefishes and ciscoes.

Salmons, trouts, and charrs comprise the most popular game fishes in North America. This attribute, coupled with their own formidable powers of dispersal (George 1981), render the estimation of native range difficult for the native species (Table 7 is a conservative assessment). Whitefishes are not currently held in such high esteem by anglers, but the attitudes of past generations differed (DeKay 1842; Jordan and Evermann 1896). Thus these fishes may also have been introduced widely throughout the area before adequate records were kept.

Of the native species, only the brook trout, *Salvelinus fontinalis,* is primarily a stream fish, although this species can be found in many lakes. The whitefishes (*Coregonus* and *Prosopium*) and lake trout (*Salvelinus namaycush*) are lake dwellers. Arctic charrs, *Salvelinus alpinus,* inhabit lakes but may ascend rivers in autumn to spawn. Atlantic salmon, *Salmo salar,* are anadromous and ascend rivers and coastal streams to spawn. There are landlocked populations of Atlantic salmon as well. The introduced species arrived in earnest during the latter part of the nineteenth century and remain a favorite hatchery fish in many states and provinces. The brown trout, *Salmo trutta,* and rainbow trout, *Oncorhynchus mykiss,* are found in lakes and streams throughout the area. The Pacific salmons, *Oncorhynchus* spp., have been stocked into Lakes Ontario and Erie and several smaller lakes, although many of the stockings have not been viable. Several species of whitefish have extremely limited ranges. For example, several are known only from Lakes Ontario and Erie and a few other large lakes, and the Atlantic whitefish, *Coregonus huntsmani,* occurs only in Nova Scotia. The Great Lakes fishes were once abundant enough to support a commercial fishery, but most of the species are currently in decline. Only the lake whitefish, *C. clupeaformis,* and cisco, *C. artedi,* are widespread. The round whitefish, *Prosopium cylindraceum,* is a deep-lake fish also apparently declining in number throughout its range.

The importance of trouts to Native Americans has been reviewed by Rostlund (1952) and Butler (1993). In brief, Atlantic salmon, charrs, and the whitefishes were abundant and important sources of food and trade items for tribes throughout North America. A variety of fishing technologies were developed to exploit the fact that large concentrations of fish often were confined in relatively small areas. This made the migratory forms of particular importance. European settlers were also effective at harvesting salmonids (DeKay 1842). Due to the abundance of salmonids in lakes, their remains are likely to be found in sediments; however, to date, only Peteet et al. (1994) have reported on scales retrieved from sediment samples in the Northeast.

TABLE 7. DISTRIBUTION OF WHITEFISHES, TROUTS, CHARRS, AND SALMONS, FAMILY SALMONIDAE, IN NORTHEASTERN NORTH AMERICA.

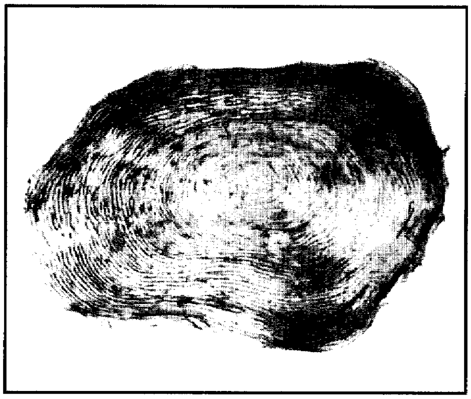
	Drainage																							
Species	Ohio	Potomac	Susquehanna	Delaware	New Jersey Coast	Hudson	Long Island	Housatonic	Connecticut	Thames	Taunton	Massachusetts Coast	Merrimack	Kennebec	Penobscot	St. Croix	St. John	Nova Scotia Coast	Mirimichi	Restigouche	St. Lawrence	Newfoundland Coast	Labrador Coast	James/Hudson Bay
Coregonus artedi	—	—	N	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	N
Coregonus clupeaformis	—	—	N?	—	—	N?	—	—	N	—	—	—	N	N	N	N	N	N	N	N	N	I	N	N
Coregonus hoyi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Coregonus huntsmani	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—	—	—	—
Coregonus kiyi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Coregonus reighardi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Coregonus zenithicus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Oncorhynchus gorbuscha	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	I	I	—	—
Oncorhynchus kisutch	—	—	—	—	—	—	—	—	—	—	—	IE	I	—	I	I	I	—	—	—	I	—	—	—
Oncorhynchus mykiss	I	I	I	I	I	I	I	I	I	I	I	I	I	I	—	—	I	I	I	—	I	—	—	—
Oncorhynchus nerka	—	—	I	—	—	I	—	IE	I	I	I	—	—	—	—	—	—	—	—	—	I	—	—	—
Oncorhynchus tshawytscha	—	—	—	—	—	—	—	—	—	—	—	—	I	I	—	—	—	—	—	—	I	—	—	—
Prosopium cylindraceum	—	—	—	—	—	N	—	N	N	—	—	—	N	—	—	N	N	N	N	N	N	—	N	N
Salmo salar	—	—	—	—	—	NE	—	NE	N	—	NE	N	N	N	N	N	N	N	N	N	N	N	N	N
Salmo trutta	I	I	I	I	I	I	I	I	I	I	I	I	I	—	—	—	I	I	—	—	I	I	—	—
Salvelinus alpinus	—	—	—	—	—	—	—	—	N	—	—	—	N	N	N	N	N	—	N	N	N	N	N	N
Salvelinus fontinalis	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Salvelinus namaycush	—	—	N	I	—	N	—	—	I	I	—	—	N	N	N	N	N	N	N	N	N	—	N	N

Information taken from Cooper (1939a, 1939b, 1940, 1941, 1942), Scott and Crossman (1973), Lee et al. (1980 et seq.), Cooper (1983), Halliwell (1984), Smith (1985), Schmidt (1986), Underhill (1986), and Scott and Scott (1988). The Great Lakes, Finger Lakes, and Lake Champlain are included in the St. Lawrence River system. N= native; E = extirpated; I = introduced; ? = status uncertain.

TABLE 8. ADULT SIZE RANGE AND HABITAT CHARACTERISTICS OF SPECIES OF WHITEFISHES, TROUTS, CHARRS, AND SALMONS INHABITING INLAND WATERS OF NORTHEASTERN NORTH AMERICA.

Species	Size Range (mm SL)	Macrohabitat			Habitat Characteristics	Abundance when present
		Ponds/ Lakes	Main Channels of Large Rivers	Tributary Streams		
Coregonus artedi	100-450	x	x		school mid-water, below thermocline	common
Coregonus clupeaformis	300-500	x	x		fresh and brackish cool water	common
Coregonus hoyi	200-300	x			Lake Ontario, deep water	rare or extirpated
Coregonus huntsmani	100-350		x		anadromous, swift current	rare
Coregonus kiyi	140-250	x			Lake Ontario, deep water	rare or extirpated
Coregonus reighardi	170-260	x			Lake Ontario, column in deep water	rare or extirpated
Coregonus zenithicus	100-400	x			Lake Nipigon, deep water	rare
Oncorhynchus gorbuscha	400-600	x	x		anadromous, most of life spent in lakes	rare
Oncorhynchus kisutch	450-600	x	x		anadromous, most of life spent in lakes	common
Oncorhynchus mykiss	250-300		x	x	cold, clear, flowing streams, some lakes	abundant
Oncorhynchus nerka	150-250	x			land-locked, depth variable	common
Oncorhynchus tshawytscha	500-800	x	x		anadromous, most of life spent in lakes	common
Prosopium cylindraceum	150-250	x	x		deep, cold lakes, northern rivers	rare
Salmo salar	400-850	x	x		anadromous, most of life spent in ocean	rare to common
Salmo trutta	200-750		x	x	cool, flowing streams, variable	abundant
Salvelinus alpinus	450-800	x	x		anadromous, cold, flowing water	common
Salvelinus fontinalis	200-400	x		x	cold, clear streams, deep, cold lakes	abundant
Salvelinus namaycush	300-500	x	x		cold, deep, well-oxygenated lakes, rivers	common

Information taken from Scott and Crossman (1973) and Smith (1985).



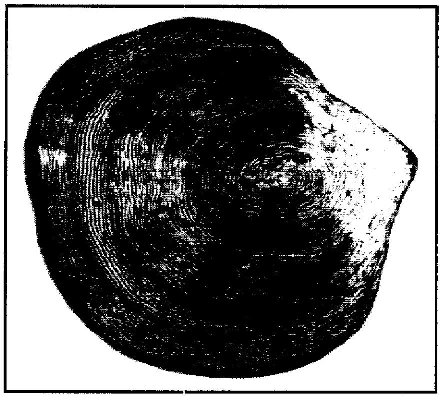


Figure 34 (left). Lateral scale from a 240-mm cisco, *Coregonus artedii*, NYSM 12646. Longitudinal dimension is 5.0 mm.

Figure 35 (center). Lateral scale from a 325-mm lake trout, *Salvelinus namaycush*, NYSM 13202. Longitudinal dimension is 2.6 mm.

Figure 36 (right). Lateral scale from a 615-mm brown trout, *Salmo trutta*, NYSM 42519. Longitudinal dimension is 5.0 mm.

Most of the species in this family are relatively large fish (Table 8). Their bodies are completely covered with scales, and their heads are completely naked. Salmonid scales are cycloid, have no radii, and have ridges that encircle a central, ovoid focus. These are the only fresh-water fishes with this combination of characteristics, although salmonids share some of these characteristics with some marine fishes that enter fresh water. Within the family, the scales of whitefish are distinguished from those of charr, trout, and salmon by the density of ridges in the fields, the width-length ratio, and size. Lateral scales of whitefish are about as wide as, or slightly wider than, they are long (Figure 34), although the more irregularly shaped dorsal, breast, and interpelvic scales have a width-length ratio near 0.70. The postero-lateral corners are broadly rounded, and the lateral and posterior margins follow the same arc. The antero-lateral corners are square, and the anterior margin has a central bulge. The ridges are more numerous in the anterior field than in the other fields. Lagler (1947) mentioned that larger scales show incipient radii. These can best be described as folds visible in the anterior field, but these features do not resemble the grooves typically termed radii. Lateral-line scales have a large, open-ended tube that sits over the focus. The length of the tube is approximately one-half the length of the scale. *Coregonus* and *Prosopium* scales are too similar to distinguish at the level attempted in this work. Casselman et al. (1981) used several shape vectors to distinguish stocks in lake whitefish populations in Lake Huron.

The lateral scales of charr are roughly ovoid. Scales usually have a width-length ratio less than 0.65, and particularly in smaller fish, these scales are about twice as long as they are wide. The scales of larger fish are wider but remain ovoid (Figure 35). Non-lateral scales are similar to lateral scales in this group of fishes. Ridges encircle the focus and follow the outline of the scale margins. The number of ridges is approximately equal in all fields; ridges are also closely spaced.

Trouts and salmons have scales that are ovoid to roughly circular. This is especially true for larger individuals (Figure 36). On many scales, particularly those from larger fish, ridges are entirely absent from the exposed part of the posterior field. They are closely spaced in the fields in which they occur. In all three genera lateral-line scales have a relatively large open-ended tube that runs longitudinally across the scale almost from the posterior to the anterior margin. However, distinguishing among the genera may be difficult since there is some overlap of characteristics.

Percopsidae, Trout-Perches

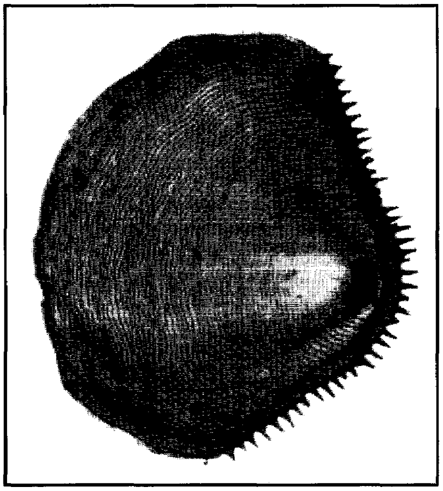


Figure 37. Lateral scale from a 115-mm trout-perch, *Percopsis omiscomaycus*, NYSM 30061. Longitudinal dimension is 1.8 mm.

