Publication CNRE-73P

Virginia Master Naturalist
Basic Training Course

# Biology, Ecology, and Management of Virginia's Freshwater Fishes

Virginia Cooperative Extension
Virginia Tech • Virginia State University

Virginia Master Naturalists

Virginia Master Naturalist
Basic Training Course

# Biology, Ecology, and Management of Virginia's Freshwater Fishes

Editors for this update:
Michael Pinder, Virginia Department of Wildlife Resources
Stephen Reeser, Virginia Department of Wildlife Resources
George Devlin, Virginia Department of Environmental Quality
Dawn Kirk, U.S. Forest Service, George Washington and Jefferson National Forests
Jonathan Harris, Virginia Department of Wildlife Resources
Paul E. Bugas, Jr., Virginia Department of Wildlife Resources, Retired

Contributing Authors
Adrienne Averett, Oregon Department of Fish and Wildlife
Larry Bandolin, retired, U.S. Fish and Wildlife Service
Paul E. Bugas, Jr., retired, Virginia Department of Wildlife Resources
John R. Copeland, retired, Virginia Department of Wildlife Resources
George Devlin, Virginia Department of Environmental Quality
Mike Duncan, Montana Fish, Wildlife, & Parks
Charles Gowan, Department of Biology, Randolph-Macon College
Scott Herrmann, Virginia Department of Wildlife Resources
Dawn Kirk, U.S. Forest Service, George Washington and Jefferson National Forests
Brian R. Murphy, Professor Emeritus, Department of Fisheries and Wildlife Sciences, Virginia Tech

Cover photo courtesy of Marie Majarov

A Project of the Outreach Committee of the Virginia Chapter of the American Fisheries Society.

VIRGINIA CHAPTER of the AMERICAN FISHERIES SOCIETY
Inland Fisheries and Aquatic Resources of Virginia
Organized in 1990

**The Virginia Master Naturalist Program** is jointly sponsored by:

Virginia Cooperative Extension — Virginia Tech • Virginia State University
Virginia Museum of Natural History
DCR — Virginia Department of Conservation & Recreation
DEQ — Virginia Department of Environmental Quality
Virginia DWR
VIMS — William & Mary — Virginia Institute of Marine Science, Center for Coastal Resources Management
Virginia Department of Forestry

## Introduction

This publication provides an overview of ichthyology, with a focus on Virginia's freshwater fishes. Ichthyology is simply the science of studying fishes. Historically, ichthyologists were naturalists who described fishes they collected. Much of our knowledge of Virginia fishes resulted from an 1867 sampling trip by Edward Drinker Cope. Cope's contributions to North American vertebrate study earned him the enviable title of "Master Naturalist." His study of Virginia fishes was followed by those of Marshall McDonald and David Starr Jordan in the late 1800s. By 1899, 180 of Virginia's fish species were described. Since 1900, a number of ichthyologists, including Robert E. Jenkins of Roanoke College, have brought us to our current knowledge of Virginia fishes (for a review of Virginia's ichthyologic history, see Jenkins and Burkhead 1993). Today, ichthyology is more than describing fish taxonomy and now includes the study of fish populations, their habitat requirements, and the people who enjoy fisheries resources. Modern ichthyologists, fisheries biologists, and aquatic ecologists are employed by government agencies, private industries, nonprofit organizations, and academia.

## Diversity and Distribution of Virginia Fishes and Their Role in Virginia Ecosystems

Understanding the diversity and distribution of fishes begins with an understanding of **zoogeography**. Unlike terrestrial animals, fish do not move across land without the assistance of flooding or major geologic events that result in **stream capture**. To understand fish distribution, you must first know river drainages and physiographic areas, since these features influence fish distribution.

### Virginia's River Drainages

Virginia contains 10 major river drainages; the Potomac, Rappahannock, York, James, Chowan, Roanoke, PeeDee, New, Big Sandy, and Tennessee. With the exception of the Rappahannock and York rivers, most of Virginia's river drainages are shared with adjacent states. Virginia fishes are not restricted by artificial boundaries, like state lines, so many of our species are present in adjacent states. In general, Virginia's fish diversity increases when moving from the northeastern to the southwestern corner of the state. Many fish species are common across drainages. Some of these river drainages harbor fish species found nowhere else but in those areas. These species are known as **endemics**. The southwestern Virginia river drainages (the Tennessee, the New, and the Roanoke) have the majority of these endemics.

In this publication, we describe:

- The diversity and distribution of fishes in Virginia and their role in Virginia ecosystems.
- Key characteristics used to identify fish and basic fish taxonomy.
- The biology and natural history of fishes, including adaptations of fish and how these relate to environmental factors.
- Threats and issues relating to fish in Virginia.
- Rare or special species that indicate habitat quality.
- Appropriate methods for studying fish.
- Basic principles of fisheries management.

### Virginia's Physiographic Areas

Virginia has five major physiographic areas, from the Appalachian Plateau, Valley and Ridge, and Blue Ridge in the western third of the state, to the Piedmont and Coastal Plain in the eastern two-thirds of the state. Each of these physiographic areas has underlying geology influencing stream characteristics and resulting habitats. Any discussion of Virginia's fishes would be incomplete without a consideration of habitats, because fishes are often uniquely adapted to their habitat. Virginia's fish fauna is primarily associated with streams and rivers, but a number of species that inhabit our coastal rivers and bays are able to move between salt and freshwater. The remarkable array of freshwater fish in the commonwealth are found from the swampy lowlands of eastern Virginia to the windswept heights of Mount Rogers. Let's examine some of these unique environments and how fish have adapted to them.

### Mountain Streams

The western third of Virginia supports over 2,000 miles of cold-water mountain streams along forested, **high-gradient** slopes where ground water comes to the surface as springs. Mountain streams typically have bedrock or boulder beds. With adequate shading and a constant supply of 55ºF water, these streams usually stay below 70°F during the heat of the summer. Mountain streams typically contain few fish species. Some mountain streams drain areas with little or no limestone geology, resulting in low **pH** values from acid precipitation.

Virginia's mountain streams typically contain brook trout (*Salvelinus fontinalis*) and blacknose dace (*Rhinichthys atratulus*), a member of the minnow (Leuciscidae) family. Brook trout are excellent swimmers and are able to recolonize mountain streams after devastating floods and severe droughts. They are the top predators in these streams. Brook trout only exist in highly oxygenated, cold, flowing water. They need loose, clean gravel to build nests and rely on the **macroinvertebrate** life, both aquatic and terrestrial, as a food source. A brook trout's body is streamlined for swift movement in pursuit of food and for stabilization in swift water. Brook trout, Virginia's only native trout, were a food staple of Native Americans and early pioneers. Blacknose dace often swim in schools among the quiet eddies of mountain streams. They are an important food item for brook trout and are a good indicator species of pollution from acid precipitation.

As these streams leave their high-gradient headwaters, water temperatures rise, food items increase, and habitat changes invite a greater diversity of fish species. Sculpins (family Cottidae), darters (family Percidae), shiners (family Leuciscidae), and suckers (family Catostomidae) are often integrated with trout populations below 1,000 feet elevation. Sculpins are small fish with a depressed body shape, huge pectoral fins, and a reduced air bladder. These features allow them to hug the stream bottom, where they feed on small insects and fish.

### Warm-water Streams

The commonwealth's warm-water streams include 25,000 miles of fishable resources. They dominate the Piedmont, Coastal Plain, and much of the Valley and Ridge provinces. Warm-water streams typically reach summer water temperatures over 70ºF and are home to most of the freshwater finfish and shellfish in the state. Streams in the Valley and Ridge province are typically medium gradient, with bedrock, boulder, and cobble bottoms. Piedmont streams are medium- to low-gradient systems with boulder, cobble, gravel, and sand bottom composition. Many Piedmont streams support diverse fish communities due to near-normal pH values, varied habitats, and warm water temperatures. Coastal Plain streams are low-gradient sand and silt systems with an abundance of woody debris and aquatic plants on the fringes. Many Coastal Plain streams are stained brown and have low pH values, due to tannic acids, thus requiring fish species adapted to these dark stained waters.

The dominant fish, by both abundance and number of species, in our warm-water streams are in the family Leuciscidae. Representatives from this family are known by many names, such as minnows, dace, chubs, and shiners. Although most are small, the native fallfish (*Semotilus corporalis*) can reach lengths of 20 inches. What members of this family lack in stature, they make up in numbers and species. Leuciscids comprise the largest fish family in North America (261 native species) and in Virginia (70 species). Because they occur in such large numbers, members of this family serve as an important food base for top-level predators. Other members, like the river chub (*Nocomis micropogon*), are wonderful architects, building large, complex nest structures used by multiple fish species for spawning.

Numerous suckers are found in warm-water streams. They serve as the fish version of vacuum cleaners, gaining nutrition from eating aquatic insects, crustaceans, and mollusks, as they "vacuum" **detritus** from pools and eddies. Some people still "dip" for suckers during spring spawning runs for canning purposes or for their **roe**.

Colorful darters, members of the perch family, are endemic to North America. In Virginia, the majority of the darters occur in the Tennessee River drainage in the southwestern portion of the state. Darters live on the stream bottom in fast flowing habitats, such as runs and riffles. Like sculpins, darters are bottom dwellers that serve as an ecological link between benthic macroinvertebrates and predators. Because darters are only found in the cleanest rivers and streams, they are excellent indicators of good water quality.

### Tidal Rivers

The Potomac, Rappahannock, York, James, Meherrin (Chowan River drainage), Nottoway (Chowan River drainage), and Roanoke rivers all have a fall line, the break between the Coastal Plain and Piedmont provinces. Downstream from the rocky fall line, these rivers are influenced by tides and salt. **Anadromous** fish, represented by striped bass (*Morone saxatilus*), herring and shad (family Clupeidae), white perch (*Morone americana*) and yellow perch (*Perca flavescens*), are known for their annual spawning runs up these tidal rivers from the Chesapeake Bay into fresh water. These species sustained Native Americans and early colonists. Commercial harvest of anadromous fish continues today in our estuaries and is a significant economic asset. The backwaters of our tidal rivers serve as nursery areas for young fish. Resident fish species, like largemouth bass (*Micropterus nigricans*) and introduced blue catfish (*Ictalurus furcatus*), can tolerate the brackish waters of the Chesapeake Bay and are a draw for professional fishing tournaments and catfish anglers in search of world records. The rare Atlantic sturgeon (*Acipenser oxyrhynchus*), known for its huge size as an adult, was once highly prized for its roe.

### Caves and Swamps

Although western Virginia has dozens of caves within its **karst** topography, cavefish (family Amblyopsidae) do not exist in Virginia's underground streams. Cavefish are present in the lower Tennessee River drainage in Tennessee, Alabama, and Kentucky, but are absent in Virginia. A close cousin, the tiny swampfish (*Chologaster cornutus*), has reduced eyes and a specialized sensory apparatus on its snout to live in the darkly stained, acid waters of southeastern Virginia.

### Lakes, Ponds, and Reservoirs

Virginia has only two natural lakes; Mountain Lake, a lake in Giles County created by a landslide, and Lake Drummond, a basin in the Dismal Swamp in southeastern Virginia. Virginia's streams and rivers have been dammed for generating power, controlling flooding, and providing recreation. Reservoirs are especially devastating to species that require flowing water for migration. Because reservoirs are artificial systems, they are often stocked with a variety of nonindigenous sport fish. Largemouth bass, bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), walleye (*Sander vitreum*), brown trout (*Salmo trutta*), rainbow trout (*Onchorhynchus mykiss*), and striped bass are present in Virginia impoundments, depending on whether their habitat requirements are met. "Baitfish" are often introduced to support these hungry predators. Stocked baitfish include blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), and threadfin shad (*Dorosoma pentenense*). The gizzard shad (*Dorosoma cepedianum*) is an unwanted, but often inadvertently stocked **pelagic** baitfish. Gizzard shad grow rapidly to large sizes (> 12 inches), making them unavailable for young **piscivores**. All these baitfish are outfitted with long, slender gill rakers. They feed by swimming with their mouths open, straining plankton from the open water. Because they feed on the base of the reservoir food chain, baitfish are an important ecological link in reservoirs.

### Economic Importance of Virginia Fishes

Some members of the catfish (Ictaluridae), sunfish (Centrarchidae) (which includes bass and "bream"), eel (Anguillidae), and pike families (Esocidae) are sought by recreational and commercial fishermen because they represent the top of the aquatic food pyramid. Their economic importance to Virginia is reflected in the number of freshwater fishing licenses sold annually (more than 450,000 in fiscal year 2024, visit https://dwr.virginia.gov/data/licenses/) and the economic impact of recreational freshwater fishing in the state (an estimated $981.2 million in total economic output, creating 6,530 jobs,) (American Sportfishing Association, 2023).

### Virginia's Fish Diversity

North America has the most diverse temperate freshwater fish diversity in the world, with over 800 native fish species inhabiting waters of the United States and Canada. The southeastern United States is the geographic center of North American fish diversity, with over 600 native fish species. Southeastern states with the richest described freshwater fish species diversity include Tennessee, Kentucky, Alabama, Georgia, and Virginia.

Describing Virginia's diverse fish species is best left up to ichthyologists and other fisheries science professionals. A good first step for Master Naturalists is to learn Virginia's major fish families. Then, become familiar with some of the representatives of those families in your area of the state. Virginia's fish fauna is comprised of fish from 26 families made up of 225 species. The most numerous family is the minnows, which contains 67 Virginia fish species. Virginia's next most diverse family is the perches, which contains 48 Virginia fish species, from the small stream-dwelling darters to walleye, a prized sport fish. Other notable diverse Virginia fish families are: the suckers with 19 native species; the catfishes with 15 species, from the large flathead catfish to the small stream-dwelling madtoms and stonecats; and the sunfishes with 20 species, many of which are prized game fishes, like the largemouth bass and the smallmouth bass (*Micropterus dolomieui*), the black crappie, and the bluegill.