The trout-perch, *Percopsis omiscomaycus*, is a northern-latitude fish found throughout the Nearctic. Scott and Crossman (1973) reported that trout-perches migrated north after deglaciation from refugia in the Mississippi Valley. Underhill (1986) argued that the northeastward migration of this fresh-water species was blocked by the Champlain Sea (c. 11,000 bp). In the Northeast, trout-perches are most common in the St. Lawrence River system west of Lake Champlain. South of the St. Lawrence River, they are present in most river drainages from western Pennsylvania east to the Connecticut River. They also occur in several streams draining into Hudson Bay. These small fishes seldom reach 150 mm in length. They primarily inhabit lakes where they can become very abundant (Cooper 1983), but they are also found in many streams and rivers.

Only the heads and, in larger specimens, the predorsal areas of trout-perches are without scales. Trout-perches have spinoid scales and no radii, a combination that distinguishes them from the scales of all other fishes in the area (Figure 37). There is a single row of spines at the posterior margin of the scale. The focus is in the posterior quarter of the scale and is encircled by few ridges. Ridges are weak and widely spaced, and most terminate perpendicular to the row of spines. Lateral scales are circular, ellipsoidal, or ovoid; if not circular, the scales are wider than long. All four corners are rounded. Lateral-line scales possess an open-ended tube on the midline often reaching the posterior margin of the scale.

Aphredoderidae, Pirate Perches

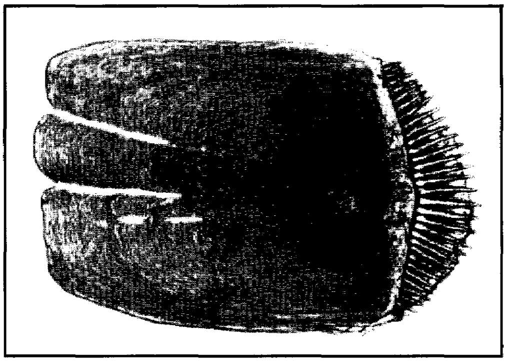


Figure 38. Lateral scale from an 80-mm pirate perch, *Aphredoderus sayanus*, NYSM 17659. Longitudinal dimension is 2.9 mm.

Aphredoderus sayanus, the pirate perch, belongs to a monotypic family confined to eastern North America. It is distributed in a "U" around the Appalachian Mountains with the tops of each arm reaching into New York. Like those of *Esox americanus*, pirate perch populations in the extremities are regarded as distinct subspecies. The western form, *A. s. gibbosus*, is native to a few creeks and ponds in western New York and Pennsylvania but is now rare (Smith 1985). The eastern nominal subspecies is relatively abundant on Long Island and southern New Jersey but has not been collected recently in southeastern Pennsylvania (Cooper 1983). It does not appear to have been introduced into areas outside its native range in the Northeast. Pirate perches are typically found in lowland lakes or low-gradient streams. They are relatively small fish and seldom reach 100 mm.

Squamation is almost complete in pirate perches; only the interorbital region is free of scales. Pirate perch scales are distinguished by a single row of long, finger-like ctenii, numerous extremely fine ridges and few weakly developed radii (Figure 38). These scales are peripheral ctenoid. The single row of long, narrow, closely packed, pungent ctenii dominates the posterior field of the scale. The anterior margin of the ctenii is slightly concave, and the medial ctenii are longest. The ridges are semicircular and meet the ctenii perpendicularly. They do not encompass the weakly formed focus. These ridges are closely spaced and arcuate between the radii.

There are from 2 to 4 primary radii on lateral scales and from 0 to 2 on other scales. Secondary radii, when present, are peripheral. All radii are weakly formed and often appear to be folds in the ridges. This effect is particularly obvious near the focus. The indistinct focus is about 75% of the length from the anterior margin. The lateral scales are longer than wide with parallel sides and rounded anterior and posterior margins. The anterior margin is scalloped with deep indentations at the radii. A short, open-ended tube sits over the focus and runs posteriorly onto the row of ctenii in the lateral-line scales.

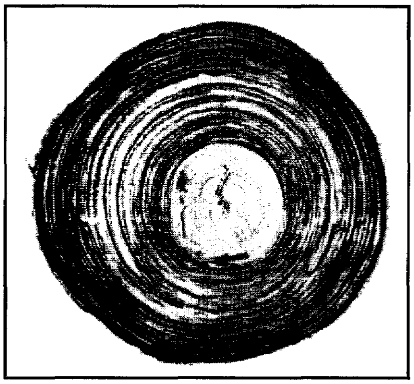
GADIDAE, CODS

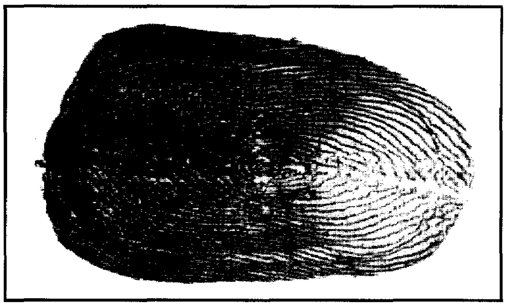
Only a few members of this primarily marine family are found in inland waters. One species, *Lota lota,* the burbot, is a holarctic freshwater fish inhabiting large lakes and rivers throughout the area. The most southern are relic populations found in the headwaters of the Allegheny River in Pennsylvania (Cooper 1983) and the Susquehanna River in New York (Smith 1985). Although this fish inhabits large rivers and lakes, and usually spawns under the ice in shallow bays and backwaters, burbot also makes mid-winter spawning runs into small tributary streams (Scott and Crossman 1973). This migratory behavior allowed certain Native American tribes to capture it in abundance during this season (Rostlund 1952). A second species, Atlantic tomcod (*Microgadus tomcod*), is an anadromous form found during winter in estuaries from Labrador to the Hudson River and as a permanent resident of lakes in Quebec and Newfoundland (Scott and Scott 1988). Seven other species have been reported as strays in coastal rivers and streams (Smith and Lake 1990).

Cods are relatively large fishes; burbot grow to just under 1 m total length, and Atlantic tomcod, the smallest of the group, can grow to over 30 cm. Burbot appears to possess no scales, when in fact, the entire body is covered with embedded scales. The head is naked, but embedded scales cover the opercle. Scales are readily visible on other cods. Atlantic tomcod has scales on its body but a naked head. Several of the marine strays possess scales on both bodies and heads.

The difference in scale morphology within the Gadidae is greater than that found in most families (Peabody 1931). Burbot scales are distinctive. They are circular with a central focus and evenly spaced, concentric ridges about the focus (Figure 39). There are no radii and no ctenii. Scales of the Atlantic cod, *Gadus morhua,* are similar. The scales of *Urophycis, Enchelyopus,* and *Merluccius* also lack radii and ctenii. The scales of fishes in these three genera are also similar in shape. They are ellipsoidal and longer than they are wide. In *Urophycis* and *Enchelyopus,* the focus is a central point, but the ridges are not concentric. Instead, they meet at an acute angle along the midline of the scale and run parallel to the lateral margins of the scale (Figure 40). In *Merluccius,* the focus lies in the anterior part of the scale. The ridges meet along the midline in the anterior field as in *Urophycis,* but they are concentric in the posterior field. The lateral line is scaleless. Instead, the two rows of scales adjacent to the lateral line are slightly modified.

Atlantic tomcod scales are easily distinguished by the presence of broken radii in all four fields (Figure 41). The radii fan out from the focus to the scale margins in broken, staggered segments. Radii are densest in the anterior and posterior fields. The total number of radii per scale is more than 25 and increases to over 50 as the fish grows. The focus is approximately one-third the length of the scale from the anterior margin. Ridges are widely spaced, encircle the focus, and are about equal in number in all four fields. Scales are ellipsoidal and longer than they are wide. The margins are entire with no indentations or cuts.





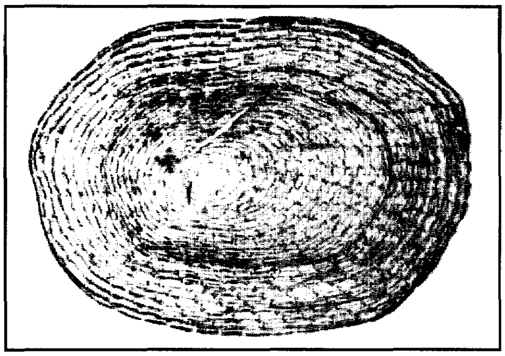


Figure 39 (top). Lateral scale from a 532-mm burbot, *Lota lota,* NYSM 15084. Longitudinal dimension is 1.6 mm.

Figure 40 (center). Lateral scale from a 206-mm white hake, *Urophycis tenuis,* NYSM 2551. Longitudinal dimension is 3.5 mm.

Figure 41 (bottom). Lateral scale from a 171-mm Atlantic tomcod, *Microgadus tomcod,* NYSM 9710. Longitudinal dimension is 1.8 mm.

BELONIDAE, NEEDLEFISHES

Figure 42. Lateral scale from a 352-mm Atlantic needlefish, *Strongylura marina*, NYSM 6954. Longitudinal dimension is 3.5 mm.

Needlefish are common, near-shore predators that range south along the Atlantic coast from Cape Cod. Only *Strongylura marina*, the Atlantic needlefish, commonly enters fresh water. This species is reported from all the major rivers in the area and has been taken at sites over 100 km upstream in the Susquehanna, Delaware, and Hudson Rivers (Lee et al. 1980 et seq.). Adults typically range in size from 30 to 50 cm.

The bodies of Atlantic needlefish are covered with fine, overlapping scales, and the head is covered with scales except in the suborbital region. Scales also advance onto the long snout and chin. Atlantic needlefish scales are cycloid and lack radii (Figure 42). Lateral scales are distinctive; they have a diffuse focus, ridges do not extend into the lateral fields, and these scales are much wider than long. Ridges are parallel in the anterior and posterior fields and more numerous in the posterior field. All four corners are squared, and the lateral margins are parallel to each other. The anterior and posterior margins of the scales are arched. Scales from the dorsal and caudal peduncle region of the fish possess a distinct focus, which is closer to the posterior margin than to the anterior margin of the scale. The ridges on these scales encircle the focus, are continuous, evenly spaced, and equal in number in all four fields. These scales are slightly longer than wide, and all four corners are rounded. They do not have regular shapes.

CYPRINODONTIDAE, KILLIFISHES

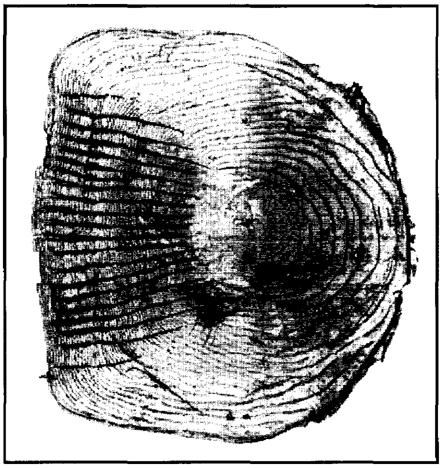


Figure 43. Lateral scale from a 100-mm mummichog, *Fundulus heteroclitus*, NYSM 42501. Longitudinal dimension is 4 mm.

The killifishes, or toothcarps, are small fishes inhabiting fresh or brackish water. There are six species of this family found in inland waters in the Northeast. These fishes are extremely tolerant of salt water and are frequently found on off-shore islands throughout the area. Grouping these fishes into one family is reasonable here, since the scales of these species are similar to each other and are difficult to distinguish from those of *Gambusia* (see below). However, the grouping is largely one of convenience for this work. Parenti (1981) reclassified the genera placed in this family by earlier workers into four families. The sheepshead minnow, *Cyprinodon variegatus*, remains in the Family Cyprinodontidae, whereas the other five species are included in the Family Fundulidae.

Four of the species found in the Northeast are closely associated with the ocean. Their occurrence in inland waters is confined to coastal marshes, ditches, and the mouths of coastal streams. Sheepshead minnow and rainwater killifish, *Lucania parva*, are found in coastal streams from Cape Cod to southern New Jersey. They are also present on most of the larger off-shore islands. Striped killifish, *Fundulus majalis*, is primarily a near-shore fish that also enters the mouths of streams. It is also common on off-shore islands. Spotfin killifish, *F. luciae*, has been reported from streams on Long Island and the southern New Jersey coast. The mummichog, *F. heteroclitus*, is also a primarily marine fish that moves into tidal creeks from Newfoundland to New Jersey, but populations of mummichogs are also found in upstream fresh-water marshes in several of the larger rivers in the area, including the Delaware and Hudson Rivers. The banded killifish, *F. diaphanus*, is a primarily fresh-water fish found throughout the area from Newfoundland and

Anticosti Island to western Pennsylvania. All species are typically found in standing or sluggish water and are often associated with dense aquatic vegetation.