## Key Characteristics Used to Identify Fish

The key characteristics used to identify fish rely heavily upon the presence or absence of exterior features (Figures 12-1 and 12-2). Body shape and specific traits also assist in distinguishing the identity of many fish species. A summary of general traits is included in this section. The main areas of description begin with the head, body, and tail. The head region is located from the tips of the jaws to the outside edge of the operculum. The body region continues from the **operculum** to the base of the **caudal fin**. The side of a fish is defined as the **lateral** region. The **dorsal** region refers to the back or top of the fish. The **ventral** region is located along the bottom or underside of the fish. The anterior region describes the front of the fish while the posterior refers to areas located near the rear.

The main types of body shape are **fusiform**, tapering, rectangular, oval (disk-shaped), and eel-like (Figure 12-4). A fish with a fusiform body shape is streamlined, with tapering edges at both ends, while a fish with a tapering body shape has narrowing depth near the tail. A fish with a rectangular body shape has a quick narrowing adjacent to the **caudal peduncle**. Fish with an oval or disk-shaped body are more of a rounded shape. An eel-like fish has a long, serpentine body shape.

Body proportion is the measurement of a fish's length with regards to its depth. An elongated body shape has a small depth in comparison to its body length. A prime example of an elongated body design would be the chain pickerel (*Esox niger*). A deep body shape has a depth measurement that is large when compared to the body length. Adult specimens of bluegill have a deep body shape.

Description of mouth position helps with some identification characteristics. Fish with a **terminal mouth** have jaws that are relatively even in length and meet at a point at the tip of the head (Figure 12-5). A largemouth bass is a prime example of a

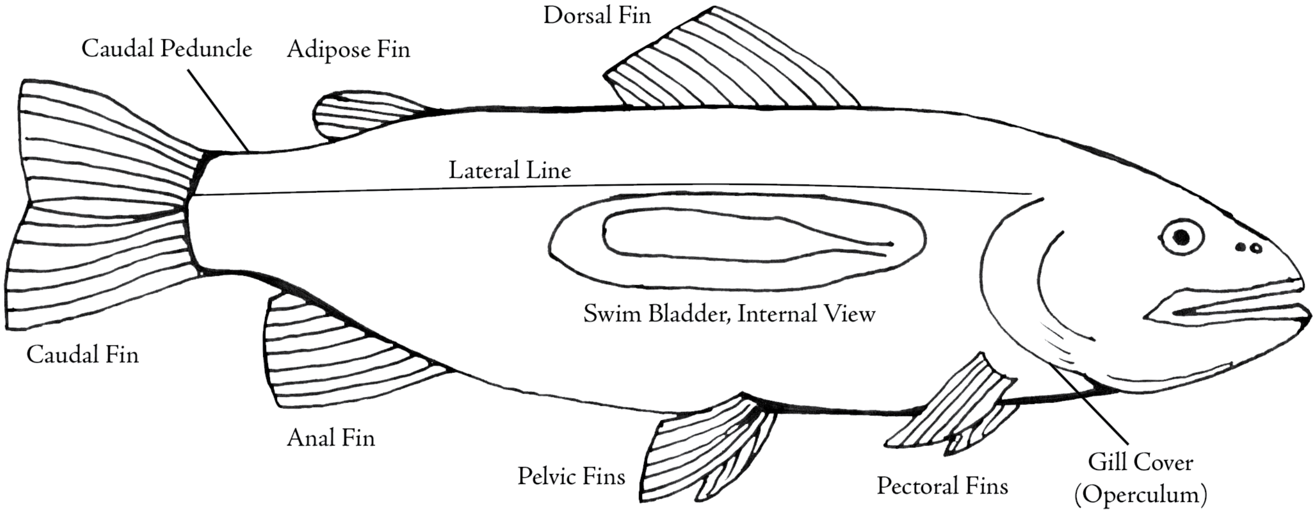



*Figure 12-1. Internal and External Features of Soft-Rayed Fish (based on illustration by Scott Herrmann)*

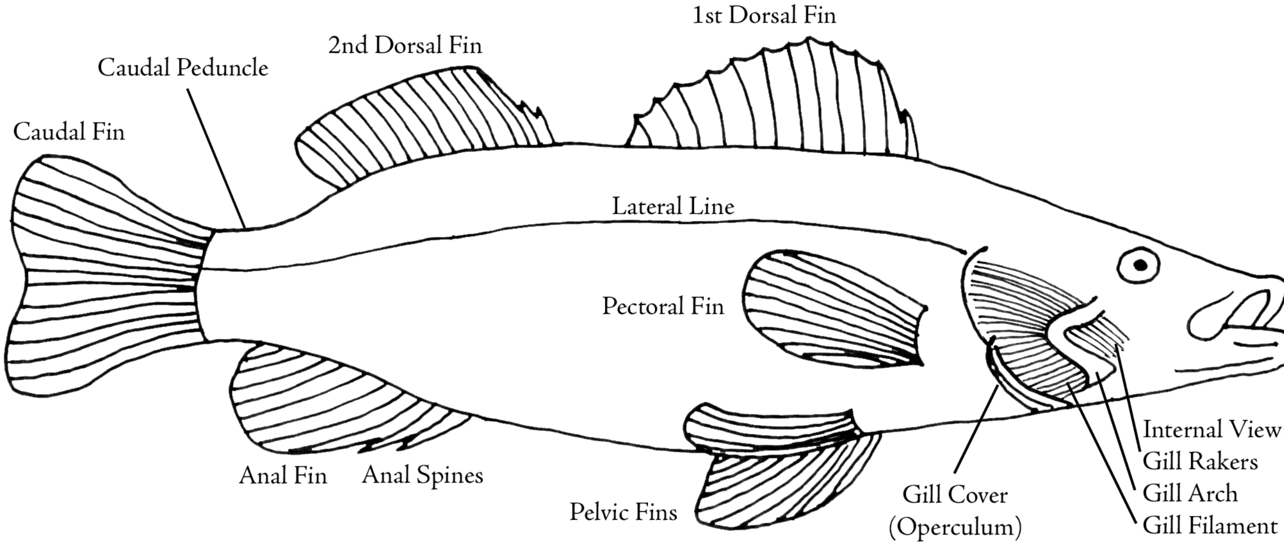



*Figure 12-2. Internal and External Features of Spiny-Rayed Fish (based on illustration by Scott Herrmann)*

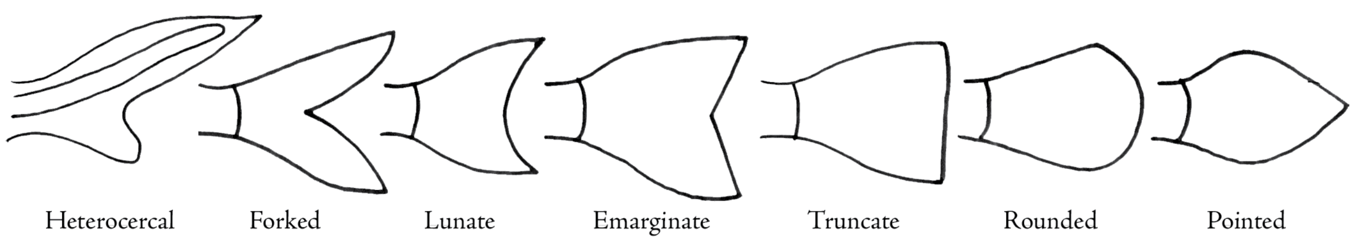



*Figure 12-3. Caudal (Tail) Fin Shapes (based on illustration by Scott Herrmann)*

fish with a terminal mouth. Fish with a **superior mouth** have a lower jaw projecting beyond the upper jaw. Certain *Clupeids*, like hickory shad (*Alosa mediocris*) have a slight superior alignment of their jaws. An **inferior mouth** is one with an opening under the head, with the upper jaw protruding well out in front of the lower jaw. Members of the sucker family have an inferior mouth, making them natural bottom feeders. Fish with **subterminal mouths** have an upper jaw reaching slightly beyond the lower jaw. Members of the catfish family have subterminal mouths, allowing them to feed heavily upon the bottom for prey items.

Fin description and the location of fins are additional key characteristics that aid in fish identification (Figure 12-3). Fish have three unpaired fins that can be used for identification purposes. The caudal fin is used to identify a variety of fish families. A prime example is the **heterocercal** caudal fin of sturgeon (family Acipenseridae) and paddlefish (family Polyodontidae). Other types of caudal fins are displayed below (Figure 12-3). The **dorsal fin** is a median fin that runs down the center of the dorsal region. The dorsal fin can be supported by a specific series of **spines** or **fin rays**. Dorsal fins come in variety of shapes and sizes, from the long, undulating dorsal fin of the bowfin (*Amia calva*) to the sharp-spined dorsal fin of a white perch. The **anal fin** is a median fin that runs along the midline of the ventral region, near the anus. The anal fin can be supported by numerous spines or soft fin rays. Some fish families, like the eels (family Anguillidae), can be easily identified by the presence of a dorsal fin that is joined with the caudal fin and the anal fin. **Pectoral** and **pelvic fins** are paired fins that are located on both sides of the body of most freshwater fish. Pectoral fins are positioned behind the operculum (gill plate). Pelvic fins are in the ventral region with various positions from the throat to the abdomen. The **adipose fin** is a fleshy fin located between the dorsal and caudal fins of catfish and trout and salmon (family Salmonidae) (Figure 12-1).

The presence, or in some cases, the absence of scales, helps to identify some fish species and fish families. A prime example of a fish lacking scales is the catfish. Scale types can also be used in identification. **Cycloid scales** have smooth regions exposed, which makes for a body that is soft to the touch. Trout and salmon have cycloid scales. **Ctenoid scales** have spiny exposed edges that give fish a rough feel. Ctenoid scales can be easily felt by anyone who has ever handled a yellow perch (*Perca flavescens*). **Ganoid scales** are similar to a thick coat of scaled armor. These interlocking scales provide a protective layer for the gars (family Lepisosteidae).

Fish have other specific features that allow for easy identification. The longnose gar (*Lepisosteus osseus*) has long, beak-like jaws full of teeth. Catfish have chin barbels. Sticklebacks (family Gasterosteidae) have long dorsal spines. Fish families are identified primarily by the features described in the Fish Taxonomy section. The identification to a certain species within a large fish family takes a lot more patience. Specific characteristics of spine and fin ray counts, scale patterns, scale numbers, jaw structure, body coloration, and pigmentation all can be used for further identification.

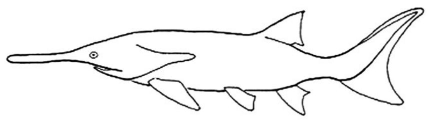
## Fish Taxonomy

Taxonomy is the scientific classification of organisms into an ordered system of groups. Virginia has 225 fish species from 26 taxonomic families. A picture-based taxonomic key can be used to identify fish to family.

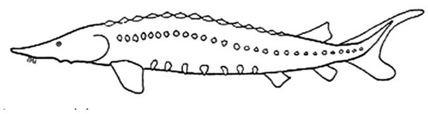
The ancient lineage of the family Peteromyzontidae (Lampreys) is characterized by the absence of paired fins and jaws and the presence of seven external gill openings. All other fish families have a least one set of paired fins and one external gill opening per body side. The Petromyzontidae family has 6 species in Virginia, with parasitic forms like the sea lamprey (*Petromyzon marinus*), as well as nonparasitic forms like the American brook lamprey (*Lampetra appendix*).

Petromyzontidae

Caudal fin type is used when defining other fish families. A heterocercal caudal fin is seen in the paddlefishes (family Polyodontidae) and sturgeons (family Acipenseridae). The paddlefish, *Polyodon spathula,* is known from the Clinch and Powell River drainages of Virginia. It is identified by its large, paddle-shaped snout and long opercular flap. The Acipenseridae family is distinguished by rows of large bony plates or **scutes** along the length of the body. Additional defining characteristics include a ventral mouth and barbels along the underside of the snout. The Atlantic sturgeon (*Acipenser oxyrhynchus*) is found in multiple Virginia river systems while the very rare shortnose sturgeon (*Acipenser brevirostrum*) has only been found in Potomac River.



Polyodontidae

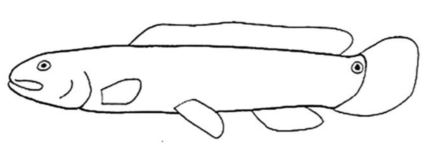


Acipenseridae

Two fish families with an abbreviated heterocercal caudal fin are the gars (family Lepisosteidae) and the bowfin (family Amiidae). Defining characteristics of the Lepisosteidae family are their long, beaklike jaws lined with sharp teeth. Their dorsal fin is located toward their posterior end and their body is covered with thick ganoid scales. Longnose gar (*Lepisosteus osseus*), found in large rivers and some reservoirs, is the only gar species in Virginia.

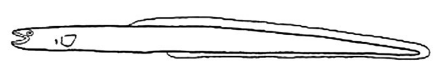
Lepisosteidae

The Amiidae family is represented by the bowfin (*Amia calva*). Bowfins have a long undulating dorsal fin and jaws of normal length. The bowfin body is covered with cycloid scales and has a bony (**gular**) plate under the lower jaw. Bowfins are native to the Coastal Plain and the lower Piedmont. They have been introduced to the Roanoke and New River drainages.