Killifishes are small fishes that rarely exceed 150 mm in length. They can become abundant in preferred habitats, and since they spend much of their time in the water column or at the surface, a fishery can be developed for them, although there does not appear to be any evidence that Native Americans in the Northeast ever used them for food (Rostlund 1952).

The bodies of members of all six species are covered with scales. The amount of squamation on the head varies among species. Killifish scales lack ctenii, but they are more robust than other cycloid scales (Figure 43). The scales of fish in all six species have radii on the anterior field, and the count varies from 10 to 21. The radii are crooked and roughly parallel, arising at a line just anterior to the focus and proceeding to the anterior margin. In general, these radii are secondary; they do not reach the focus, which is enclosed by two or more unbroken ridges. The exception is the striped killifish in which from 50 to 70% of the radii do reach the focus, radii are radial rather than parallel, and there are from 9 to 11 total radii. In scales of all species, the focus is central. Ridges surround the focus and are equal in number in the lateral and posterior fields but more abundant and crowded in the anterior field. The ridges are bowed inward between the radii in the scales of sheepshead minnow and those of striped, spotfin, and rainwater killifishes. They are straight in scales of mummichogs and banded killifish. The scales are subquadrate with squared antero-lateral corners and rounded postero-lateral corners. Scales of the mummichog and spotfin killifish are roughly as wide as they are long. Sheepshead minnow and banded and rainwater killifish scales are wider than they are long. Striped killifish scales are longer than wide. In all species, the lateral margins are parallel to each other, the posterior margin is broadly rounded, and the anterior margin is straight or slightly convex. There are small indentations on the anterior margin at the radii. In all six species, the non-lateral scales are round or ovoid, are smaller and have fewer radii than the lateral scales. The lateral-line scales are distinguished by a pore on or immediately posterior to the focus.

Poeciliidae, Livebearers

Gambusia is the only genus of this family found in northeastern North America. *Gambusia holbrooki* is native to coastal streams in southern New Jersey. *Gambusia affinis* has been introduced into ponds in Pennsylvania (Cooper 1983), northern New Jersey (Lee et al. 1980 et seq.), and New York (Smith 1985) with mixed success. Mosquitofish typically inhabits ponds and low-velocity streams where that can become very abundant.

The bodies of these small fish are completely covered with scales. The chin, snout, and suborbital region are the only areas free of scales. Mosquitofish scales cannot be readily distinguished from those of the Cyprinodontidae. They are cycloid and have radii on the anterior field. The focus is approximately 60% of the scale length from the anterior margin, which is slightly different from the more central position of the focus in killifishes. The lateral scales are almost semicircular, with broadly rounded postero-lateral corners and squared antero-lateral corners. The anterior margin of the scale is straight to slightly convex with small indentations at the radii. There are only secondary radii; these radii are almost parallel and originate along a line slightly anterior to the focus, so that one or more ridges encircle the focus. Nine to eleven radii originate on this line. Non-lateral scales are more rounded and range from circular (predorsal) to ovoid (breast). The focus is more central in these scales, and the number of radii ranges from 6 to 13. The lateral-line scales possess a small pore near or over the focus.

ATHERINIDAE, SILVERSIDES

Figure 44. Lateral scale from an 80-mm rough silverside, *Membras martinica*, NYSM 7329. Longitudinal dimension is 2.7 mm.

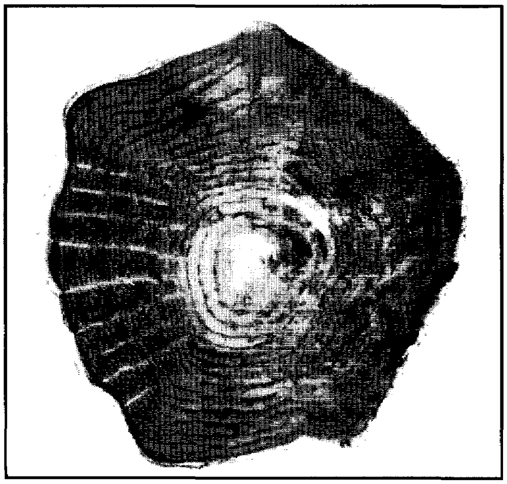


Figure 45. Lateral scale from a 100-mm Atlantic silverside, *Menidia menidia*, NYSM 2833. Longitudinal dimension is 2.4 mm.

Four members of this large family, which has a worldwide distribution, are found in fresh and brackish waters in the Northeast. The brook silverside, *Labidesthes sicculus*, is present in lakes and streams and is usually closely associated with dense aquatic vegetation. It is found in the St. Lawrence and Ohio River drainages in western Pennsylvania and New York. It has also been collected in the Mohawk River system of eastern New York (Greeley 1935). This population may have gained access to this drainage via the Erie or Barge Canal. The other three silversides are coastal. The inland silverside, *Menidia beryllina*, occurs in coastal streams southward from Massachusetts. This species also is reported to occur far upstream in several major rivers and their tributaries (Cooper 1983; Smith and Lake 1990). *Menidia menidia*, the Atlantic silverside, is a marine fish that enters tidal rivers and creeks and coastal marshes throughout the area southward from the Gulf of St. Lawrence. The rough silverside, *Membras martinica*, is a warm-water marine fish that strays north to the Hudson River. It enters the Hudson River and migrates upstream to river km 180 (Beebe and Savidge 1988); Smith (1985) noted a resident population in the Hudson River around river km 60.

Silversides are small fish that rarely reach 120 mm in standard length. They school, at least during daylight, and can be extremely abundant. They are typically found in the water column and often at the surface. Follett (1983) and Gobalet (1990b) reported that many atherinid scales were found in middens along the Pacific coast. These fishes may also have been used extensively by Native Americans on the East Coast as well.

Bodies and most of the heads of silversides are scaled; only the snout and chin lack scales. The scales of these four species of silversides lack ctenii, but the similarities end with this generalization. Cockerell (1910a) first noted the difference in scales among the genera of Atherinidae. Scales of *Membras martinica* usually lack radii, have no ridges in the area of the scale posterior to the focus, exhibit a broken posterior margin, and possess a conspicuous extension in the middle of the anterior margin (Figure 44). These crenate scales possess a suite of characteristics that make them easily distinguishable from the other three fishes in the family and all other fishes in the region. The ridges closest to the focus are parallel to each other and the anterior margin. The central portion of the more distal ridges also run parallel to the anterior margin, but they bend at right angles at the antero-lateral border and proceed back to about the middle of the scale. Radii are found on scales from the caudal peduncle region only; these scales consistently have 4 or 5 secondary radii. The weakly formed focus is central. All scales have the central process on the anterior margin and are wider than long. The antero-lateral corners are square, and the postero-lateral corners are rounded. The posterior margin is frayed. Lateral-line scales possess an open-ended tube that runs back along the midline from the focus.

Menidia and *Labidesthes* scales are cycloid, have a central focus, and have radii in the anterior field (Figure 45). They most closely resemble the scales of killifish and mosquitofish but can be distinguished from them in that they have fewer ridges in the lateral field than in either the anterior or posterior fields. The lateral scales of Atlantic and inland silversides, genus *Menidia,* have from 7 to 12 secondary radii, which are crooked and unevenly spaced. The focus is central. Ridges encircle the focus, but the number of ridges differs in each of the fields. There are very few ridges in the lateral fields, typically less than one-half the number present in the other fields, and those present are widely spaced. Ridges in the posterior field are dense and poorly defined. The ridges in the anterior field are well defined but broken by the radii. Between the radii, ridges are straight or slightly bowed. *Menidia* scales are wider than long and semi-circular. The antero-lateral corners are square, and the postero-lateral corners are round. The posterior profile is broadly rounded, and the anterior margin is slightly convex and uneven. Caudal peduncle scales are squared and possess from 10 to 14 robust radii. Lateral-line scales in the Atlantic silverside possess open-ended tubes that lie along the midline with posterior opening on the focus and the rest in the anterior field. The lateral-line scale in the inland silverside has a pore over the focus.

Labidesthes scales differ from those of *Menidia* in that they are ovoid with all four corners rounded. They possess from 6 to 8 secondary radii in the anterior field and a central focus. The ridges are weak in all fields, but the basic pattern described for *Menidia* is true for brook silverside as well; the lateral fields have slightly fewer ridges than the anterior or posterior fields.

GASTEROSTEIDAE, STICKLEBACKS

Figure 46. Lateral plate from a 57-mm threespine stickleback, *Gasterosteus aculeatus,* NYSM 22798. Longitudinal dimension is 2.5 mm.

Sticklebacks make up a small family of fishes with a circumpolar distribution in the northern hemisphere (Berra 1981). Although several species of sticklebacks inhabit inland waters in northeastern North America, members of only one possess scales, or more appropriately, lateral bony scutes or plates. The threespine stickleback, *Gasterosteus aculeatus,* is widely distributed in coastal streams from the Delaware River to James Bay. In the St. Lawrence River system, upstream populations are also established in Lake Ontario and the Ottawa River (Scott and Crossman 1973). These fish rarely exceed 75 mm in length, but they can be locally abundant.

The number of lateral plates on individual threespine sticklebacks varies from 0 to more than 30. Often members of a population or subspecies can be characterized by plate number. Stickleback scales are unlike those of any other fish in northeastern North America. The plates are oblong and much wider than long (Figure 46). No ridges are apparent, but the plates display surface ornamentation. The anterior half of the scale is smooth. The posterior half is covered with small tubercles that radiate from a raised point in the middle of the scale. Each plate also is distinguished by a projection on the anterior margin.

PERCICHTHYIDAE (MORONIDAE), TEMPERATE BASSES

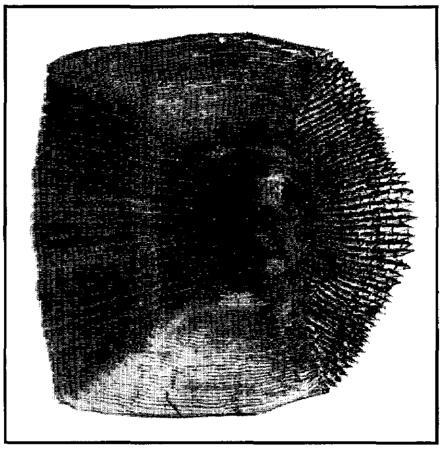


Figure 47. Lateral scale from a 276-mm striped bass, *Morone saxatilis*, NYSM 19538. Longitudinal dimension is 5.4 mm.

Three species of temperate basses are currently found in northeastern North America. White perch, *Morone americana*, and striped bass, *M. saxatilis*, are native in large coastal rivers from Quebec to New Jersey. White bass, *M. chrysops*, was historically present in the Ohio River system and the Great Lakes. All three species have expanded their ranges during the last century. White perch has moved north and westward. Scott and Christie (1963) argued that this species gained access to Lake Ontario through the Oswego River and the Erie or Barge Canal. Recent entry into Lake Champlain may have been aided by the Champlain Canal (Plosila and Nashett 1990). Its presence in many fresh-water lakes throughout the Northeast, in Lake Erie (Larsen 1954), and in the St. Lawrence River (Vladykov 1952) may be the result of stocking efforts or out-migration from stocked populations.

Striped bass is an anadromous species. The young remain in the river through their first summer, but as adults, they migrate up coastal rivers to spawn. Historically, they inhabited many coastal marshes throughout the area. Attempts to establish landlocked fresh-water populations in the area have been unsuccessful. White bass have moved east during the last several decades. They have been stocked into the Allegheny Reservoir (Eaton et al. 1982) giving them access to the upper Allegheny River system, and Smith (1985) has argued that they have gained access to the lower Hudson River via the Erie or Barge Canal.