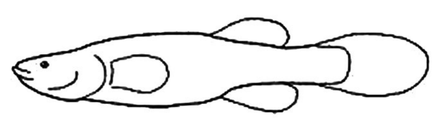


Amiidae

The next taxonomic divergence involves the presence or absence of pelvic fins. The absence of pelvic fins is a characteristic of the eels (family Anguillidae) and cavefishes (family Amblyopsidae). The Anguillidae family is represented by the American eel (*Anguilla rostrata*). This **catadromous** species has a serpentine body shape with continuous dorsal, caudal, and anal fins. The family Amblyopsidae has one species in Virginia, the swampfish (*Chologaster cornuta*). The swampfish differs from the American eel because its dorsal, caudal, and anal fins are separated. Swampfish are a small (1 to 2 inches long), **nocturnal** species found in backwaters of the Nottoway and Blackwater Rivers.



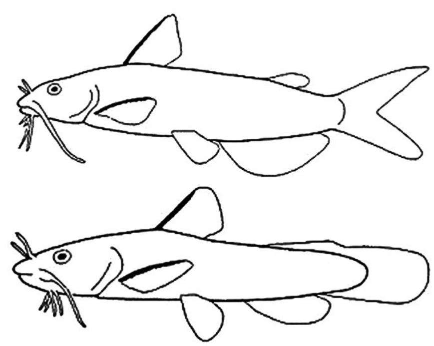
Anguillidae



Amblyopsidae

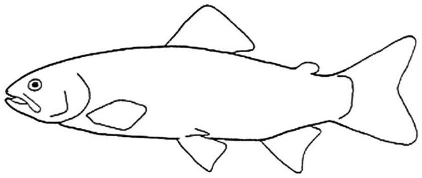
The next taxonomic split is the presence or absence of an adipose fin. Three families have an adipose fin: bullhead catfishes (Ictaluridae), salmon and trout (Salmonidae), and trout perches (Percopsidae). Multiple families are distinguished by the lack of an adipose fin.

The Ictaluridae family consists of species with **barbels** present above and below the mouth and no scales on the body. In Virginia, there are 15 species of catfishes in four genera. In the genus *Ictalurus*, there are two species of forktail catfishes, the blue catfish (*Ictalurus furcatus*) and the channel catfish (*Ictalurus punctatus*). The genus *Pylodictis* has one species, the flathead catfish (*Pylodictis olivaris*). *Ameiurus* (bullheads), a group of medium-size catfishes with large heads, has six species. The genus *Noturus*, small catfishes known as madtoms, accounts for six species in Virginia. Species in the *Notorus* genus have adipose fins with the posterior edge attached to the caudal fin.



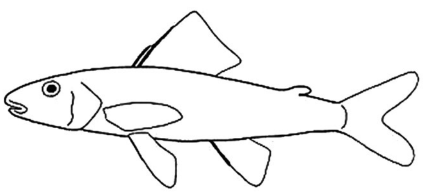
Ictaluridae

The family Salmonidae has cycloid scales on the body and fins without spines. Three species, brook trout, brown trout, and rainbow trout are present in mountain streams and some reservoirs in the western third of the state where they are premier game fish for anglers. The brook trout is the only native representative of this family in Virginia.



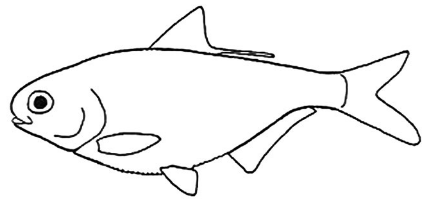
Salmonidae

The family Percopsidae is represented by one species, the eastern trout perch (*Percopsis omiscomaycus*). This species was previously found only in the upper Potomac River drainage, but is now considered **extirpated** from Virginia. The eastern trout perch has two weak spines in the dorsal fin, one weak spine in the pelvic and anal fins, a large dorsal fin, and an unscaled head.



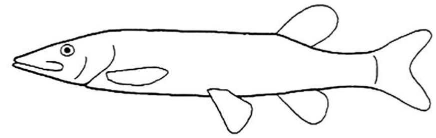
Percopsidae

The family Clupeidae has a laterally compressed (keel-like) body with sharp-edged **imbricated scutes**. American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), alewife, and blueback herring are anadromous, so they are primarily found in Virginia's coastal rivers. Gizzard shad are widespread through multiple large river systems and reservoirs. Threadfin shad (*Dorosoma petenense*) have been stocked in some Virginia reservoirs as prey fish, but in our cold winter climate, they frequently die due to temperature shock.



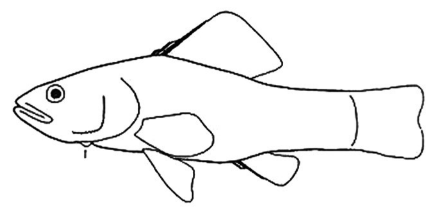
Clupeidae

The remaining fish families have bodies that are not keel-like. With the exception of the Eastern Mudminnow, if the snout is shaped like a duck bill, the species belongs to the Esocidae family. Chain pickerel is the most abundant representative of this family. Redfin pickerel (*Esox americanus*), the smallest *Esocid*, is found in small streams in the Coastal Plain. Northern pike (*Esox lucius*) are a nonindigenous species stocked in a few Virginia reservoirs where they do not reproduce naturally. Muskellunge (*Esox masquinongy*) is the prized trophy game fish of this family. This nonindigenous sport fish is stocked in several rivers and reservoirs to provide trophy fishing opportunities. Some populations are naturally reproducing in areas where they were originally stocked. The Eastern mudminnow (*Umbra pygmaea*), is also a member of the Esocidae family that inhabits waters of the lower Piedmont and Coastal Plain. It is a survivor that can inhabit the shallowest and stagnant water. A characteristic of the mudminnow family is the lack of a protractible mouth. The upper jaw is attached to the snout by a wide bridge of tissue known as the **frenum**.



Esocidae

Families without a duckbilled snout are distinguished by the position of their anus. If the anus is located immediately behind the head and in front of the pelvic fin base, the fish belongs to the Aphredoderidae family (pirate perches). The only species in this family, the pirate perch (*Aphredoderus sayanus*), inhabits the darkly stained waters of the Coastal Plain and central Piedmont.

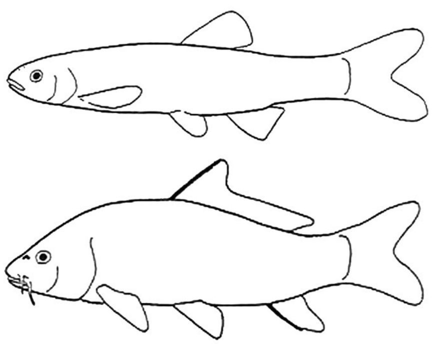


Aphredoderidae

If the anus is located in front of the anal fin, posterior to the base of the pelvic fin, it fits into one of 12 remaining Virginia fish families. Five of these fish families have one dorsal fin and less than four dorsal fin spines. These five families are distinguished by the shape of their caudal fin. A forked caudal fin describes species from the Leuciscidae (Minnow) and Catostomidae (Sucker) families.

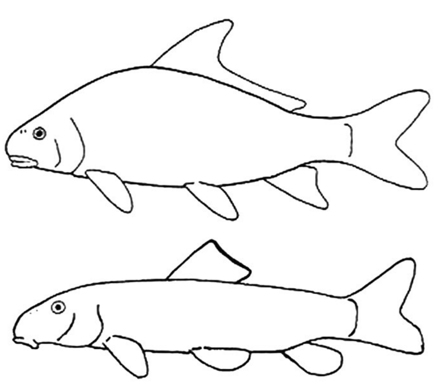
The family Cyprinidae contains the Old World minnows with only the non-native Common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) found in Virginia. True minnows (or New

World minnows) ae in the family Leuciscidae. It is the largest fish family in North America and in Virginia with 70 species. Specific traits of these families include dorsal fins with 9 or less rays, 17 branched caudal rays, and **pharyngeal** arches with 6 or less teeth.



Cyprinidae

The Catostomidae family is represented by 19 species in Virginia. Distinguishing characteristics include dorsal fins with 10 or more rays, 16 branched caudal rays, and pharyngeal arches with 10 or more teeth. *Catostomids* inhabit many river systems across the state. The creek chubsucker (*Erimyzon oblongus*) and northern hogsucker (*Hypentelium nigricans*) are two abundant species from this family.

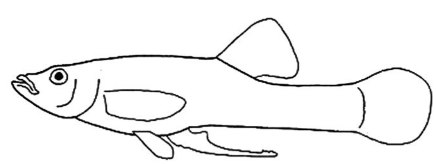


Catostomidae

The remaining two families (from the group mentioned above with one dorsal fin and fewer than four dorsal fin spines) have one dorsal fin and a rounded caudal fin. They are the Fundulidae (killifishes), and Poeciliidae (livebearers) families.

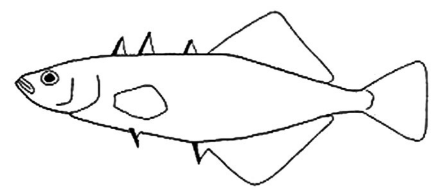
The Fundulidae (not pictured here) and Poeciliidae families have similar body forms, and both of them have extensible mouths. The Fundulidae family has a distinguishable branched third anal ray with the same shape in both sexes. Five species of killifishes are known in Virginia. The banded killifish (*Fundulus diaphanous*) is abundant in coastal river systems and limited populations are found in mountain streams.

The Poeciliidae family has a third anal fin ray that is not branched. Males have an anal fin ray that is modified into an **intromittent** organ that assists with livebearer reproduction. A representative of this family, the eastern mosquitofish (*Gambusia holbrooki*), is found in numerous waters statewide, primarily due to its introduction for mosquito control.



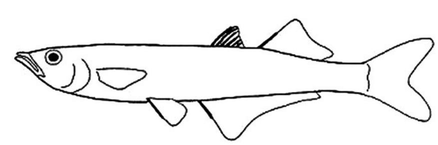
Poeciliidae

The last main assemblage of fish families are defined by the presence of two dorsal fins. The Gasterosteidae family (sticklebacks) has a pelvic fin with a single prominent spine and the first dorsal fin has widely separated spines with a separate membrane for each spine. Three species of sticklebacks are found in Virginia.



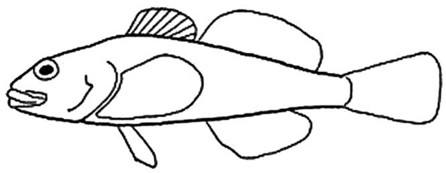
Gasterosteidae

All other Virginia fish families lack a pelvic spine. Fish with pelvic fins in an abdominal position that have well separated dorsal fins are members of the Atherinidae family (silversides). The brook silverside (*Labidesthes sicculus*), which inhabits the Clinch and Powell rivers, is the only species of this family found in Virginia.



Atherinidae

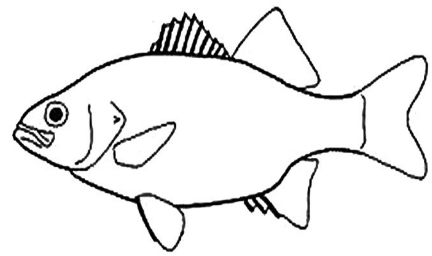
Representatives of the Cottidae family (sculpins) have three to four rays in their pelvic fins, which are located in a **thoracic** position, and an unscaled body. There are 10 species of sculpins in Virginia, primarily in the western mountain streams. The mottled sculpin (*Cottus bairdi*) is the most widespread species in this family in Virginia.



Cottidae

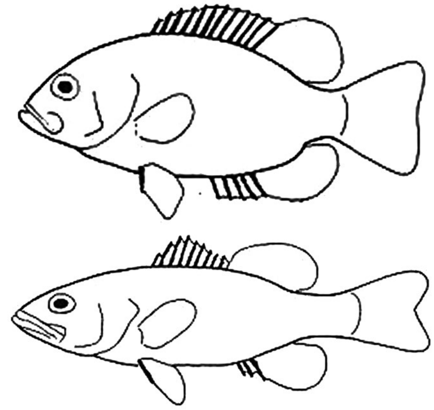
The remaining fish families all have scaled bodies and pelvic fins with five or more rays. The number of anal spines separates these families. The families Moronidae (striped basses) and Centrarchidae (sunfishes and basses) have anal fins with three or more spines.

The Moronidae family has the first and second dorsal fins narrowly separated or slightly conjoined and they have **pseudobranchae**. Four North American species of Moronidae live in freshwater and marine habitats where they are sought as sport fish by anglers. Three of these species are found in Virginia. Striped bass (*Morone saxatilis*) inhabit coastal rivers and some reservoirs (where they are typically maintained with annual stocking). Virginia is one of a few states with a naturally reproducing reservoir striped bass population in Kerr Reservoir (also known as Bugg's Island Lake). White perch (*Morone americana*) are found in coastal rivers and some reservoirs, since they can live in a variety of habitats. White bass (*Morone chrysops*) are more numerous in southwestern Virginia rivers, but a few populations are found in Virginia reservoirs, including Kerr, Claytor, and Holston.



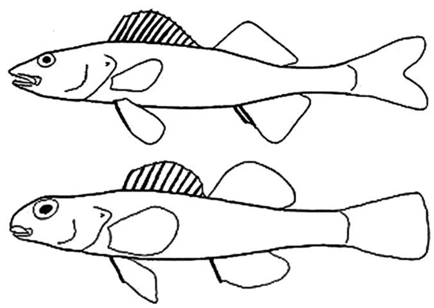
Moronidae

The Centrarchidae family has their first and second dorsal fins moderately or broadly conjoined and they do not have psuedobranchae. Nineteen species from the Centrarchid family inhabit Virginia waters. This diverse family contains many popular sport fish species. The genus *Ambloplites* contains the rock bass (*A. rupestris*) and the Roanoke bass (*A. cavifrons*). The genus *Pomoxis* consists of the popular sport fish species black crappie (*P. nigromaculatus*) and white crappie (*P. annularis*). The genus *Enneacanthus* (banded sunfishes) consists of three small species, including the blackbanded sunfish (*Enneacanthus chaetodon*), a state endangered species found in southeastern Virginia. The genus *Micropterus* consists of the very popular sport fish often called black basses: the largemouth bass, smallmouth bass, and spotted bass (*M. punctulatus*). The genus *Lepomis* consists of seven sunfish species with the bluegill being one of the most popular sport fish species in this genus.



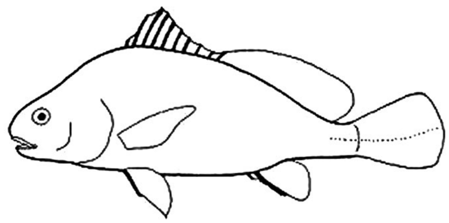
Centrarchidae

The families Percidae (perches) and Sciaendiae (drums) have anal fins with one to two spines. The Percidae family is a large family, boasting 176 species worldwide, with 92 percent of those found in North America. Virginia has an abundant *Percid* family, with 48 species found here. The genus *Perca* is represented by yellow perch (*P. flavescens*), found in coastal rivers and some Virginia reservoirs. The genus *Sander* includes the popular sport-fish species walleye, found in multiple Virginia rivers and reservoirs, and the lesser known sauger (*S. canadense*), which are only found in the Clinch and Powell rivers in southwest Virginia. The genus *Percina* is represented by 16 species of darters in Virginia, including the state and federal endangered Roanoke logperch (*Percina rex*). The genus *Etheostoma* is represented by 21 species of darters, 6 in the genus *Nothonotus*, and one each in the genus *Allohistum* and *Ammocrypta*. Some darter species have incredible coloration especially the males during the breeding season. The candy darter (*Etheostoma osburni*) is considered one of the most beautiful freshwater fish in North America.



Percidae

The Sciaenidae family has a specific characteristic of a second anal spine that is broad and long and a lateral line extending onto the caudal fin. The males have the ability to make a drumming noise to attract a mate. In this family, only the freshwater drum (*Aplodinotus grunniens*) inhabits Virginia waters. Their range is primarily concentrated in the Clinch and Powell river systems, with an introduced population in Kerr Reservoir.



Sciaenidae

## Adaptations, Biology, and Natural History of Fishes

### Body shape

Fish have evolved various physical and behavioral adaptations to survive in specific habitats. One obvious adaptation is body form or shape (Figure 12-4.), which can tell us a great deal about where and how a fish lives. Fast-swimming, open-water fishes are streamlined and elliptical in cross-section, or fusiform. An example of a fusiform shaped fish from Virginia is the brook trout. Fishes that are not constantly moving but are capable of short bursts of speed are more laterally compressed and called compressiform. A good example of **compressiform** shaped fish are sunfish of the Centrarchidae family. Fish that are flattened dorsoventrally, such as skates, are termed **depressiform**, which suits them for life on the bottom. Other fish that live on the bottom and are flattened on their ventral side include sculpins and catfish.

### Fins

In addition to body shape, fins also vary according to the fish's way of life. The caudal fin (or tail) is especially telling. Those fish that swim rapidly and are constantly on the move generally have a forked or crescent-shaped caudal fin. Species with truncate, rounded, or **emarginate** caudal fins may be strong swimmers but somewhat slower than those with forked tails. Fishes with small caudals or those continuous with the dorsal fin tend to be weak swimmers and

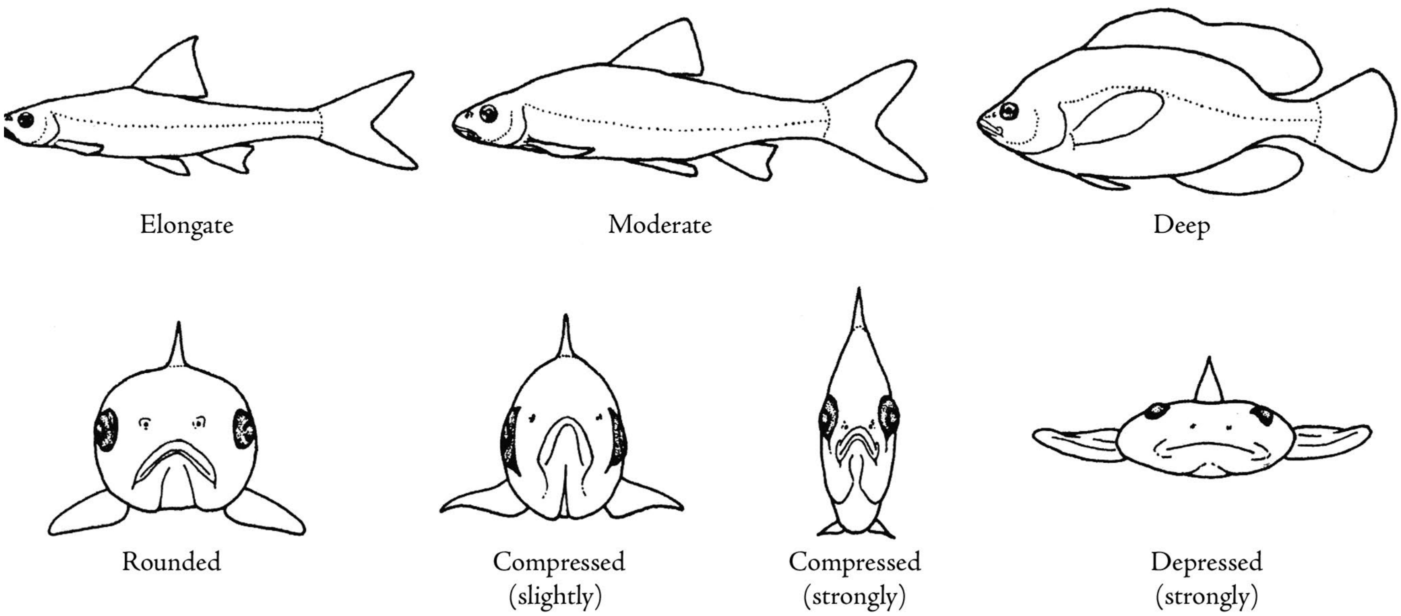



*Figure 12-4. Fish body shapes (from Jenkins and Burkhead 1993).*

move along the bottom. Benthic dwelling fish, however, have other advantageous adaptations. For example, the position of the paired pectoral and pelvic fins in sculpins and darters creates a friction plate (a rough surface) that helps them hold their place among rocks. The fleshy adipose fin has little function, but is found on trout, trout perch and catfish.

### Mouth

Mouth shape and placement provide clues about how a fish feeds and what it eats (Figure 12-5.). Surface feeders, such as topminnows, possess a superior mouth, whereas bottom feeders, such as suckers and some minnows, will have the mouth oriented downward (inferior mouth). Top predators tend to have terminal mouths with developed rows of teeth. Subterminal mouths are made for shoveling along the bottom surface for prey items (catfish). Many predatory fishes, such as the largemouth bass, have rows of teeth in broad pads both in the mouth and on the **pharyngeal** bones to catch and hold prey and aid in swallowing. The central stoneroller (*Campostoma anomalum*), a grazing minnow, has a hard ridge on the lower jaw to scrape algae from rocks. Herbivorous or detritus-eating fishes have relatively long, coiled intestines, often many times the length of their body. Carnivorous fishes generally have short intestines, while omnivorous fishes have guts of intermediate length. A longer gut increases the surface area and allows for more time for absorption of nutrients.

### Color

Coloration is another important adaptation of fish to their environment. Fish living on sand, such as the glassy darter (*Etheostoma vitreum*), are a pale translucent color. Fish living on stony substrates are either a dark color or boldly mottled, so they blend into the background. The mottled sculpin is a good example. Fish living in vegetated habitat, such as the chain pickerel, generally have vertical

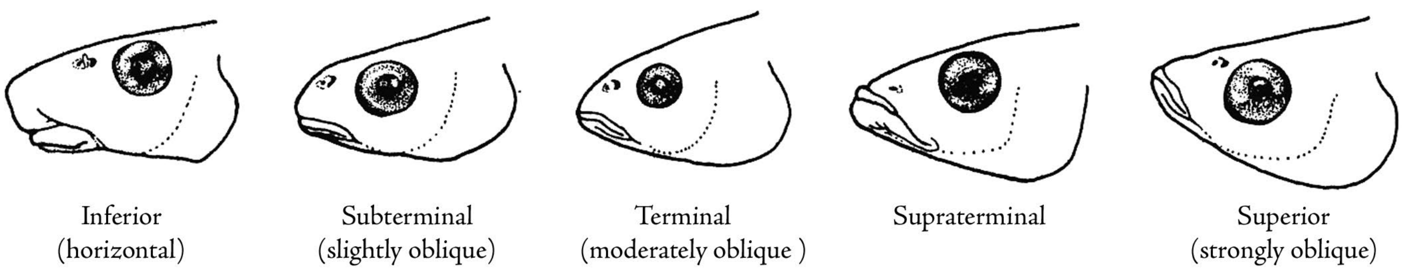



*Figure 12-5. Mouth positions (from Jenkins and Burkhead 1993)*

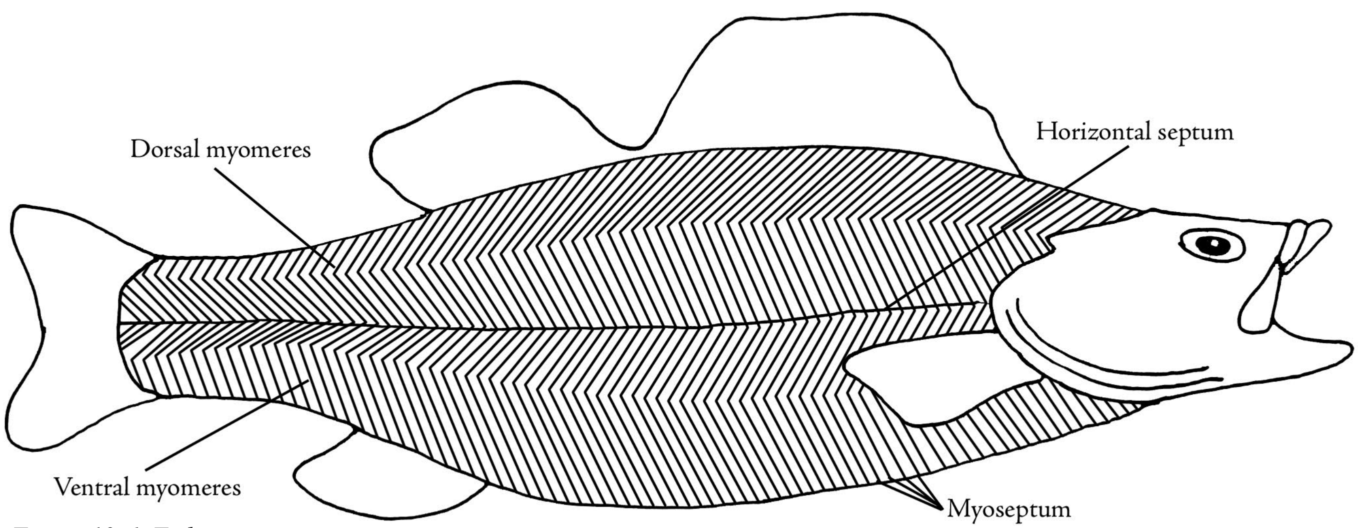



*Figure 12-6. Fish myomeres*

bars or large, circular color patterns. Most fish, but especially those that live in open water have countershading, which is a coloration pattern where they are dark colored on the dorsal surface and light colored on the ventral surface. The pattern provides camouflage and allows them to blend in when viewed from above or below. Many fish exert some control over their color, becoming paler on pale-colored backgrounds, and vice versa, within a time frame of two to three minutes.

### Swimming

The most obvious thing about a fish is that it can swim. What is not obvious is how it moves through the water with what seems so little effort. The ancient Greek philosopher Aristotle first asked this question, but it was not until the advent of high-speed film that good answers were obtained. The simple answer is that the fish flexes its body into an undulating "S" shape, pushing against the surrounding water to generate thrust. Some fish, such as eels, involve their entire body in the process, while others, such as tuna, primarily just their caudal fin.

The flexing is generated by muscles called **myomeres** that occur in vertical bands along the fish's body (Figure 12-6.). When you use a fork to flake a fish filet, you are separating the myomeres. The myomeres contract in sequence from head to tail, alternating on each side of the body in perfect sequence to generate the "S" shape. It is an incredibly efficient way to move through water. Using this swimming mechanism, a 1,500 pound tuna (family Scombridae) can reach speeds of 50 miles per hour and a steelhead trout (*Oncorhynchus mykiss*) can leap more than 15 feet straight up out of the water.