The bodies of all three species are covered with scales; only the snout and chin are naked. The scales of the temperate basses are transforming ctenoid (Figure 47). The anterior margin of the ctenial patch does not reach the focus. Only apical ctenii are sharp; ctenial bases are quadrate. The apical ctenii are long and narrow, and the ctenial patch is dense with the numerous rows and columns tightly packed. The ctenii are stacked in columns that radiate from the center of the anterior margin of the patch. Both primary and secondary radii are present in the anterior field. Secondary radii may be peripheral or medial. The focus-length ratio averages 0.67. Lateral scales are subquadrate, the antero-lateral corners are square, and the postero-lateral corners are rounded. These scales tend to be only slightly wider than they are long. The tube on the lateral-line scales runs longitudinally along the midline in the center of the scale; both ends are open. The non-lateral scales vary in shape and have fewer radii than the lateral scales. The ctenial patch is similar to that found on the lateral scales. The anterior margin is posterior to the focus, the patch is densely packed, and the apical ctenii are numerous, long, narrow, and pointed. The family is treated with greater detail by McCully (1961).

There is one notable difference between the scales of striped bass and those of white perch and white bass. There are from 18 to 23 radii on the lateral scales of striped bass; the number of primary radii ranges from 11 to 17. The number of radii on white perch and white bass scales ranges from 11 to 15 with primary radii numbering between 6 and 11. Oates et al. (1993) also noted that ctenial bases of striped bass scales make up more of the length of the ctenius than the spine, whereas the ctenial base of white perches makes up a relatively shorter part of the ctenius.

SERRANIDAE, SEA BASSES

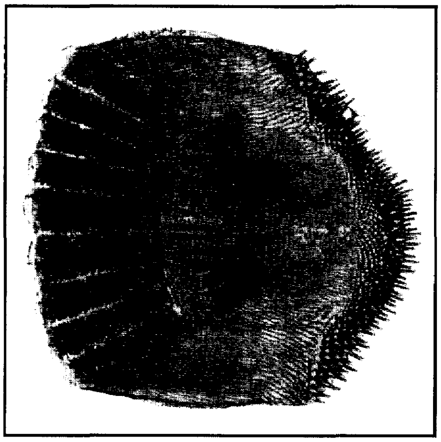
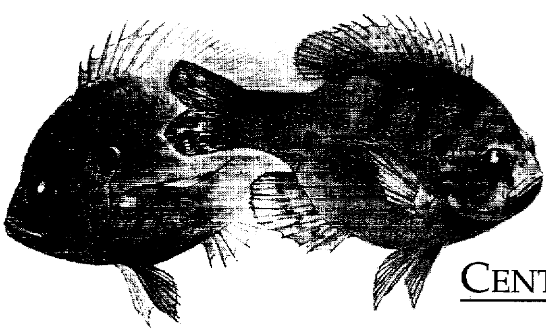


Figure 48. Lateral scale from a 123-mm black sea bass, *Centropristis striata*, NYSM 14293. Longitudinal dimension is 5.8 mm.

This large family is composed of fishes inhabiting continental shelves and slopes in tropical and subtropical seas worldwide. Black sea bass, *Centropristis striata*, is occasionally found in inland waters in northeastern North America. This species has been reported off the Atlantic coast from Nova Scotia (Scott and Scott 1988) to the Delaware Bay (Grosslein and Azarovitz 1982), but it is rare north of Cape Cod (Bigelow and Schroeder 1953). This fish is a seasonal migrant that moves north and inshore in spring, and south and offshore in autumn. Spawning occurs just offshore, and juveniles move into nursery areas in the estuaries of the east coast. In the Hudson River, individuals have been taken up to river km 70 (Smith and Lake 1990).

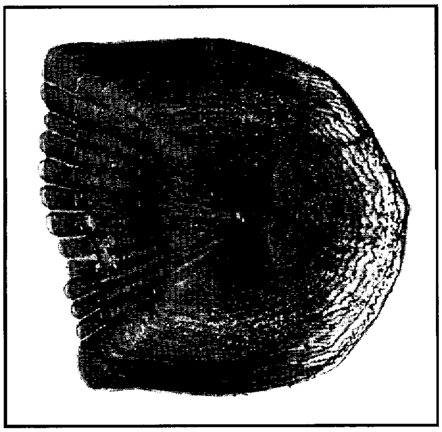
Black sea bass is covered with scales; only the snout, chin, and suborbital region are naked. The lateral scales of black sea bass are transforming ctenoid, subquadrate, and possess radii in the anterior field (Figure 48). Two features distinguish the lateral scales from those of other fishes in northeastern North America: the ctenoid patch extends anteriorly to the focus, and there are no secondary radii. There are 10 primary radii on the central lateral scales which diverge from the focus to the anterior margin of the scale. The number of radii on scales mesial to the pectoral fin ranges from 9 to 12 and from 7 to 9 on scales of the caudal peduncle. The ctenial patch is arranged in columns and rows; the columns radiate from the focus, and adjacent columns are staggered. The apical ctenii are pungent, and the ctenial bases remain on the interior of the patch. The apical ctenii are long, more than three times the width of the base, and are set at varying angles. Some are blunted, and others are bifid. Ctenial bases are longer than wide and fit snugly. There are no ridges in the posterior field; they emanate perpendicularly from the ctenial patch. Ridges are arcuate between the radii, and there are more ridges in the anterior field than in the lateral fields. The focus is three-fourths the length from the anterior margin of the scale. Scales are about as wide as they are long. The anterior margin of the scale is crenate; the antero-lateral corners are square, and the postero-lateral corners are rounded. Non-lateral scales vary in shape and tend to be longer than wide. Primary radii range from 3 to 8, and secondary radii are rare. The lateral-line scales exhibit a sack extending anteriorly over the focus and open posteriorly on the underside of the scale. McCully (1961) described the scales of this genus in more detail.

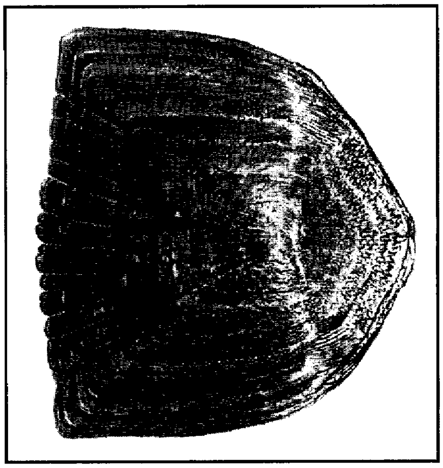
Smith and Lake (1990) have reported the capture of a gag, *Mycteroperca microlepis*, at river km 70 of the Hudson River. This marine stray is uncommon in inland waters, but it is present offshore from Cape Cod south. The scales differ from those of the black sea bass. They are small, ovoid, and lack strong ctenii. Lateral scales are about twice as long as they are wide and have 2 or 3 primary radii in the anterior field. Secondary radii are rare.



CENTRARCHIDAE, SUNFISHES

Of the 34 species that make up this North American fresh-water fish family, 16 are found in the streams and lakes of the Northeast. At least two of these species–the warmouth (*Lepomis gulosus*) and redear sunfish (*L. microlophus*)–are recent introductions to the Northeast, and





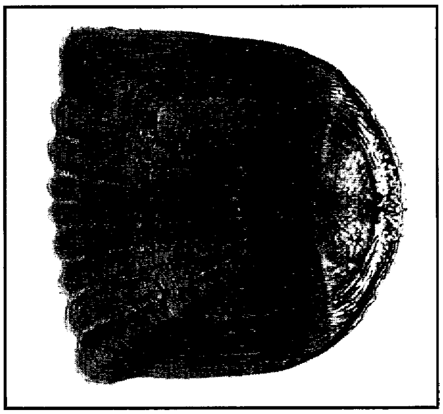


Figure 49 (top). Lateral scale from a 104-mm mud sunfish, *Acantharchus pomotis*, NYSM 3534. Longitudinal dimension is 4.5 mm.

Figure 50 (center). Lateral scale from a 154-mm redbreast sunfish, *Lepomis auritus*, NYSM 23849. Longitudinal dimension is 5.4 mm.

Figure 51 (bottom). Lateral scale from a 197-mm largemouth bass, *Mircopterus salmoides*, NYSM 42502. Longitudinal dimension is 6.1 mm.

most of the others, although native to certain drainages in this area, have greatly expanded their ranges by widespread introductions during the past century (Hartel 1992; Lee et al. 1980 et seq.). The sunfishes and crappies are characterized by deep, laterally compressed bodies and are common inhabitants of lakes, impoundments, and main channels of larger rivers. However, any low-gradient area, even in headwater streams, appears to be suitable for these fishes. The black basses (*Micropterus* spp.) are more fusiform and occur, again, in lakes, ponds and large rivers and also in the mid-elevation tributaries.

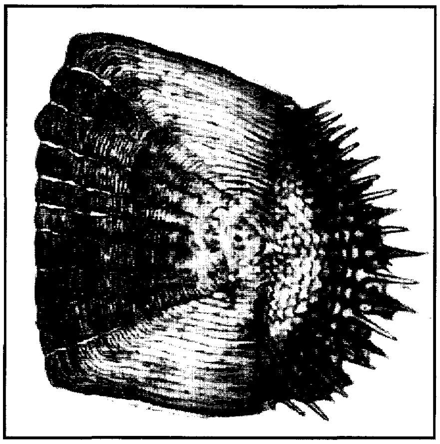
All members of the family present in the Northeast are almost completely covered with scales; only parts of the head are without squamation. In general, centrarchid scales are transforming ctenoid and have from 8 to 15 primary radii in the anterior field that converge posteriorly at the focus. Lateral scales are typically subquadrate; the antero-lateral corners are square, and the postero-lateral corners are rounded. The anterior margin of the scale is crenate. The ctenial patch, if developed, is diamond-shaped and does not extend anteriorly to the focus. The columns of ctenii are staggered and diverge from the anterior point to the margin. The apical row of ctenii are sharp, but even many of the anteriormost ctenii retain at least blunt points. The focus is always in the posterior half of the scale.

Acantharchus scales lack obvious ctenii but retain the other characteristics of ctenoid scales (Figure 49). Radii are present in the anterior field only, and the focus is from 50% to 60% of the scale length from the anterior margin. Lateral scales are subquadrate and about as wide as they are long. There are from 7 to 10 primary radii and from 1 to 5 secondary radii on these scales; the secondary radii are always peripheral. Regenerated lateral scales typically have more radii with counts as high as 21. Of the scales sampled, ctenii were present on those from the caudal peduncle, mesad to the pectoral fin, and on the dorsum behind the rayed-dorsal fin. The ctenii are arrayed irregularly in the patch, each retaining its sharp point. Ctenii are not visible on the remaining scales; however, the ridges in the posterior field are less numerous than in the other fields and are crenelate. The numbers of ridges in the anterior and lateral fields are about equal. The shapes of the breast, interpelvic, and predorsal scales differ from the lateral scales. These scales tend to be ovoid and much longer than wide. They lack ctenii, typically have fewer than 8 radii, and the focus tends to be more central.

The lateral scales of *Ambloplites*, *Enneacanthus*, *Lepomis*, and *Pomoxis* are heavily ornamented with staggered columns of ctenii and tend to be wider than long (Figure 50). Radii are present in the anterior field; all species have both primary and secondary radii, and secondary radii may be interspersed among the primary radii or on the periphery. The number of primary radii ranges from 5 to 14 and varies among individuals and species. The size of the ctenial patch is also highly variable among species. *Pomoxis* has a small patch of weak ctenii confined to a narrow wedge along the midline of the scale posterior to the focus. In the other genera, the ctenial patch is large and made up of many sharp ctenii. The angle at the anterior edge of the ctenial patch is obtuse. Ctenii are present on lateral and post-dorsal scales and, on some specimens, breast scales. The number of ridges in the lateral fields tends to equal that of ridges in the anterior fields. Other scales lack ctenii and resemble those of *Acantharchus*. Oates et al. (1993) noted that the focus of black crappie (*P. nigromaculatus*) scales differed from that of white crappie (*P. annularis*) scales. In the black crappie, the ridges in the focus are dense and highly convoluted. In the white crappie, the focal area is essentially clear except for scattered, isolated ridges.

Micropterus scales differ slightly from those of other centrachids. They tend to be longer than wide, there tends to be only from 5 to 8 radii in the anterior field, and secondary radii are often absent (Figure 51). In other respects, these scales are similar to those of *Pomoxis* in that the ctenial patch is small and the ctenii tend to be weak.

PERCIDAE, PERCHES



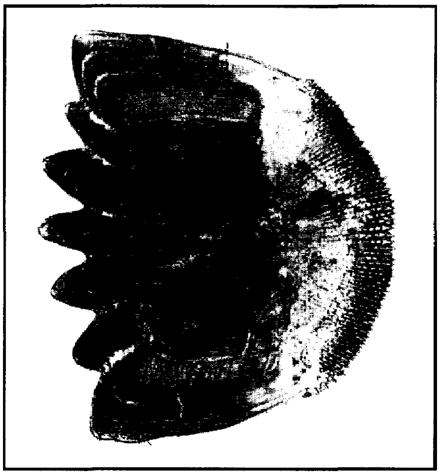


Figure 52 (top). Lateral scale from a 94-mm logperch, *Percina caprodes*, NYSM 15956. Longitudinal dimension is 3.2 mm.

Figure 53 (bottom). Lateral scale from a 205-mm yellow perch, *Perca flavescens*, NYSM 36969. Longitudinal dimension is 5.4 mm.

The perches and darters are a part of a large north temperate family that ranges from western Asia, through northern Europe to eastern North America. In northeastern North America, over 140 species, most of them darters, inhabit almost all types of aquatic habitats (Table 9). The stream-dwelling darters often have limited ranges and have not been widely introduced outside their native ranges, since they are not popular game or bait fishes. Some (e.g., the banded darter, *Etheostoma zonale*) have gained access to new drainages in recent years and have become abundant in these new systems (Cooper 1983). The yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*S. vitreum*) have been widely introduced throughout the area in the past century (Table 10). Yellow perch is ubiquitous in fresh waters throughout the area. It is presumed to have been primarily a lowland species, but it has gained access to many upland lakes during the past century. For example, Mather (1886) reported that it was not native to Adirondack lakes. George (1981) recorded the presence of yellow perch in all Adirondack watersheds and briefly recapitulated the stocking history. Sauger and, to a much greater extent, walleye are important game fishes. Both are native to the Mississippi, St. Lawrence, and James Bay drainages. In the Northeast, the range of sauger has remained relatively static, but the walleye has been introduced outside its ancestral drainages. Currently, it is present in the drainages of southern New England and the Mohawk, Delaware, and Susquehanna River drainages. George (1981) reviewed the stocking history of this fish in Adirondack lakes during the early years of the twentieth century. Despite the abundance and relatively large size of these three percids, Rostlund (1952) stated that they were much less important to Native Americans than many other fishes. He attributed this to the high percentage of waste in each fish and the relatively low caloric value. He also mentioned that early European explorers rarely made note of these fishes in their accounts, another indication of the low esteem in which these fishes were held by the native population.

Percids have scales over most of their bodies and heads. Percid scales are transforming ctenoid, have radii in the anterior field, and have a ctenial patch that almost abuts the focus. Beyond these three generalities, the scales of percids differ in several important characteristics (Coburn and Gaglione 1992). The scales of the fishes in the three darter genera (*Ammocrypta, Etheostoma*, and *Percina*) are characterized by primary and secondary radii in the anterior field and ctenial bases that are wider than they are long (Figure 52). The scales of yellow perch, sauger, and walleye have primary radii in the anterior field, but they typically lack secondary radii, and their ctenial bases are longer than wide (Figure 53).

TABLE 9. ADULT SIZE RANGE AND HABITAT CHARACTERISTICS OF SPECIES OF DARTERS INHABITING INLAND WATERS OF NORTHEASTERN NORTH AMERICA.

Species	Size Range (mm SL)	Macrohabitat: Ponds/ Lakes	Macrohabitat: Main Channels of Large Rivers	Macrohabitat: Tributary Streams	Habitat Characteristics	Abundance when present
Ammocrypta pellucida	40-55			x	flowing mid-size streams, sand	rare, declining
Etheostoma blennioides	65-100			x	mid-size streams, riffle areas, rubble	common
Etheostoma caeruleum	40-65			x	small to mid-size streams, riffles, rubble	abundant
Etheostoma camurum	35-55		x		deep riffles, runs, rubble	rare, declining
Etheostoma exile	45-55	x	x		cool, clear lakes, sluggish rivers	rare
Etheostoma flabellare	50-90			x	shallow riffles, slow to fast flow	common
Etheostoma fusiforme	30-50	x		x	slow-moving, soft-bottom streams, swamps	common
Etheostoma maculatum	40-70			x	deep, fast riffle, rubble to boulder	rare, declining
Etheostoma microperca	25-35			x	clear, cool pools, seeps, pothole lakes	common
Etheostoma nigrum	30-60		x	x	highly variable	abundant
Etheostoma olmstedi	30-70		x	x	highly variable	abundant
Etheostoma tippecanoe	30-40			x	slow, shallow riffles, clean substrates	rare to common
Etheostoma variatum	50-75		x		rapidly flowing riffles, rubble, boulder	common
Etheostoma zonale	45-60		x		moderate to rapid flowing riffles, rubble	common
Percina caprodes	100-150	x	x	x	highly variable	abundant
Percina copelandi	45-60	x	x		shallows of lakes, channels of rivers	rare to common
Percina evides	50-60		x		deep, swift runs, boulders, rubble	extirpated
Percina macrocephala	65-100		x		mid-channel, deep, swift runs, clear	rare
Percina maculata	50-80			x	clear, slow to moderate flow, gravel	common
Percina oxyrhyncha	70-100		x		deep, swift riffles or runs, boulders	extirpated
Percina peltata	50-80			x	swift riffles, gravel to rubble	rare to common

Information taken from Scott and Crossman (1973), Trautman (1981), and Smith (1985).

TABLE 10. DISTRIBUTION OF DARTERS, YELLOW PERCH, WALLEYE, AND SAUGER, FAMILY PERCIDAE, IN NORTHEASTERN NORTH AMERICA.

	Drainage																							
Species	Ohio	Potomac	Susquehanna	Delaware	New Jersey Coast	Hudson	Long Island	Housatonic	Connecticut	Thames	Taunton	Massachusetts Coast	Merrimack	Kennebec	Penobscot	St. Croix	St. John	Nova Scotia Coast	Mirimichi	Restigouche	St. Lawrence	Newfoundland Coast	Labrador Coast	James/Hudson Bay
Ammocrypta pellucida	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma blennioides	N	N	N	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma caeruleum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma camurum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Etheostoma exile	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma flabellare	N	N	N	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma fusiforme	—	—	—	N	N	—	N	—	—	N	N	N	N	—	—	—	—	—	—	—	—	—	—	—
Etheostoma maculatum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Etheostoma microperca	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma nigrum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Etheostoma olmstedi	—	N	N	N	N	N	N	N	N	N	N	N	N	—	—	—	—	—	—	—	N	—	—	—
Etheostoma tippecanoe	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Etheostoma variatum	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Etheostoma zonale	N	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Perca flavescens	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	—	—	N
Percina caprodes	N	—	—	—	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Percina copelandi	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—	—
Percina evides	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Percina macrocephala	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Percina maculata	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	—
Percina oxyrhyncha	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Percina peltata	—	—	N	N	—	N	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stizostedion canadense	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	—	—	N
Stizostedion vitreum	N	N	I	I	I	I	—	I	I	I	—	—	I	—	—	I	—	—	—	—	N	—	—	N

Information taken from Cooper (1939a, 1939b, 1940, 1941, 1942), Scott and Crossman (1973), Lee, et al. (1980 et seq.), Cooper (1983), Halliwell (1984), Smith (1985), Schmidt (1986), Underhill (1986), and Scott and Scott (1988). The Great Lakes, Finger Lakes, and Lake Champlain are included in the St. Lawrence River system. N = native; E = extirpated; I = introduced; R = recent arrival, possibly introduced.

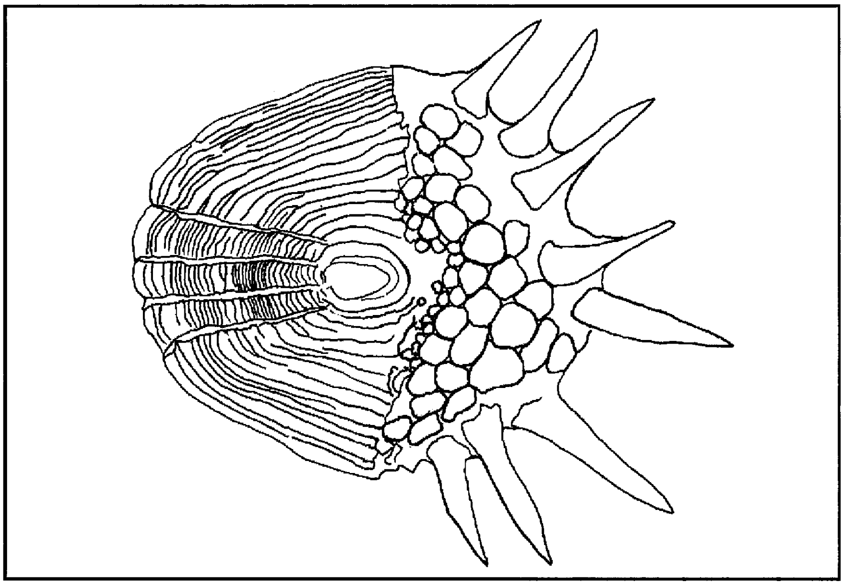


Figure 54. Stellate scale from between the pelvic fins of a logperch, *Percina caprodes*, NYSM 15956. Longitudinal dimension is 2.6 mm.

The most diagnostic feature of darter scales is shape of the ctenial bases. On darter scales, the ctenial patch is composed of several columns arranged in staggered rows. Ctenii are present only in the apical row; within each column, the ctenial bases are rectangles that are wider than long. The ctenial patch extends forward from the posterior margin to a point just posterior to the focus. The anterior margin of this patch is usually a straight line. The focus sits back from the anterior margin between 50% and 70% of the length of the scale. Primary and secondary radii fan out from the focus to the anterior margin of the scale. The number of primary radii ranges from 5 to 9; from 3 to 13 secondary radii may also be present on a scale. Usually these are found peripheral to the primary radii. Ridges are present in the lateral and anterior fields in about equal numbers. They meet the anterior margin of the ctenial patch at right angles. One or two ridges usually encircle the focus.

Lateral scales are typically wider than they are long, although the ratio between the transverse and longitudinal axes depends upon the species and the position of the scale on the fish. The scales are subquadrate, and all four corners are rounded. The lateral and anterior margins are entire and usually straight. Non-lateral scales may differ in size and shape from lateral scales, but other characteristics hold. Darters in the genus *Percina* often sport a row of modified scales, termed stellate, along their bellies from the pelvic girdle to the vent (Figure 54). The scale itself is fairly typical of that of a darter; the difference is that several, but not all ctenii, are enlarged, making the scale appear something like a starburst. Lateral-line scales have a tube that begins in the anterior quarter of the scale and extends to the posterior margin.

The scales of the eastern sand darter, *Ammocrypta pellucida*, are extremely small and differ from other darters. These scales possess relatively few radii (from 3 to 5), and all radii are secondary. The focus is almost central in this species as well. However, other characteristics are similar to those of a typical darter.

The scales of yellow perch, sauger, and walleye differ from those of darters in three key aspects. As noted, the basal ctenii are longer than they are wide, secondary radii are rarely present, and the anterior margin of the scale is deeply cleft where the radii intersect. Radii are present in the anterior field. The ctenial patch fills the posterior field and consists of rows and columns. Ctenii occur only in the apical row. All ctenial bases are rectangular with the longitudinal dimension from 1.5 to 3 times the transverse one. The anterior margin of the patch lies just posterior to the focus and is usually straight. Primary radii number from 4 to 8; secondary radii, if present at all, are peripheral and number from 1 to 3. The focus sits in the posterior one-third of the scale, ranging from 65% to 75% of the scale length back from the anterior margin of the scale. Ridges meet the anterior margin of the ctenial patch at right angles; the 1, 2, or 3 nearest the focus surround it. Ridges are closely spaced and are equally abundant and dense in both lateral and anterior fields. Between radii, ridges bow outward following the contour of the anterior margin.