In most fish, the fins are not used to generate thrust (except for the caudal fin), but instead are used as stabilizers, rudders, and brakes. The body generates the speed, and the fins provide maneuverability. If you watch a fish carefully, you will see that it has very precise control of each of its fins. This control is due to **rays** and spines. All fish have rays in their fins, and more evolutionarily-advanced ones also have spines. Fish raise and lower their fins by controlling the rays or spines. Each ray or spine is connected to a bone called a **pterygiophore** (pronounced, "ter-ridge-e-o-four"), which is embedded in the myomeres but not connected to the rest of the skeleton. By flexing the myomeres, the fish can pull the pterygiophores forward to lower the fins or backward to raise them. This fine-tuned mechanism allows the fish to independently control each fin, providing very precise control over movement.

A fish's ability to swim efficiently is also due to its capacity to maintain neutral buoyancy in the water (neither sinking nor floating). To do this, a fish must perfectly match its density to the density of the surrounding water. The complication is that water density changes with depth and temperature, and so the fish must be able to precisely adjust the density of its own body on an almost continuous basis. How? Most fish use a specialized organ called the **swim bladder** (Figure 12-1). This gas-filled bladder lines the top of the body cavity, and a fish can pump gas into and out of it in order to adjust its overall body density, much like scuba divers adjust their density using a buoyancy compensation device. Working together, the body, fins, and swim bladder allow a fish to move quickly and accurately through water, a substance which is 780 times more dense than air.

### Breathing

Fish use gills to take in oxygen from the surrounding water and release carbon dioxide. In ancient fish, such as lampreys, there are seven openings along each side of the body, each leading to a blind sac (the gill chamber) lined with gill tissue. Muscles around each gill chamber contract to squeeze water out like a balloon, and then relax to allow new water to flow in. As fish evolved more efficient respiratory systems, two major advances were made. The first was the "flow through" system. All fish more advanced than the lampreys take water in through their mouths and force it out through the gill opening. This eliminates the need to pump water in and out of the gill chamber, greatly reducing the energy the fish must devote to breathing. The second major advance was that fewer openings were needed. A few very-ancient sharks have seven gill slits just like the lamprey, but modern sharks have only five. Even more advanced fish, such as trout, minnows, and bass have just one gill opening per side, covered by a flap called the operculum. Inside the operculum are four bony gill arches, each holding a set of gill filaments (Figure 12-2). You can see the white gill arches when you look down the throat of a fish, and you can see the red gill filaments when you lift the operculum. The gill filaments are red because they are filled with oxygenated blood, which is pumped around the body by the heart. The gill arches often have spines on them called gill rakers to prevent food from escaping out the gill opening.

## Osmoregulation

One of the most important physiological adjustments that fish make involves **osmoregulation**, or the maintenance of proper water and salt balance in their tissues (Figure 12-7) Because a fish's internal salt concentration is usually different from the water in which it swims, it must be able to prevent excessive gain or loss of water. The body fluids of freshwater fish have a higher salt concentration than the surrounding freshwater, while marine species have more dilute body fluids than the sea water around them. Osmoregulation is accomplished by the kidney, the gills, some special organs, and to some extent, by the body covering (skin and scales) in its role as a barrier. Fishes that live in both fresh and saltwater at some point in their life cycle, for example, shad or American eels, must adjust their osmoregulatory mechanisms accordingly. Aquatic organisms devote more attention to osmoregulation than terrestrial ones because diffusion of salts to and from the surrounding water is constantly occurring, pushing the fish out of osmotic balance.

Freshwater and saltwater fish face exactly opposite challenges regarding osmoregulation. Freshwater fish are **hyperosmotic**, meaning that the desired salt concentration of their tissues is higher than that of the surrounding water. Because substances always diffuse from

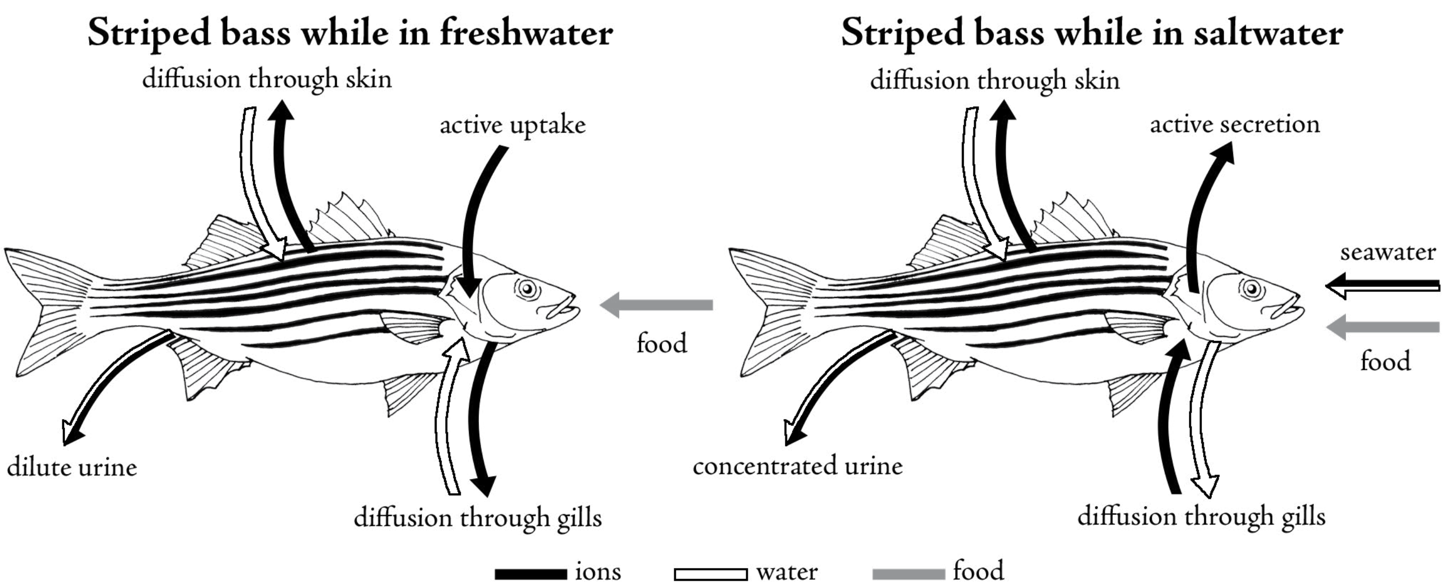



*Figure 12-7. Osmoregulation in freshwater and saltwater fish. In freshwater fish, such as striped bass when they move into rivers, salts (ions) flow out of the body through a process called diffusion. Diffusion is when ions flow from an area of higher concentration to an area of lower concentration. Freshwater fish make up their ion loss by taking them from the water. In saltwater fish, such as striped bass when they are in the ocean, ions flow into the body. Saltwater fish constantly remove ions from their bodies. In both cases, water flows in the opposite direction from ions.*

higher concentrations to lower ones, salt is constantly trying to diffuse out of the body, and water is constantly trying to diffuse in. This is particularly true at the gills because those tissues must be very thin in order to promote diffusion of oxygen. Freshwater fish maintain an osmotic balance under these circumstances in two ways. First, they produce high quantities of very dilute urine, so they have very large, efficient kidneys. Second, they use specialized **chloride cells** in the gills that are able to pump salt into the body against the concentration gradient. Saltwater fish have the opposite problem. They are **hyposmotic** (less salty than the surrounding water), so salt is constantly trying to diffuse into the body and water out of the body. Saltwater fish use essentially the same machinery as freshwater fish to maintain osmotic balance, but they run it in the opposite direction. Their kidneys produce small amounts of very concentrated urine, and their chloride cells pump salt out of the body.

As if all of this osmoregulatory activity was not challenging enough, consider the obstacles that certain species, such as striped bass, face when they migrate between fresh- and saltwater as part of their life cycle. They must exactly reverse all of their osmoregulatory apparatus as they make the transition from saltwater to fresh when returning to spawn, and then again as they return to the ocean. This is particularly difficult for the newly hatched juvenile fish making their way to sea for the first time. One reason why estuaries, such as Chesapeake Bay, are so important for migrating fish is because they provide a gradual transition from fresh to saltwater, allowing the fish's metabolism to adjust to the new conditions.

## Senses

Fish have the same five senses humans possess (sight, hearing, touch, smell, and taste). Anglers are often well informed about fish sensory systems, but they are often a mystery to other people. Can fish detect color? What's the purpose of catfish "whiskers"? How can schooling fish move in unison? Let's examine how freshwater fish detect food, swim from danger, or find a place to spawn.

**Sight:** The role a fish species fills in nature often reflects the degree of vision the animal possesses. For instance, large predators like muskellunge, striped bass, and brown trout have large, well-developed eyes. They are able to see 360º, with the exception of straight down and straight back. Because their eyes are placed forward on their bodies, they are in a perfect position for hunting. Fish can discern brightness and color with rods and cones found in their retinas. Shallow water fish usually have excellent color vision, but do not have the full range of colors available to them that humans possess. Water filters out color, so reds are lost first as one goes deeper, then yellow, followed by blue. Some fish, like bullhead catfish, have "beady" eyes and poor vision. Bullheads spend much of their time in deeper, murkier areas of ponds, lakes, and rivers. They rely on other senses to help them get their next meal.

**Hearing:** Remember your physics? Sound travels four times faster in water than in air, so most fish have developed a keen sense of hearing. Fish don't have ears, so how do they accomplish this feat? They usually pick up sound directly through the bones of the head. Fish equilibrium is maintained through this inner ear, which is a chamber containing **otoliths** and other sensitive receptors. In some fish, such as minnows, catfish, and suckers, a series of small bones connect the air bladder with the inner ear. This is called the **Weberian apparatus** and its purpose is to convey pressure changes in the air bladder with sound.

**Touch:** Fish possess a system of sensing touch called the **lateral line system** that is truly unique (Figures 12-1 and 12-2). The lateral line system is a hollow canal running just under the scales from head to tail along each side of the fish, about half-way down the side of the body. A special row of scales covers the lateral line, each with a small opening (the pore) connected to the lateral line canal by a tube. If you look closely at a fish, you can see the pores that form a single row of white dots along each side. These pores connect the lateral line canal to the outside world. Any pressure wave sent by nearby objects is picked up by the lateral line and a signal is sent to the brain. One spectacular way the lateral line is used is to coordinate the movements of fish in schools. If you watch a school of fish closely, you will be amazed at how perfectly they coordinate their movements, which is an example of the lateral line at work. Fish are also very sensitive to slight changes in water temperature. The fact that many game fish carefully "mouth" soft plastic baits, suggest that their sense of touch is more sophisticated than we know.

**Smell:** Anglers are familiar with homemade and commercial "stinkbaits" that are supposed to improve their chance of catching a fish. Stinkbaits work well because fish have a well-developed sense of smell. Pacific salmon are hatched in streams high in the mountain ranges of western North America, leave for the ocean after a year of growth, swim for years in the Pacific Ocean, then return as adults to spawn in the same stream reach where they hatched from eggs. Pacific salmon find their natal stream using their remarkable sense of smell. Displaced sunfish can find their way back to their home area through smell. Minnows give off warning odors that signal other members of their school to disperse. Female fish emit odors that are picked up by males when it is time to mate.

**Taste:** If you have ever observed fish in an aquarium, you may have seen that they are quick to "spit out" unsavory food items. Brook trout are known to strike anything from floating hemlock needles to hand-tied flies. They are quick to reject the hemlock debris, indicating that they, too, have a sophisticated sense of taste. Common carp can actually sense the difference between sweet, salty, bitter, and acid taste. Taste buds are located on the head of a fish, concentrated on **barbels** (like catfish), on their lips (common in suckers), or inside their mouths.

## Growth, Reproduction, and Life History

Most animals grow to their adult size and then stop getting bigger. Fish, on the other hand, continue to grow larger and larger throughout their lives, assuming enough food and space is available. "**Indeterminate growth**" has profound effects on every part of a fish's life cycle, especially reproduction. To understand why, you need to understand how fish use the energy they obtain from their food. The energy a fish gets in its food must be divided up and used for growth, reproduction, and metabolism. This is true for all animals, but because fish have indeterminate growth, they have an extra choice. Should they devote energy to getting bigger or to reproduction? (Assume for the moment that they have little choice about putting a given amount of energy towards metabolism). Other animals do not have to make this choice, once they reach adulthood, because they stop growing, and all their energy can go to metabolism and reproduction. The choice about whether to grow or reproduce is made even more complicated because the two are related. It is almost universally true in fish that bigger females can produce more eggs, and bigger males attract (and can defend) more mates. So, it makes sense that the fish wants to get bigger in order to have more success when reproducing. But, as we've just seen, getting bigger actually takes energy away from reproduction itself. Fish face a tough choice, grow big now and reproduce later, or reproduce now, but stay small.

Fish adaptations to different environments include different reproductive strategies or breeding habits. Most freshwater fish in Virginia can be grouped into two different categories, the nonguarders and the guarders. Nonguarders include fish that lay **pelagic**, or drifting, eggs. Shad eggs drift downstream until they sink and become lodged in the substrate. Other nonguarders may deposit their eggs in natural or constructed hiding places or nests. The male central stoneroller (*Campostoma anomalum*) carries stones away from the breeding area, forming a pit in which the eggs are laid. In many chub species, the males carry stones in their mouths to create a large rock pile nest. In several species of darters, the female shuffles into the gravel and buries eggs. The advantage of gravel spawning is that the loose gravel allows water to pass through, bringing oxygen to the buried eggs. There is also variation among nest-guarding fishes. After an elaborate courtship, female sculpins attach sticky eggs on the underside of a flat rock, which is then guarded by the male. Sunfishes and bass create nests in gravel or vegetation, which are guarded by the male. Some catfishes seek out cavities in which to lay their eggs and protect them from predators. An advantage of guarding a nest is it reduces the chance of eggs being eaten before they hatch, thus increasing the odds of the offspring's survival.