Lateral scales are D-shaped and slightly wider than long. The posterior margin is broadly rounded. The antero-lateral corners are square, and the anterior margin is straight, although broken at each radius by a deep cleft. Non-lateral scales share most of the characteristics of lateral scales; however, they have fewer radii and differ in shape by having rounded antero-lateral corners. Lateral-line scales have a large, open-ended tube that bisects the scale from a point just posterior to the anterior margin over the focus almost to the posterior margin. Close examination of the focus may allow separation of the three species found in the Northeast. The focus in *Perca* is filled with ridges. Oates et al. (1993) noted that the focus in walleye scales was also filled with ridges, whereas the focus in sauger scales was largely empty, with only a few scattered ridges.

Pomatomidae, Bluefishes

Figure 55. Lateral scale from a 204-mm bluefish, *Pomatomus saltatrix*, NYSM 11993. Longitudinal dimension is 3.1 mm.

Bluefish, *Pomatomus saltatrix*, is the only member of this small family found in the area. This is an oceanic fish that moves inshore only when water temperature increases in late summer and early autumn. During this period, it is found from Delaware Bay to Cape Cod (Grosslein and Azarovitz 1982) and, on occasion, enters the Gulf of Maine (Bigelow and Schroeder 1953). Large fish typically remain in the ocean, although Smith (1985) reported their presence in the Hudson River upstream into Haverstraw Bay. However, even those fish that remain in the ocean are close enough to shore to enable anglers to harvest them (Bigelow and Schroeder 1953; DeKay 1842). Young fish (called snappers or snapper blues) migrate into harbors and estuaries throughout the area. Beebe and Savidge (1988) reported individuals captured in the Hudson River 220 km upstream.

The bodies of bluefish are covered completely with scales. On the head, only the opercles and cheeks have scales. The bluefish scale is spinoid and distinctive (Figure 55). The spines are triangular and laid out in rows. The patch looks like several pruning-saw blades laid against each other. In addition, bluefish are the only fish in this area that possess spined scales with numerous secondary and few primary radii in the anterior field. The lateral scales examined had from 3 to 16 secondary radii and no primary radii. Only one of the caudal peduncle scales examined had a primary radius. The radii are not evenly spaced, vary considerably in length, and approach the anterior margin at different angles. The number of ridges that encircle the focus is approximately equal in all fields. On most scales, there is an acute bend in the ridge at the postero-lateral borders. The focus is a point just slightly posterior to the midpoint of the scale. Lateral scales are almost rectangular with the width exceeding 1.5 times the length. The breast and interpelvic scales are irregularly shaped. Lateral-line scales possess an open-ended tube along the midline equally distant from the anterior and posterior margins of the scale.

CARANGIDAE, JACKS

Figure 56. Lateral scale from a 150-mm crevalle jack, *Caranx hippos*, NYSM 11240. Longitudinal dimension is 1.3 mm.

Jacks are typically marine fishes. Smith and Lake (1990) have listed four species that enter the Hudson River, but only the crevalle jack, *Caranx hippos*, commonly moves upstream into the fresh-water part of the river. Lookdown, *Selene vomer*, and Atlantic moonfish, *S. setapinnis*, have been taken on occasion as far upstream as river km 65. The fish that move upstream are small, usually less than 25 cm in length.

The bodies and heads of jacks are covered with thin scales. The scales of these four species are cycloid and lack radii (Figure 56). They are most similar in appearance to salmonid scales, but they tend to be much wider than long. Ridges surround the indistinct, central focus and are more numerous in the anterior and posterior parts of the scale. On many scales, the ridges meet along a line through the focus giving them a chevron-like appearance in the lateral fields.

SPARIDAE, PORGIES

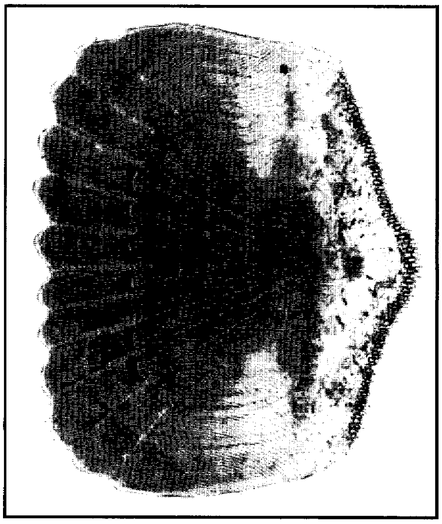


Figure 57. Lateral scale from a 147-mm scup, *Stonotomus chrysops*, NYSM 11468. Longitudinal dimension is 4.5 mm.

The porgies are another group of primarily marine, perch-like fishes that occasionally enter and reside in fresh or brackish water. Three species have been reported from the inland waters of the Northeast from Nova Scotia south to Delaware Bay. The pinfish, *Lagodon rhomboides*, has been taken from coastal streams from Cape Cod, Long Island, and New Jersey. Beebe and Savidge (1988) recorded its presence in the Hudson River 65 km upstream. The scup, *Stenotomus chrysops*, is present from Nova Scotia and New Brunswick to New Jersey. It has been taken in the St. Croix River estuary (Scott and Scott 1988) and the Hudson River (Beebe and Savidge 1988). Sheepshead, *Archosargus probatocephalus*, is also present in the same general area as scups, although there are no reports of it in major rivers. These fishes can grow to over 200 mm in length.

The porgies have relatively large scales over their entire bodies. Their heads, except for the chin, pre-orbital, inter-orbital, and snout, are also covered with scales. The scales of these three species of porgies are transforming ctenoid, have radii in the anterior field, and are slightly wider than long (Figure 57). They differ from the other perch-like species in that peripheral radii occur in the lateral fields, and the ridges bend out to the lateral margin at the postero-lateral border instead of meeting the ctenial patch. Ctenii form a patch in the posterior field that reaches anteriorly almost to the focus. Ctenii occur only in the apical row; interior rows are composed of blunt ctenial bases that are usually longer than wide. Individual ctenii are relatively short, less than 5% the length of the scale. Scales have from 8 to 13 radii that fan out from the focus to the anterior margin. Secondary radii are always on the periphery, and on most scales, these radii spill into the lateral fields. The radii are straight and tend to be evenly spaced. The focus sits at the base of the radii in the posterior half of the scale. Ridges are about equal in number in the lateral and anterior fields but, except for the 2 to 4 nearest the focus, do not continue around into the posterior field. Instead, they bend toward the lateral margin.

Lateral scales are essentially rectangular with all four corners squared and wider than long. The anterior margin is scalloped. Breast scales and those posterior to the dorsal fin are similar to the lateral scales. Interpelvic and predorsal scales are smaller and irregularly shaped, often lack ctenii, and have from 1 to 3 radii. The lateral-line scales are distinctive. On most, an open-ended tube lies across the midline of the scale over and anterior to the focus. In addition, one or two small tubes or pores branch back onto the posterior field.

Sciaenidae, Drums

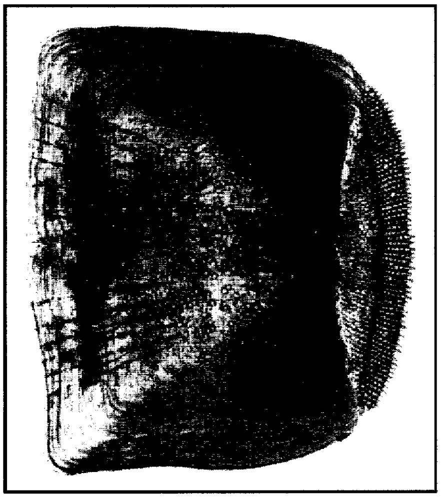


Figure 58. Lateral scale from a 252-mm freshwater drum, *Aplodinotus grunniens*, NYSM 23850. Longitudinal dimension is 7.1 mm.

Drums inhabit near-shore, shallow-water habitats in tropical and temperate seas throughout the world. In North America, only one species is confined to fresh water, although several species are known to enter coastal streams and rivers. The freshwater drum, *Aplodinotus grunniens*, is common in large-water habitats throughout the Mississippi River and St. Lawrence River systems. It has recently been taken in the Hudson (Smith and Lake 1990) and Mohawk Rivers. Along the Atlantic coast, from Massachusetts south, seven species have been reported to ascend rivers. Silver perch (*Bairdiella chrysoura*), weakfish (*Cynoscion regalis*), and spot (*Leiostomus xanthurus*) are all reported from both the Delaware and Hudson Rivers and on occasion, are seasonally abundant. Two other species–Atlantic croaker (*Micropogonias undulatus*) and northern kingfish (*Menticirrhus saxatilis*)–are taken rarely in fresh water (Grosslein and Azarovitz 1982; Smith and Lake 1990). An additional two species–red drum (*Sciaenops ocellata*) and spotted seatrout (*Cynoscion nebulosus*)–stray into the more southern estuaries of the region (Lee et al. 1980 et seq.). With the exception of the silver perch and spot, drums in northeastern inland waters can be large fishes and can attain lengths in excess of 50 cm. Some species (e.g., red drum and spotted seatrout) grow to lengths over 1 m, although larger individuals may not move into fresh water. Freshwater drum remains have been collected at archaeological sites in the Northeast, but there is no indication that this was a favored food species (Rostlund 1952).

All drums have scales that cover their bodies and most of their heads. Drums have scales similar to the other perch-like fishes found in the Northeast. The scales are transforming ctenoid, have radii in the anterior field only, and are D-shaped (Figure 58). In contrast to the scales of most perch-like fishes, drum scales have foci surrounded by many ridges, usually more than five. This characteristic is shared with scales from the temperate basses in the genus *Morone*. Drum scales differ from those of *Morone* by having fewer primary radii–from 3 to 7 in drums versus from 8 to 17 in *Morone.* Of course, there are exceptions, and this dichotomy does not always hold, so other characteristics may help to separate these two groups. In *Morone,* the apical ctenii tend to be long and narrow whereas apical ctenii in drum scales are usually shorter and stouter. Finally, drum scales tend to have from 5 to 7 ridges surrounding the focus, and *Morone* often have more than 15. This final characteristic does not hold for all scales; in fact, silver perch scales have foci typically surrounded by more than 15 ridges.

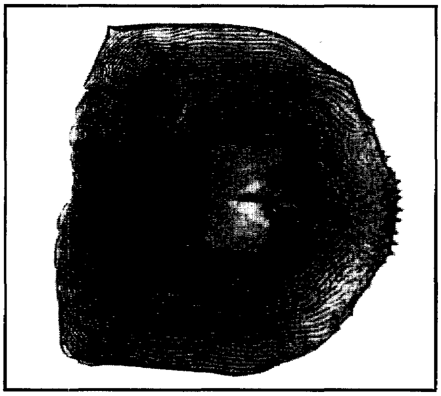
In general, the scales of the drum species are similar. Ctenii and ctenial bases cover the posterior one-fifth of the scale. They are arranged in staggered columns, and ctenii occur only in the apical row. Radii expand from the focus in the anterior field; the spaces between the radii are roughly equal. Primary and secondary radii are interspersed. The focus is in the posterior one-third of the scale, and it is surrounded by several ridges. The outer ridges meet the anterior edge of the ctenial patch at an oblique angle. The number of ridges is roughly equal in the lateral and anterior fields. Lateral scales are as wide or slightly wider than they are long. The postero-lateral corners are rounded, and the posterior margin is broadly rounded. The antero-lateral corners are square, and the anterior margin straight. Non-lateral scales are long, narrow, and have an abbreviated ctenial patch. Lateral-line scales have a tube that runs along the midline of the scale from a point anterior to the focus to the posterior margin.

The genera can be distinguished to some extent by the number of radii, the shape of the basal ctenii, and the shape of the anterior edge of the ctenial patch. In freshwater drum, lateral scales have from 4 to 7 primary radii and from 4 to 9 secondary radii. The ctenial bases are rectangles; they are either square or slightly longer than wide. The anterior edge is straight. Three of the seven marine species found in the Northeast enter fresh water frequently enough to be included here. All three have ctenial bases that are as wide or wider than they are long. In all three species, the central part of the ctenius is a raised ridge. Spot have from 4 to 6 primary radii and from 3 to 5 secondary radii. On any scale, the number of primary radii typically exceeds the number of secondary radii. The anterior edge of the ctenial patch expands toward the focus along the midline of the scale, making the patch diamond-shaped. Weakfish have from 3 to 5 primary radii and from 10 to 18 secondary radii. The anterior edge of the ctenial patch is indented along the scale midline, giving the patch a crescent shape. Silver perch have a ctenial patch that sits well behind the focus, and many ridges encircle the focus entirely. The anterior margin of the ctenial patch is straight. There are from 5 to 7 primary radii and from 3 to 7 secondary radii in the anterior field.