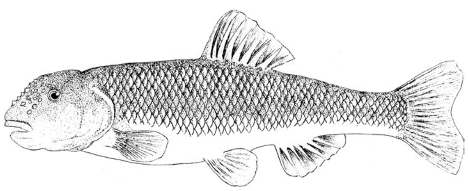


*Figure 12-8. Male chubs from the genus* Nocomis *carry stones in their mouths to create spawning mounds. (Drawing by Mike Pinder.)*

The tough choice between growth and reproduction has produced some very interesting **life history strategies** in fish. A life history strategy is a set of behaviors used to complete important parts of the life cycle, such as finding a mate, rearing young, and obtaining food. For example, striped bass, shad, and herring, have all evolved a life history strategy that includes **anadromous migrations**, where they are born in freshwater, migrate to saltwater as juveniles, grow to adulthood in saltwater, and then return to freshwater to spawn (and in many cases die). Why would a fish go through such a complicated life cycle? Wouldn't it be better to just stay in freshwater the entire time? After all, if you are born in a place, and you will eventually spawn there, why leave in between? The answer seems to be tied to solving the "grow or spawn" problem. In order to be a successful spawner, the fish needs to be as large as possible. And, it turns out that there is a lot more food in the ocean than in freshwater. If you want to get big, you need to go to the ocean to eat. So, the fish has adopted a very complicated strategy: be born in freshwater, make dangerous migrations to saltwater in order to grow, and then return to freshwater to reproduce.

And, just when all that seems to make sense, consider the American eel. It undergoes a **catadromous migration**. American eel are born in saltwater (in the Sargasso Sea off the coast of Bermuda), migrate to freshwater, where they grow to adulthood, and then return to the Sargasso to spawn and die. If fish migrate to where the food is, why do striped bass and eels migrate in different directions to find food? After all, in Virginia, both species can be found in the very same rivers and migrate to the very same ocean, but in opposite directions. The answer is a bit complicated and has to do with the evolutionary history of the two species. The ancestors of striped bass evolved in freshwater, so that is where today's striped bass must spawn (changing something as basic as where you spawn is not easy). The ancestors of eels evolved in saltwater, so that is where they must spawn. The reason they each decided to migrate to food in another habitat also seems tied to where the ancestors originally evolved. Striped bass evolved in temperate zones, where the ocean is more productive than freshwater, and eels in tropical zones, where the reverse is true. Striped bass had to go to the ocean to find the most food, and eels had to go to the rivers. Then, as eels expanded their range northward outside the topics, they retained their migratory habits, even though they do not seem to make much evolutionary sense anymore. As you might predict, there is some recent evidence that eels in the north (where the ocean is more productive than freshwater) are not all migrating to freshwater anymore. There seems to be a population of northern "ocean eels" that stay in the ocean where food is abundant.

Eels and striped bass are just two of Virginia's more than 200 freshwater fish species, but there is an important lesson to be learned from them: fish life histories are extremely flexible. Fish display an incredible array of life history strategies, so it is not possible to make broad generalizations. Even within a species, big differences occur. The rainbow trout that live in Virginia's rivers for their entire lives are the exact same species as the steelhead trout that grow to over 20 pounds in the Pacific Northwest and make anadromous migrations to the ocean and back. The point is that if you boldly say, "This is how this species completes its life cycle," you are likely to be right for some rivers and lakes but wrong for others. As a naturalist, your job is to figure out how *your* fish in *your* river behave. This is both the frustration and the fascination involved with studying fish: they are wonderfully, maddeningly, complicated.

## Threats and Issues Relating to Fish in Virginia

"Freshwater species in the United States are disappearing at a rate two to five times faster than native land animals, a rate equal to those of tropical rain forest fauna" (Helfrich *et al.* 2003). **Anthropogenic** disturbances, or human activities, are the greatest source of threats and issues to Virginia fishes and their habitats. Such activities include land use and channel alterations, dams, pollution, and introduction of invasive species, resulting in habitat loss and degradation, the leading cause of fish and aquatic resource imperilment.

Fish kills and other impacts, some not so visible to the casual observer, occur to fish and their habitats as the activities of humans disturb aquatic ecosystems and their **ecological integrity**. Understanding cumulative impacts and future threats to Virginia fishes due to human population growth, climate change, and **emergent contaminants** present challenges to fisheries and water resource managers. In this chapter, we focus on sediment and its impact to fisheries. Pollution impacts to aquatic ecosystems are covered in depth in the chapter on Aquatic Ecology and Management.

**Sediment** and pollution impacts to waterways usually result from upstream land-use activities that impact the immediate area and the downstream area too. In a recent assessment of threats to freshwater fauna, a team of researchers reported that altered sediment loads and nutrient inputs from agricultural and urban **nonpoint source pollution** are the top threats in the eastern United States (Richter *et al*. 1997). Sediment is the leading cause of water quality impairment in America's waters, including the Chesapeake Bay. Early studies on the impact of sediment on fish were related to the mortality of the egg and juvenile stages of salmonids. Trout and many other fish species spawn in nests built with coarse substrate such as gravel. The eggs and fry are dependent on clean interstitial spaces between the gravel for water flow to help with oxygenation and waste removal. Mortality occurs when these spaces become clogged with fine sediment and silt. High levels of deposited sediment can cause the loss of habitat quality and quantity and result in large reaches of streams that lack fish. Suspended sediment and turbidity can impair the feeding ability of fish that are sight feeders, resulting in decreased growth rates and health. Fish gills can also be clogged with fine sediment causing impaired respiration. Overall, excessive sediment may result in increased physiological stress and decreased tolerance to disease and toxics.

In Virginia, like most of the eastern United States, forests have been cut for timber or cleared for farmland for the past 300 years. Currently across much of the commonwealth, forested and agricultural lands are being converted into residential areas and industrial and commercial areas. Land use and channel alterations affect the aquatic **ecosystem** in many ways. Individual fish, fish populations, and fish communities can be threatened as well as their habitat.

## Sources of excessive sedimentation from land and channel conversion include:

(See Figure 12-9. Stream embeddedness)

Logging and forest road construction that reduce canopy cover, alter flow regimes (including groundwater), and increase the supply of organics and sediment to nearby waters.

Poor agricultural practices that result in vegetation removal in **riparian** and **floodplain** areas, increased chemical application (fertilizers, pesticides) near waterways, and allow direct access of animals to waterbodies.

Road and bridge construction that alter stream banks and channel characteristics, increase sediment loading, and degrade water quality.

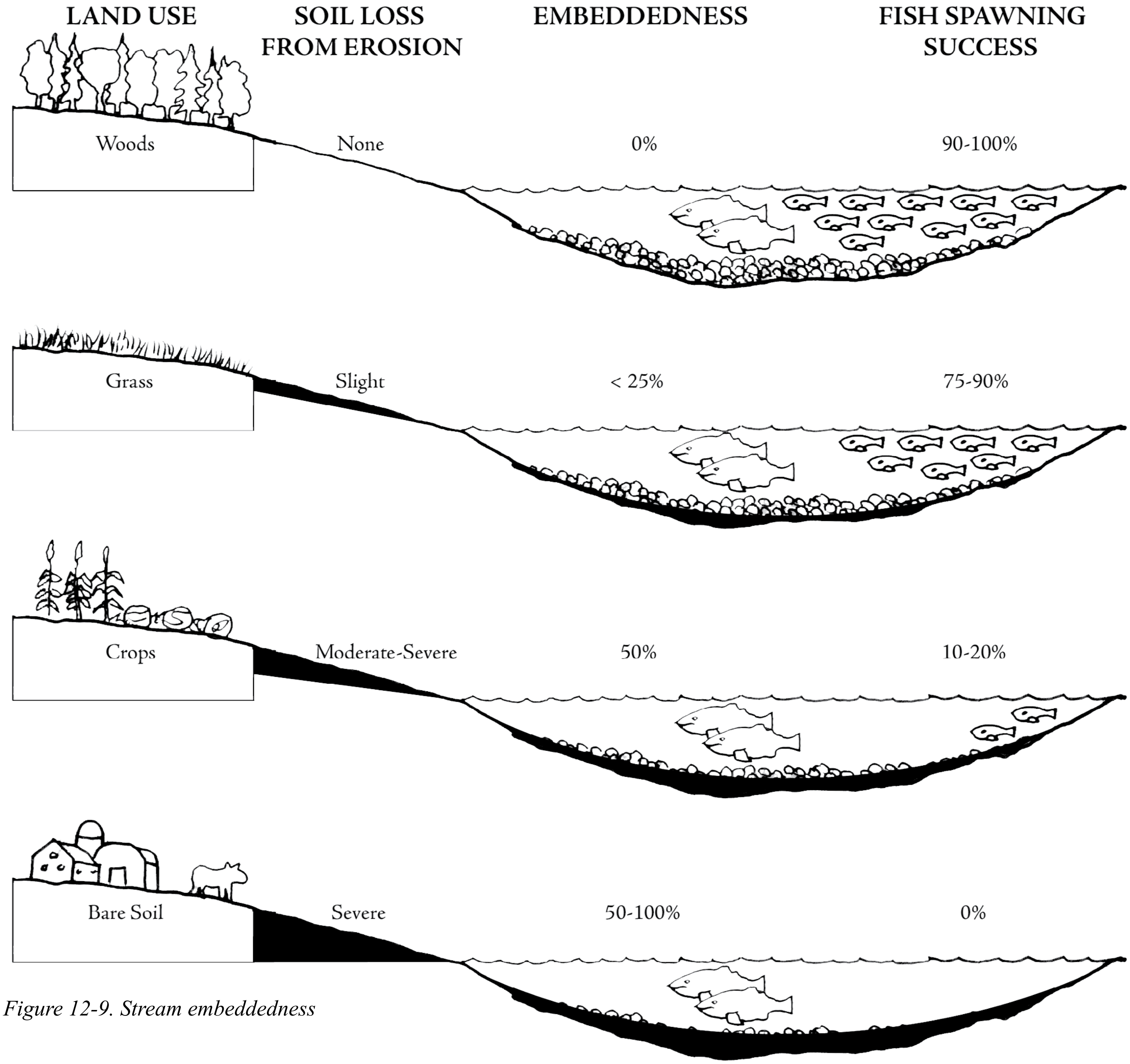



*Figure 12-9. Stream embeddedness*

Residential, industrial, and commercial development that increase impervious surfaces within watersheds, increasing surface **runoff**, sediment loads and temperatures in streams, and **pollutant** loading to streams and shallow groundwaters.

Sand and gravel mining in streams and rivers that alter the bottom composition and stability, resulting in changes to channel morphology.

Channel modifications, including enlargement, realignment, and straightening; removal of instream or stream-bank vegetation and woody debris; and bank stabilization using riprap or concrete that increase water velocity and soil erosion.

### Exotic Species

The introduction and transfer of **exotic species** or the transfer of nonnative species to new areas are the greatest threats to Virginia's ecosystems after habitat fragmentation and destruction. Exotic species typically have no natural predators. They can impact native fishes through increased predation, transfer of diseases and/or parasites, and competition for food and space. Exotic species may breed with native fish, resulting in hybridization and loss of native genetic purity (Jenkins and Burkhead 1993). Recent introductions of exotic aquatic species to Virginia include the northern snakehead (*Chana argus*) and the zebra mussel (*Dreissena polymorpha*). Zebra mussels, found in a quarry in Prince William County in 2002, were successfully eradicated in 2006. Even though this introduction was successfully eradicated, zebra mussel could be introduced to Virginia again. Two exotic species of crayfish, virile crayfish (*Orconectes virilis*) and the red swamp crayfish (*Procambarus clarkii*), are widespread in Virginia. Two other exotic species, the rusty crayfish (*Orconectes rusticus*) and the Southern White River crayfish (*Procambarus zonangulus*), have been introduced to river drainages in adjacent states, so they may soon be more widespread in Virginia. All of these introductions can impact native species through direct competition and food-chain disruption.

According to the United States Geological Survey's 2004 Summary Report of Nonindigenous Aquatic Species in the United States Fish and Wildlife Service Region 5 (stretching from Virginia to Maine), Virginia has the most introduced fish species, with nearly 100. Within Region 5, stocking is the dominant pathway of fish introductions, accounting for nearly 50 percent of the species. Bait release is the second most commonly used pathway and aquarium releases (or escapes from tropical fish farms) are third. Many fish species were introduced by individuals and government agencies into drainages outside their native range, and many have adjusted to their new homes quite readily. An example is the smallmouth bass, which is native to the Tennessee River but is now found throughout most of Virginia's rivers.

### Uncertain Threats: Population Growth, Climate Change, and Emerging Contaminants

In 2005, Virginia supported an estimated population of 7.6 million people. By 2030, the commonwealth is expected to reach 9.3 million people, a 22 percent increase over 25 years. Virginia's population growth will increase demand on water resources. Land-use alterations will increase with increasing population growth. The use of low-impact and smart growth development techniques may mitigate impacts to Virginia's fishes. Regardless of the magnitude of change in meteorological events in Virginia, we can expect drought impacts with increasing water demand. In other words, the next protracted drought is not an "if," but rather, a "when" scenario. Fishery and water-resource managers must evaluate how demographic and socioeconomic changes affect Virginia's vulnerability to critical climatic events, including impacts to water resources and aquatic fauna. Emergent contaminants such as pharmaceuticals, plastics, personal care and household products, and pathogenic microorganisms are discharged with municipal **effluent** and other human and animal waste streams into our waterways. Although discharged at low levels, many of these compounds are persistent in the environment and may **bioaccumulate** in long-lived organisms. Impacts to fish from these emergent compounds may include altered reproduction, fetal and nervous system development, and increased susceptibility to disease.

## Rare or Special Species that Indicate Habitat Quality

As you've already read in earlier sections of the chapter, Virginia has a rich diversity of fish. Many of these species have specific habitat requirements, such as clean, fast flowing water and certain substrates or cold-water temperatures. These habitat qualities are often altered as land use or climate changes. The effects of these changes depend on whether the animal is a **generalist** or a **specialist**. Generalists can often tolerate significant disturbances while specialists may not be able to cope with habitat degradation or alteration. Several of Virginia's fish species classified as specialists are listed as threatened or endangered. Examples include the blackbanded sunfish that requires shallow ponds with abundant submerged aquatic vegetation and the sickle darter (*Percina williamsi*) that is found primarily in rivers with an abundance of woody debris. A current list of these species is available on the Virginia Department of Wildlife

Resources website. Listing by state and federal agencies provides the animals with extra protection from development and changing land use. Rare and unique species often have a small range and very specific habitat requirements that complicate management efforts.

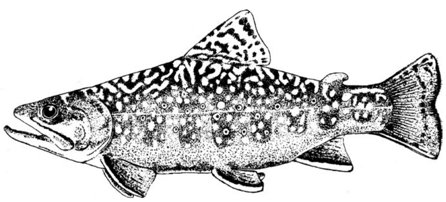


*Figure 12-10. The brook trout is Virginia's only native species from the* Salmonidae *family. (Drawing by Mike Pinder.)*

The brook trout is one native Salmonid requiring special management strategies since they are an intolerant species with specific habitat requirements. Brook trout, once found throughout the mountainous areas of the state, have had their range reduced over the past 100 years due to nonnative trout introductions and habitat alterations. Brook trout require clean, cold water to thrive. These fish are greatly impacted by increasing water temperatures and sedimentation, which often results from development, agriculture, or logging. Many populations of brook trout have been pushed to the headwater sections of streams due to these disturbances. Increased awareness of these habitat requirements has helped to protect many of Virginia's headwater streams from improper logging and development practices.

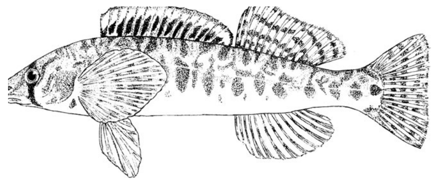


*Figure 12-11. The Roanoke logperch* (Percina rex) *is a state and federal endangered species affected by sedimentation due to poor erosion and sediment control practices. (Drawing by Mike Pinder.)*

The Roanoke logperch (*Percina rex*) is a state endangered species endemic to the Roanoke and Chowan river drainages. This rare fish feeds by flipping rocks with its long snout to eat the macroinvertebrates underneath them. Due to this feeding behavior, the Roanoke logperch is very susceptible to sedimentation that fills in its feeding habitat. Strict erosion and sediment controls must be used by developers and construction firms in watersheds containing the species. Because young logperch use backwaters and adults use fast flowing riffles and runs, a variety of habitats must be made available to them to ensure their long-term survival.

The striped bass is an anadromous fish, spending part of its life in freshwater and part in saltwater. Every spring, striped bass return to the Chesapeake Bay and its tributaries to spawn. Many rivers used by this species for spawning are blocked by dams. Dams cause two problems for striped bass, they block upstream access for spawning fish and they alter streamflow. The first problem is relatively straightforward, but the second problem may not be as obvious. Striped bass eggs are semi-buoyant and must remain suspended in the water column to develop properly. The eggs may fall out of the water column and suffocate if the right flows are not available. Changing water levels, either from natural events or dams, greatly affects the likelihood the eggs will hatch successfully. The specific habitat requirements of the striped bass often lead to erratic differences in spawning success from year to year.

It is important to understand the role specific habitats play in the lives of fish. Different fish require different habitats. If we lose habitat diversity and integrity, we will lose much of Virginia's fish diversity. Many threatened and endangered species require very specific habitat. Long-term stability of stream ecosystems is strengthened by habitat and fish diversity. Population vulnerability to environmental changes often increases as **species richness** declines. Recognizing unique fish species and the habitats they live in will help protect the integrity of all of our stream ecosystems.

## Methods for Studying Fish

The fisheries resources of the United States are a public resource managed for the benefit of the American people. The responsibility for management is shared among federal and state governments and Indian tribes. With some fish being harvested for food and others suffering from over-harvest or degraded habitat, fisheries biologists work to maintain viable populations of many species. Managing fish populations requires collecting a host of information. Important information needs are population size, rate of growth, size at first spawning, harvest, habitat health, and societal desires. The job of fisheries managers is to gather and analyze the data and to balance societal desires and the resource needs.

Population size is generally estimated using two methods, mark/recapture and depletion sampling. Mark/recapture methods collect fish, give them a recognizable mark (using a fin clip or tag), then release them, allowing them to mix with the population. Later fish collection in the same area captures both marked and unmarked fish. Estimates of the population size are calculated based on the ratio of marked and unmarked fish. Depletion sampling captures and temporarily removes fish from an area until few, if any, fish remain in the area sampled. Population size is approximately the total number of fish captured.

Fish growth is an indicator of the habitat quality and the number of fish competing within the habitat. Fish scales, spines, or bones are examined to determine age. Aging trees via counting rings is a good visual comparison, although fish age and growth determination is more complex. By knowing a fish's length and weight at its current age, a biologist can calculate its size at earlier ages. Growth rate is a measure of the population health in relation to the habitat and other populations.

It is important to protect enough spawners to maintain or, in some cases, increase population size. By capturing fish during spawning season, biologists determine age and size of sexually mature fish. Public demands sometimes require supplementing populations that, for various reasons, cannot sustain themselves. Fish are captured, spawned artificially, raised in a hatchery and then stocked.

Harvest is generally divided between commercial harvest and recreational harvest. Fish mortality is divided into natural and harvest mortality. Harvest mortality is determined by directly observing the fishery or by indirect calculations of change in population size that is greater than what would occur from natural mortality.

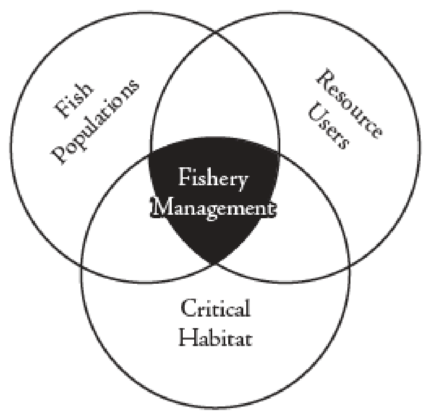
Biologists cannot sample entire populations, so it is necessary to capture a representative sample to provide the information necessary to make scientifically sound decisions. To determine the proper type of capture gear to be used, fish biology, characteristics of the waterbody, and, most importantly, study objectives must be considered. Fish capture gear can be divided into active and passive types. Active gear is moved to intercept and capture fish. Common active gear includes seine nets, trawl nets, and electrofishing. Seines are generally used in still or slow flowing shallow water to capture smaller fish. One end of the seine is held on shore, the other end is pulled into deeper water, then parallel to shore, and then pulled back to shore. Trawl nets are funnel shaped and generally used in large bodies of water. They can be sized to capture various sizes of fish. A trawl is attached to a boat and pulled through the water at a speed that exceeds the fish's ability to escape. The net can be run at various depths, depending on the habitat occupied by the species being collected. Electrofishing is conducted by introducing electricity into the water. Fish that are intercepted by the electric field are either immobilized or drawn toward one of the electrodes, where they are netted. Electrofishing gear is manufactured for mounting on a boat, or carried on the back. Boat mounted gear is used in lakes or large rivers. Backpack electrofishing gear is used to sample small rivers and streams or other shallow water. It is carried by a biologist, who, with assistance from other waders, nets the fish captured in the electric field.

Passive gear works by taking advantage of fish movements and includes trap nets and gill nets. Trap nets function by leading the fish along a blocking net (usually set perpendicular to shore) through a series of funnels into a holding area. The fish are netted out of the holding area. Gill nets, which are suspended in open water areas, entangle fish that attempt to swim through them. Gill nets and trap nets typically are used in lakes, reservoirs, or slow-moving rivers. The size or the openings in both gill and trap nets can be pre-selected to capture the size and species of fish sought. Other passive gear includes radio-telemetry, photography, sound, and other high tech devices that count or otherwise detect fish without capture.

Most of these sampling techniques require special training and permits so they are not recommended as ways for Master Naturalists to study fish. Master Naturalists can observe fish in streams and rivers using techniques like snorkeling and other visual observation devices.

## Basic Principles of Fisheries Management

Depending on who you are talking with, fisheries management can mean many things. To private landowners, it may mean fish stocking in their small ponds. To members of Trout Unlimited, it may mean removal of introduced trout species from their favorite native brook-trout stream. To bass anglers on a Virginia reservoir, it may mean highly restrictive size limits on harvest to help develop a trophy fishery. To concerned consumers, it may mean government or international regulation of commercial fishermen to help improve the over-harvested state of most global fish stocks. These stakeholders have something in common: they want to see an improvement in a particular fishery, and they look to fisheries managers to bring about that improvement. A **fishery**, then, is *a system wherein users harvest some type of benefits from aquatic organisms*. And that brings us to a working definition for **fisheries management:** the intentional manipulation of fish stocks and related factors to produce benefits important to human users. Fisheries management occurs at the intersection of three important dimensions of a fishery:




Fish populations themselves are the most obvious emphasis in fisheries management programs, but we don't have a fishery unless we have people using the resource in some way. It may be the typical consumptive use, where the benefits to people are the fish harvested. But there are many examples of benefits that people gain from fisheries without harvesting the fish (e.g., catch-and-release fisheries or members of conservation organizations who derive a psychological benefit from knowing that our aquatic ecosystems are healthy). Directing the use of fish populations by people constitutes a powerful and important tool for fisheries managers. Additionally, sustainable fish populations cannot exist without the proper habitat (for spawning, feeding, hiding from predators, etc.), so habitat management can be a critical component of management programs. Let's look more closely at each of these management areas in the context of typical fisheries management programs in Virginia.

### Fish populations

The direct manipulation of fish populations to improve fisheries can take many forms. Since the dawn of fish culture in the U.S. in the 1800s (note: fish culture started in Asia over 2000 years ago!), fish stocking has been thought of as perhaps the primary tool for fisheries managers to improve fish populations. Stocking can take three different approaches (as illustrated in Table 1), and each approach has associated objectives and costs. Fish stocking is only a small part of effective management, and fisheries managers also perform many other actions to influence and improve fish populations. These actions are used to alter one of three dynamics of fish populations: mortality, recruitment, and growth. For instance, managers may take steps to reduce unwanted fish species by increasing mortality through harvest (i.e. common carp or overabundant sunfish in ponds, lampreys in the Great Lakes, snakeheads in the Potomac River, or non-native rainbow and brown trout in native brook trout streams). Managers may increase survival of small, juvenile fish and increasing their recruitment to adults through minimum size limits in areas where fish harvest is high. Managers may try to increase fish growth by adding fish feeders in small ponds, which is rarely effective due to cost. Poor condition or growth of fish can also be attributed to improper harvest, which brings us to the second factor of emphasis for fisheries management actions.

### Resource users

Users obviously have a direct impact on any resource that they use, and fisheries are no exception. Most global fisheries are in poor condition because too many people are harvesting harvesting more fish than the given fish populations can sustain. Fish are being harvested before they have a chance to reach optimum sizes or, in many cases, even reach reproductive size. Freshwater fisheries in the U.S. are in much better shape than most global fisheries because management programs have been in place to control harvest and other user actions for decades. Management of fishery users typically takes the form of restrictive regulations and are generally designed to reduce the impacts of harvest on fish populations, spread the sustainable harvest between more anglers, or to protect particularly sensitive species or populations. Table 2 lists some typical approaches to the use of regulations in Virginia and other states. Fisheries managers also survey anglers frequently to assess their desires for and satisfaction with fishing opportunities. This gives managers valuable information to adjust their management plans for various bodies of water.

### Critical Habitat

Different types of habitats are critical for various life stages of fish. Natural stream channels provide lots of habitat variety for fish (pools, riffles, runs, boulders, woody debris, etc.), but human activities often modify stream habitats by altering stream channels and flow, usually to reduce flooding problems in human habitats. Fisheries managers may try to return sections of streams to a more natural state, which generally increases habitat diversity and improves fish populations and fishing opportunities. Fisheries managers in Virginia also face issues of habitat quality in standing waters. Given that there are only two natural lakes in Virginia (Mountain Lake, and Lake Drummond), most of what we think of as “lakes” in Virginia are actually human-made impoundments. These impoundments were often cleared of standing forests before impoundment, so many impoundments have very limited fish habitat. The same is true for many small ponds, which often are formed in pasture areas. In both these cases, fish populations can benefit from the placement of habitat enhancements, such as simple brush shelters, old Christmas trees, etc. In rare cases, ponds and impoundments may suffer from an overabundance of structure, in the form of dense aquatic weed beds. While these plants may enhance survival of small fish, they often lead to stunted prey fish populations and unhappy anglers and other lake users. A variety of measures are used to control overabundant aquatic weeds, including mechanical removal, chemical treatment, and the stocking of grass carp (an herbivorous fish). Table 3 lists some examples of typical fisheries management actions involving habitat.