MUGILIDAE, MULLETS

Mullets are primarily marine fishes and are found throughout the world. Several species inhabit fresh water, and others stray into fresh and brackish water. *Mugil cephalus,* the striped mullet, and *M. curema,* the white mullet, are found in the rivers and streams of the Atlantic coast south of Cape Cod (Bigelow and Schroeder 1953). Both species ascend the Hudson River at least to river km 60. Mullets are water-column and surface fishes that can grow to over 50 cm in length. They are commonly caught for food by peoples throughout the world (Hildebrand and Schroeder 1928; Hora and Pillay 1962), and they may have been used by Native Americans for this purpose.

Mullets are fusiform fishes covered with scales. The scales of these mullets are whole ctenoid, possess radii in the anterior field, and often have a fossa or pore over or near the focus (Figure 59). Ctenii are weak and organized into a patch, but the positioning of individual ctenii within the patch is irregular, and the size of the patch varies among scales. The anterior edge of the patch does not reach anteriorly to the focus. In striped mullet, the ctenii are laid out in the typical imbricating pattern found in most ctenoid scales. In white mullet, the patch is a mosaic of non-overlapping, inlaid ctenii (Figure 60). Radii are a mix of primary and secondary; the secondary radii are usually peripheral. Central radii in both species tend to be parallel, whereas the peripheral radii are radial and converge on the focus. Scales of striped mullet have 2 or 3 more radii than do those of white mullet. The focus is roughly central and is often obscured by a pore or fossa. The fossa runs along the midline, parallel to the lateral margins, and is present on about 55% of striped mullet scales and 95% of white mullet scales. Many regenerated scales also possess the fossa. Ridges surround the focus or meet the ctenial patch perpendicularly. They are more numerous and denser in the anterior field than in the lateral or posterior fields. Ridges are bowed inward between the radii. In both species, there is a strong notch in the anterior margin at the central radius. Lateral scales of the striped mullet are quadrate with squared antero-lateral corners and rounded postero-lateral corners. The lateral scales of the white mullet are more triangular with a narrow posterior field. Non-lateral scales are similar to lateral ones with the interpelvic scale standing out as the major exception. The interpelvic scales lack ctenii and are much longer than wide, particularly in striped mullet where length exceeds width by a factor of 3 or 4.



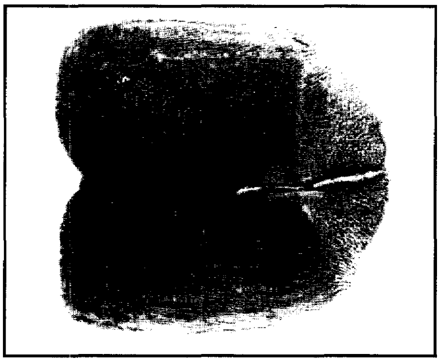


Figure 59 (top). Mullet scales often possess a pore or fossa near or over the scale focus, as shown in this lateral scale from a 120-mm striped mullet, *Mugil cephalus*, NYSM 37910. Longitudinal dimension is 3.6 mm.

Figure 60 (bottom). Lateral scale from a 132-mm white mullet, *Mugil curema*, NYSM 19855. Longitudinal dimension is 3.8 mm.

Eleotridae, Sleepers

Sleepers are a group of tropical marine fishes, although a few species range into higher latitudes and into brackish or fresh water. One species, the fat sleeper, *Dormitator maculatus*, has been reported in inland waters in New York and New Jersey (Lee et al. 1980 et seq.). When present in inland waters, fat sleepers are found in shallows and ditches and are associated with aquatic vegetation (Lee et al. 1980 et seq.). Although this species reaches lengths of 250 mm along the coast of the Gulf of Mexico (Hoese and Moore 1977) and 600 mm elsewhere (Nelson 1984), specimens taken in the Hudson River are relatively small fish and measure about 50 mm (Smith and Lake 1990).

Both the head and body of this species are completely scaled. The scale of the fat sleeper can be distinguished from those of all other fishes in the Northeast by the position of its focus and ctenii. The focus sits well back on the scale, almost on the posterior margin (Figure 61). Consequently, there appears to be no posterior field. Ctenii form a single row along the posterior margin of the scale and are evenly spaced. Ctenii are sharp and relatively short, measuring less than 10% of the

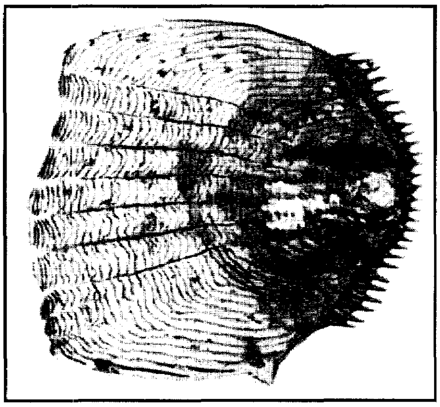


Figure 61. Lateral scale from a 32-mm fat sleeper, *Dormitator maculatus*, NYSM 12059. Longitudinal dimension is 1.5 mm.

scale length. Ridges are weakly formed. Only one or two encircle the focus; the remainder meet the posterior margin perpendicularly. Ridges are much more numerous in the anterior field than in the lateral fields. Five to fifteen radii radiate from the focus. Lateral scales are pentagonal; antero-lateral corners are square, postero-lateral corners are obtuse, and the fifth angle, bisecting the posterior margin, is acute. The lateral sides are parallel to each other, and the anterior margin is not indented at the radii. Non-lateral scales vary in shape and structure. The predorsal, breast, and interpelvic scales are ovoid and lack ctenii.

BOTHIDAE, LEFTEYE FLOUNDERS

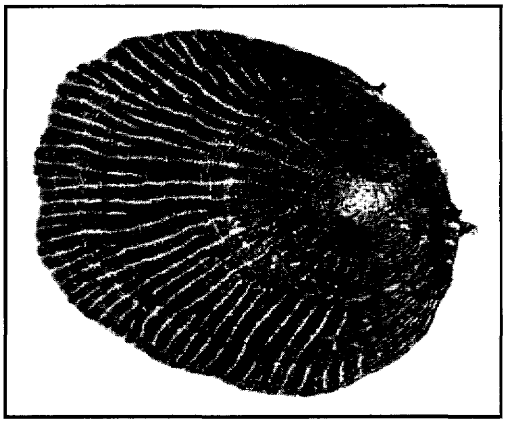


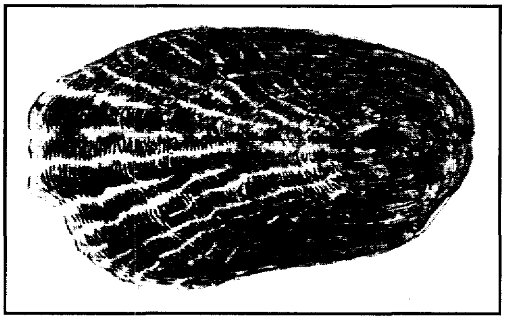
Figure 62. Lateral scale from the left (eyed) side of a 198-mm windowpane, *Scophthalmus aquosus*, NYSM 42490. Longitudinal dimension is 2.3 mm.

Of the many lefteye flounders inhabiting coastal waters in the north Atlantic Ocean, only five have been recorded from inland waters. Of these, only two species appear with regularity–the summer flounder (*Paralichthys dentatus*) and the windowpane (*Scophthalmus aquosus*) (Scott and Scott 1988; Smith and Lake 1990). Both species are found from southern New Jersey to Maine; the range of the windowpane extends to the Gulf of St. Lawrence and Newfoundland. Individuals of both species found in inland waters (i.e., the estuarine portions of larger rivers) tend to be small, although the maximum size for summer flounder is almost 1 m (Hildebrand and Schroeder 1928) and for windowpane is 45 cm (Scott and Scott 1988). Adults in the Pleuronectiformes (flatfishes in this and the next two families) are not bilaterally symmetrical. This asymmetry is noticeable in the squamation. The scales on the eyeless side are from 10% to 30% smaller than their counterpart on the eyed side, and the size of the scales also varies with the body region from which it is taken. This has also been noted by Batts (1964) for flatfishes from Puget Sound. Scales on the blind side have approximately one-half the number of total radii, although the number of primary radii is about equal in the two groups of scales. Cockerell (1911) developed a key to aid in identifying the species of flatfishes found in the western north Atlantic Ocean.

Both summer flounder and windowpane are completely covered with scales. Scales extend out onto the medial fins. Scales of lefteye flounders are easily distinguished from all other fishes treated here but share several characteristics with those of righteye flounders (see below). The scales of summer flounder and windowpane are without ctenii, and they possess several crooked radii that fan out from a focus that is in the posterior one-third of the scale (Figure 62). These scales differ from those of winter flounder (Pleuronectidae) in that they lack ctenii. Scales on the blind sides of winter flounders may also lack ctenii, and it is these scales that make separating the two groups difficult.

The numerous radii are crooked, closely spaced, and made up of a mixture of primary and secondary types. In most scales, a primary radius lies along the midline of the scale, and all other radii proceed from it at acute angles. The majority of radii are secondary in both species. Ridges encircle the focus but are noticeably discontinuous in the lateral fields. They are equally dense in the anterior and lateral fields and are sparse and wavy in the posterior field. The focus sits close to the posterior margin of the scale. All scales tend to be circular or ovoid in shape, and all corners are rounded.

PLEURONECTIDAE, RIGHTEYE FLOUNDERS



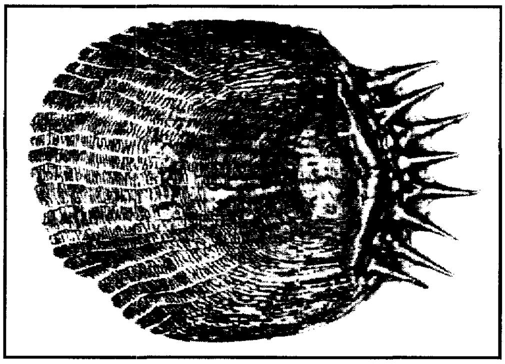


Figure 63 (top). Lateral scale from the left (blind) side of a 198-mm winter flounder, *Pleuronectes americanus*, NYSM 42491. Longitudinal dimension is 1.9 mm.

Figure 64 (bottom). Lateral scale from the right (eyed) side of a 198-mm winter flounder, *Pleuronectes americanus*, NYSM 42491. Longitudinal dimension is 1.9 mm.

Winter flounder, *Pleuronectes americanus*, is the only member of this marine family that commonly enters tidal rivers. The yellowtail flounder, *Limanda ferruginea*, and witch flounder, *Glyptocephalus cynoglossus*, have also been taken in brackish water (Scott and Scott 1988; Smith and Lake 1990). Winter flounders range north to Labrador (Grosslein and Azarovitz 1982) and observe seasonal inshore-offshore migrations, particularly in more southern populations. Individuals spawn in the shallows of upper estuaries throughout the area in winter and early spring and maintain discrete local stocks (Grosslein and Azarovitz 1982). These fish seldom reach 45 cm in length, but they can be locally abundant.

Winter flounder is completely scaled, with scales extending out onto the medial fins. Scales in winter flounder (Figure 63) share several characteristics with those of the lefteye flounders. On any given fish, however, about one-half of the scales (i.e., those on the eyed side) differ markedly, since they possess large, pungent ctenii (Figure 64). On some fish, even the scales of the blind side show blunt buds. When ctenii are present, the posterior margin of the scale is dominated by fewer than 12 large (i.e., from 12% to 15% of scale length), sharp ones that can arise from several rows so that the bases form an irregular line. On some scales, a thickening formed by several ridges can be detected anterior to the ctenii bases (Batts 1964). Radii are numerous, crooked, and fan out from the focus. They are present only in the anterior field. Ridges are more numerous in the anterior field than in the lateral fields. On many scales, they are weak, poorly formed, and discontinuous. On scales that lack ctenii, ridges do encircle the focus, but they are very sparse in the posterior field. The focus sits in the posterior one-third of the scale. The shape of the scales on any fish varies. Scales in the caudal peduncle region are ovoid with all corners rounded, whereas lateral scales tend to be quadrate with squared corners. The anterior margin of the scales are arched and scalloped with small indentations at the radii.

SOLEIDAE, SOLES

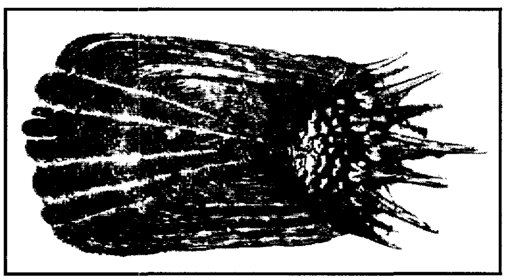


Figure 65. Lateral scale from the right (eyed) side of a 120-mm hogchoker, *Trinectes maculatus*, NYSM 42451. Longitudinal dimension is 2.7 mm.

The hogchoker, *Trinectes maculatus*, is the only member of this family found in inland waters in the northeastern part of the continent. It is rare north of Cape Cod (Bigelow and Schroeder 1953) but enters, and can be abundant in, the more southern estuaries. In the Hudson River, hogchokers have been taken as far upriver as Albany (Smith and Lake 1990). These are small fish, with a maximum reported size of 200 mm.

Hogchoker is completely covered with scales. Scales extend out onto the tip of both medial and paired fin rays and spines. They are very narrow with a few long ctenii (Figure 65). The ctenial patch is distinctive. The anterior margin of the patch fans out from the focus. The ctenii of the apical row are long, about one-fourth the length of the scale. Each ctenius has a wide base that narrows abruptly to form the spine. Interior rows are made up of wide ctenial bases. There are rarely more than six columns of ctenii and ctenial bases on lateral scales, and other scales have even fewer. There are from 4 to 6 primary radii present in the anterior field. Each scale also has 1 to 3 secondary radii, which are usually peripheral. Ridges emerge perpendicularly from the ctenial patch and proceed around the focus. The count is about equal in the anterior and lateral fields. Ridges are arcuate between radii. The focus is central or subcentral. Lateral scales are about twice as long as wide. The antero-lateral corners are square, and postero-lateral corners are rounded. The anterior margin of the scale is crenate.

Appendix

Appendix A. Material Examined, Identifying Catalogue Number, and Standard Length.

Family and species	Specimen 1 Museum No.	Specimen 1 SL (mm)	Specimen 2 Museum No.	Specimen 2 SL (mm)
Amiidae				
Amia calva	546	239	12248	340
Hiodontidae				
Hiodon tergisus	24802	195	40758	205
Elopidae				
Elops saurus	49	295		
Anguillidae				
Anguilla rostrata	6836	555	22490	525
Clupeidae				
Alosa aestivalis	19673	247	19864	211
Alosa mediocris	310	192	11634	207
Alosa pseudoharengus	6178	214	22030	318
Alosa sapidissima	12392	240	19875	242
Brevoortia tyrannus	6952	202	11627	267
Clupea harengus harengus	621	122	622	64
Dorosoma cepedianum	18228	190	39820	155
Engraulidae				
Anchoa mitchilli	647	47	40853	70
Cyprinidae				
Campostoma anomalum	17370	98	39514	86
Carassius auratus	18375	108	19922	87
Clinostomus elongatus	10108	75	15715	70
Couesius plumbeus	4550	97	25196	80
Ctenopharyngodon idella	7026	100	35119	475
Cyprinella analostana	12791	57	25023	58
Cyprinella spiloptera	25583	50	25838	70
Cyprinus carpio	4588	131	41811	92
Erimystax dissimilis	40434	72	40488	80
Exoglossum laurae	5162	101	40256	91
Exoglossum maxillingua	4646	96	41646	84
Hybognathus hankinsoni	39626	57	40335	54
Hybognathus regius	24910	63	41646	88
Luxilus chrysocephalus	14115	91	16596	92
Luxilus cornutus	15514	109	40040	78
Lythrurus umbratilis	14563	43	25963	49
Macrhybopsis storeriana	5406	106	5411	142

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Family and species	Specimen 1 Museum No.	Specimen 1 SL (mm)	Specimen 2 Museum No.	Specimen 2 SL (mm)
Margariscus margarita	26348	68	32104	60
Nocomis bigutatus	30020	102	30028	92
Nocomis micropogon	40314	92	40379	98
Notemigonus crysoleucas	6483	140	6668	155
Notropis amblops	5380	67	5381	63
Notropis amoenus	28426	57	41472	75
Notropis anogenus	13081	38	34467	43
Notropis atherinoides	9487	80	11720	67
Notropis bifrenatus	41913	38	42024	40
Notropis bucattus	40343	63	40417	65
Notropis chalybaeus	5553	35	6574	35
Notropis dorsalis	15460	46	39640	54
Notropis heterodon	25877	48	42044	53
Notropis heterolepis	5718	47	16564	70
Notropis hudsonius	34570	99	41635	69
Notropis procne	15648	44	28542	49
Notropis rubellus	39515	56	42325	49
Notropis stramineus	28664	53	40476	53
Notropis volucellus	41313	78	41330	69
Phoxinus eos	11433	47	24912	53
Pimephales notatus	6559	59	41651	50
Pimephales promelas	29473	57	29559	51
Rhinichthys atratulus	14405	62	41639	57
Rhinichthys cataractae	26006	110	41638	64
Rhodeus sericeus	11744	54	11745	45
Scardinius erythrophthalmus	41752	83	42040	175
Semotilus atromaculatus	14209	135	31686	120
Semotilus corporalis	6657	103	42041	164
Tinca tinca	AMNH633	166	AMNH37593	120
Catostomidae				
Carpiodes carpio	7502	185		
Carpiodes cyprinus	13142	172	13990	248
Catostomus catostomus	13805	118	32911	195
Catostomus commersoni	38344	173	38347	200
Cycleptus elongatus	7501	460		
Erimyzon oblongus	18282	115	18286	168
Erimyzon sucetta	13736	71	32696	37
Hypentelium nigricans	40035	170	41482	94
Ictiobus cyprinellus	7500	340	ROM28266	540
Moxostoma anisurum	40497	99	40501	91
Moxostoma carinatum	ROM13412	455	ROM28250	157
Moxostoma duquesnei	40493	112	40498	102
Moxostoma erythrurum	40503	84	41422	175
Mosoxtoma hubbsi	ROM23118	420	ROM51793	491
Moxostoma macrolepidotum	40466	118	40500	121
Moxostoma valenciennesi	38368	180	38370	155

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Family and species	Specimen 1 Museum No.	Specimen 1 SL (mm)	Specimen 2 Museum No.	Specimen 2 SL (mm)
Esocidae				
Esox americanus	1730	228	1740	170
Esox lucius	13425	246	13428	272
Esox masquinongy	13328	248	27430	245
Esox niger	14352	278	41669	159
Umbridae				
Umbra limi	1383	45	1385	47
Umbra pygmaea	1405	87	1435	57
Osmeridae				
Osmerus mordax	1294	165	22952	98
Salmonidae				
Coregonus artedi	725	211	733	248
Coregonus clupeaformis	717	250	735	240
Oncorhynchus mykiss	739	290	12928	132
Prosopium cylindraceum	17635	181	24801	260
Salmo salar	757	130	759	244
Salmo trutta	12696	188	14951	312
Salvelinus alpinus	ROM21036	358	ROM44576	368
Salvelinus fontinalis	1199	197	12548	116
Salvelinus namaycush	1282	242	1283	240
Percopsidae				
Percopsis omiscomaycus	6537	56	6612	61
Aphredoderidae				
Aphredoderus sayanus	2290	61	17659	78
Gadidae				
Lota lota	15089	340	15208	445
Microgadus tomcod	2537	163	5781	113
Urophycis regia	7336	242	30056	146
Urophycis tenuis	2550	165	2551	203
Belonidae				
Strongylura marina	1610	334	11230	352
Cyprinodontidae				
Cyprinodon variegatus	39445	43	41455	37
Fundulus diaphanus	33913	74	33921	80
Fundulus heteroclitus	34171	90	34172	70
Fundulus luciae	14852	33	14956	31
Fundulus majalis	34506	96	39407	98
Lucania parva	1656	35	41451	31
Poeciliidae				
Gambusia affinis	1689	36	17654	37

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Family and species	Specimen 1 Museum No.	Specimen 1 SL (mm)	Specimen 2 Museum No.	Specimen 2 SL (mm)
Atherinidae				
Labidesthes sicculus	6503	61	25667	74
Membras martinica	7327	86	14273	79
Menidia beryllina	34544	54	41493	60
Menidia menidia	2811	103	2826	113
Percichthyidae				
Morone americana	39962	142	42072	184
Morone chrysops	15079	170	25385	120
Morone saxatilis	22972	213	23097	194
Serranidae				
Centropristis striata	3527	148	14293	127
Mycteroperca microlepis	14099	79		
Centrarchidae				
Acantharchus pomotis	3524	98	3535	103
Ambloplites rupestris	3899	113	34577	149
Enneacanthus gloriosus	2270	57	41661	50
Enneacanthus obesus	3984	43	14835	65
Lepomis auritus	10759	120	41637	138
Lepomis cyanellus	11856	85	30011	94
Lepomis gibbosus	34869	108	35664	108
Lepomis gulosus	11242	103	14557	128
Lepomis macrochirus	9219	121	17722	130
Lepomis megalotis	13111	88	13112	100
Lepomis microlophus	26625	76	ROM23822	102
Micropterus dolomieu	36009	168	42075	100
Micropterus salmoides	38946	166	42074	90
Pomoxis annularis	9162	94	36435	122
Pomoxis nigromaculatus	39946	155	41761	55
Percidae				
Etheostoma blennioides	9464	73	9473	72
Etheostoma caeruleum	40201	42	40223	47
Etheostoma camurum	40207	39	ROM17363	42
Etheostoma chlorobranchium	ROM49455	58	AMNH68718	71
Etheostoma exile	13698	42	13717	43
Etheostoma flabellare	12890	59	17328	58
Etheostoma fusiforme	14837	43	39440	41
Etheostoma maculatum	16277	55	16298	57
Etheostoma nigrum	39624	49	40204	53
Etheostoma olmstedi	41224	80	42110	69
Etheostoma tippecanoe	AMNH66543	26	AMNH68074	26
Etheostoma variatum	16599	80	17464	63
Etheostoma zonale	40224	47	40525	62

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Family and species	Specimen 1 Museum No.	Specimen 1 SL (mm)	Specimen 2 Museum No.	Specimen 2 SL (mm)
Perca flavescens	17871	229	41899	104
Percina caprodes	41358	98	41789	106
Percina copelandi	10272	43	39653	48
Percina evides	12705	46	13082	41
Percina macrocephala	13085	68	40487	74
Percina maculata	40250	64	40331	70
Percina peltata	40527	69	40551	64
Percina shumardi	ROM45741	70	ROM52425	45
Stizostedion canadense	37539	243	37541	255
Stizostedion vitreum	37621	270	37646	244
Pomatomidae				
Pomatomus saltatrix	8502	194	11993	204
Carangidae				
Caranx hippos	28837	72	39688	170
Sparidae				
Archosargus probatocephalus	AMNH20729	90	AMNH86024	108
Lagodon rhomboides	12043	114	14279	90
Stenotomus chrysops	5710	74	12037	182
Sciaenidae				
Aplodinotus grunniens	37754	165	37764	178
Bairdiella chrysoura	12017	153	29526	170
Cynoscion regalis	11231	175	12032	205
Leiostomus xanthurus	6790	116	6791	99
Sciaenops ocellata	AMNH4336	134	AMNH83970	122
Mugilidae				
Mugil cephalus	14299	110	37910	130
Mugil curema	7318	95	37877	76
Eleotridae				
Dormitator maculatus	12059	31	14252	45
Bothidae				
Paralichthys dentatus	9284	184	11256	204
Scophthalmus aquosus	23171	150	38162	119
Pleuronectidae				
Pleuronectes americanus	11472	194	38160	195
Soleidae				
Trinectes maculatus	6356	110	7164	103

Unless noted, specimens are from the New York State Museum (NYSM). Specimens designated ROM are from the Royal Ontario Museum; those designated AMNH are from the American Museum of Natural History.

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