## Integrating Management Factors: Examples from Small Ponds in Virginia

The management challenges of small ponds offer the perfect example to demonstrate the interaction of the three components of fisheries management. All small ponds are not alike and the owner’s desires often determine management goals, but let’s look at some common scenarios experienced with small ponds in Virginia.

### Fish populations

Landowners with new ponds typically consult one of the many available pond management guides. Stocking rates for new ponds vary depending on management goals, but for a balanced fishery goal typically 500 bluegill or redear sunfish per acre are stocked in the first summer or fall, followed by 50 fingerling largemouth bass per acre the following year (introductory stocking).To increase variety in sportfishing opportunities, channel catfish are often added as a maintenance stocking (50 per acre, every other year).

### Resource users

Fishing on small ponds is popular, particularly for children. A well-balanced pond can easily withstand moderate fishing pressure, particularly if if largemouth bass harvest is monitored and regulated. It is very easy to overharvest bass from a small system, which results in an unbalanced fish population, stunted sunfish, and unhappy anglers. Alternatively, small ponds can become unbalanced with stunted largemouth bass with no harvest of the predator species. Small ponds typically support a standing crop of approximately 40 pounds per acre of sunfish and 10 pounds per acre of largemouth bass. Considering that less than 50 percent of the bass population may be of harvestable size, you only need to harvest a few large fish to throw a small pond (e.g., one to two acres) out of balance. Typically, bass harvest should be matched to sunfish harvest. If a pound of bass is removed, then at least four to five pounds of sunfish should be removed to maintain the predator/prey balance. If this is not done, sunfish can quickly overpopulate and stunt in size, interfering with bass reproduction, and the quality of the fishing will decline even further. At that point, the options are to correctively stock adult largemouth bass (which is very expensive), harvest large numbers of bluegill (which is often unachievable), or to renovate the pond and start over with new stockings. In the long run, it is easiest to maintain pond balance by practicing strictly regulating user harvest of bluegill and largemouth bass in small ponds. Maintaining a healthy bass population can also produce sunfish of exceptional size, which provides lots of fishing enjoyment and allows harvesting without harming the balance of the pond. The main point here is that improper use of the resource by users can result in ecological problems that can only be corrected by direct action on the fish population by managers.

### Habitat management

The most common habitat problem on small ponds is overabundant aquatic plants. This problem typically results from improper pond design (the pond is too shallow, or the banks do not have sufficient slope), and input of excess nutrients into the pond. Nutrients are often a problem when the pond is in an agricultural watershed, or when lawn fertilizers or sewage find their way into a pond. The only permanent solution is to cut off the flow of nutrients, but this often is not feasible. Pond owners are faced with using other methods to control nuisance aquatic vegetation. They may treat with chemicals (a very expensive proposition for rooted aquatic plants, but more reasonable for algae problems such as filamentous species), but this approach must be repeated every few years as the problem vegetation returns. A less costly solution for problems with some rooted vegetation is to stock an herbivorous fish species, the grass carp. Grass carp (stocked at rates between two and 15 fish per vegetated acre) can effectively control certain problem plants. Be aware that in Virginia only "certified triploid" grass carp (fish that have been genetically modified to prevent reproduction) can be stocked, and a permit is required from the Virginia Department of Wildlife Resources. Grass carp need to be stocked periodically to maintain vegetation control capacity of the population due to natural mortality and the reduced feeding efficiency of larger carp. Stocking grass carp can solve one problem (overabundant rooted vegetation) but can create another (poor survival of newly hatched fish, who need some type of cover to hide from predators). In this case, effective cover for young fish can be provided with brush or Christmas trees placed along the shoreline in shallow water.

## Summary

Fisheries management is a science that touches not just anglers, but all people interested in aquatic habitats. Effective fishery managers must appreciate all three dimensions of a fishery (the fish population, the resource users, and the importance of critical habitat) if they are to be successful. Most people think first of fish when they think about fishery management, but in truth it is the resource users who have the most impact on the character and success of a fishery. We need to remember that without the resource users, there really would be no fishery, or a need for fishery management.

Table 1: Examples of stocking types used in Virginia fisheries.

| Type of Stocking | Objective and Costs | Examples |
|---|---|---|
| **Introductory stocking** | A single or few introductions to establish a self-sustaining population; limited cost (one-time management expense). | Brown trout in the Smith River: An introduced species reproducing naturally.<br><br>Smallmouth bass in the New and James rivers: Introduced populations spawning naturally and supporting popular fisheries.<br><br>Gizzard shad in numerous reservoirs statewide: Provide forage for sport fishes. |
| **Supplemental stocking** | Intermittent stocking to supplement limited natural reproduction (ongoing moderate expense). | Muskellunge in the James and New rivers: Stocked regularly in relatively small numbers; populations also are likely supported by limited natural reproduction. |
| **Maintenance stocking** | Continual stocking to maintain a population that cannot reproduce naturally; cost is very high, and can only be justified when abundant benefits are produced. | Striped bass in Smith Mountain Lake: Thousands are stocked annually to maintain a popular fishery.<br><br>Rainbow trout in put-and-take streams: Habitat does not allow reproduction and year-round survival. |

Table 2: Examples of fishery regulations used in Virginia and other fisheries.

| Type of Regulation | Objective | Examples |
|---|---|---|
| **Fishing license** | Provide information on angler numbers and funding for management programs. | Statewide freshwater license<br><br>Saltwater recreational license<br><br>Various saltwater commercial licenses |
| **Restrictive size limits** | Protect fish until they can reach spawning age or size or some target length or length range to produce a desirable size structure in the population. | 14”-24” slot limit for largemouth bass in Briery Creek Lake: Bass in this size range must be returned alive, in order to build a trophy bass population.<br><br>42” minimum size for muskellunge on the New River: Intended to build a trophy population.<br><br>No size limits on crappie and bluegill statewide, because most sunfish are breeding by the time they are 2 years old. |
| **Creel (bag) limits on harvest** | Spread the total allowable harvest between a large number of anglers. | Daily limits of 50 bluegill and 25 crappie on most public waters in Virginia.<br><br>Daily limit of 2 striped bass on Smith Mountain Lake. |
| **Catch-and-Release** | Protect sensitive populations, allow limited escapement for spawning, or preserve limited benefits for more anglers. | American shad in sections of the James and Pamunkey rivers.<br><br>Trout on special sections of the Dan, Rapidan, and Holston rivers. |
| **Closed seasons** | Reduce disturbance of spawning fishes. | No closed seasons are used in Virginia and most other southern states.<br><br>Closed seasons to reduce disturbance of spawning fishes are common in some northern states. |

Table 3: Examples of fisheries habitat improvement techniques.

| Habitat Improvement Action | Objective | Examples |
|---|---|---|
| **Control of nuisance aquatic weeds** | Improve access for boaters and anglers. | Limited chemical spraying at Claytor Lake<br><br>Stocking of grass carp at Lake Gaston |
| **Leaving standing timber in reservoirs at the time of construction** | Provide cover for fish and improve fishing by concentrating fish. | Briery Creek Lake<br><br>Lake Moomaw<br><br>Nottoway Lake |
| **Installing brush shelters (Christmas trees, alder bundles, stump placement)** | Provide cover for small fish to improve survival and improve fishing by concentrating fish. | Christmas trees sunk in Claytor Lake and Hungry Mother Lake |
| **Large woody debris and boulders placed in streams** | Improve habitat for trout and other stream species; create cover from current, pools, etc. | North River |
| **Fertilization of small ponds** | Increases phytoplankton and zooplankton densities and fish carrying capacity; can decrease weed problems by blocking sunlight, but can *increase* weed problems if done improperly. | Lake Orange<br><br>Lake Brittle |
| **Liming** | Reduce the effects of acid precipitation. | Laurel Bed Lake<br><br>St. Mary's River |

## Glossary

**Adipose Fin –** A fleshy fin located between the dorsal (back) and caudal (tail) fins of catfish, trout and salmon (*Salmonidae*), and trout perch (*Percopsidae*).

**Anthropogenic –** Pertains to the environmental influence of human activities.

**Anadromous –** Lives adult life in saltwater, spawns in freshwater.

**Anadromous Migrations** – Migrations where adult fish move from the ocean to freshwater to spawn, and juvenile fish move from freshwater to saltwater to feed and grow to adulthood.

**Anal Fin –** A fin that runs along the midline of the bottom of a fish near the anus.

**Barbel –** One of the slender, whiskerlike tactile organs extending from the head of certain fishes, such as catfishes.

**Benthic –** Of the bottom, refers to organisms that inhabit the bottom substrate, infrequently swimming above it.

**Bioaccumulate –** The process by which chemical contaminants increase in concentration as they move through the food chain (by concentrating in predators that eat contaminated prey items).

**Catadromous –** Fish that live in fresh water but migrate to saltwater to breed.

**Catadromous Migrations –** Migrations where adult fish move from freshwater to the ocean to spawn, and juvenile fish move from the ocean to freshwater to feed and grow to adulthood.

**Caudal Fin –** A fin at the posterior end of the body of a fish (also known as the tail fin).

**Caudal Peduncle –** The tapering portion of a fish's body between the posterior edge of the anal fin base and the base of the caudal fin.

**Chloride Cells –** Specialized cells in the gills that can pump salt into or out of a fish's body against the concentration gradient.

**Compressiform –** Flattened laterally, or from the sides.

**Ctenoid Scales –** Fish scales with an exposed margin resembling the teeth of a comb.

**Cycloid Scales –** Fish scales that are rounded with a smooth edge.

**Depressiform –** Flattened dorsoventrally or from the top and bottom.

**Detritus –** Organic material typically deposited on the bottom of a waterbody.

**Dorsal –** Referring to the back or upper body of a fish.

**Dorsal Fin –** A median fin that runs down the center of the dorsal (back) region of a fish.

**Ecological Integrity –** A living system that sustains and organizes self-correcting ability to recover from disturbance toward an end-state that is normal for that system. End-states other than the pristine or natural whole may be accepted as normal and good.

**Ecosystem –** The interacting system of a biological community and its nonliving environmental surroundings.

**Effluent –** Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc. Emarginate – A fin margin that is slightly concave in at the outer edge.

**Emergent Contaminants –** Any synthetic or naturally occurring chemical or any microorganism that is not commonly monitored in the environment but has been recently detected in the environment.

**Endangered Species –** A species in danger of extinction throughout most of its range.

**Endemic –** Restricted in occurrence to a particular and usually relatively small area.

**Exotic Species –** A species accidentally or intentionally introduced into areas beyond their native, natural geographic range.

**Extirpated –** A species that has been eliminated from a particular area, but still exists somewhere else.

**Fin Rays –** Bony spines supporting the soft membrane of a fish's fin.

**Fishery** – A system wherein users harvest some type of benefits from aquatic organisms.

**Fisheries Management** – The intentional manipulation of fish stocks and related factors to produce benefits important to human users.

**Floodplain** – The flat or nearly flat land along a river or stream or in a tidal area that is covered by water during a flood.

**Frenum** – Skin-covered tissue that links the snout to the center area of a fish's upper lip.

**Fusiform** – Fast-swimming, open-water fishes that are streamlined and elliptical in cross-section.

**Ganoid Scales** – Scales found on sturgeon and gar that are armorlike, since they consist of bony plates covered with layers of dentine and enamel.

**Generalist** – Animal that can live in a variety of habitats and utilize several different food sources, usually referred to as tolerant species.

**Gill Arches** – The bony structures that hold the gill filaments.

**Gill Filaments** – The red gill tissue where oxygen and carbon dioxide exchange happens.

**Gradient** – The ratio of drop per unit distance, indicating flow conditions in a stream or river.

**Gular** – A large bony plate positioned under the bottom jaw of such primitive fish as the bowfin.

**Heterocercal** – A type of caudal fin that has the vertebral column extending into the upper lobe of the caudal fin. A primitive type of tail found on sturgeon.

**Hyperosmotic** – The condition of having body tissues more salty than the surrounding water. Freshwater fish are hyperosmotic.

**Hyposmotic** – The condition of having body tissues less salty than the surrounding water. Saltwater fish are hyposmotic.

**Imbricated Scutes** – A large, thick scale or plate that has been adapted for body protection. The term imbricated refers to the fact that these scales overlap in a regular pattern.

**Indeterminate Growth** – The situation whereby an organism continues to grow its entire life, as long as food is available, without ever reaching a maximum adult body size. Fish show indeterminate growth, but most other organisms do not.

**Inferior Mouth** – One with an opening under the head, with the upper jaw protruding well out in front of the lower jaw.

**Intromittent** – An external reproductive organ used in copulation.

**Karst** – An area with limestone geology, expressed in sinkholes, caves, and springs.

**Lateral** – The side (between the dorsal and ventral surfaces).

**Lateral Line System** – A sense organ running along the side of a fish's body that is capable of detecting pressure waves in the water. This system is used to detect moving objects in the water and to coordinate schooling behavior.

**Life History Strategies** – A set of behaviors used to complete important parts of the life cycle such as finding a mate, rearing young, and obtaining food.

**Macroinvertebrate** – Animals without a backbone that can be seen without a microscope.

**Myomeres** – Fish muscles.

**Nocturnal** – Active at night.

**Nonindigenous** – Not native to a given area.

**Nonpoint Source Pollution** – Diffuse pollution sources (i.e. without a single point of origin or not introduced into a receiving stream from a specific outlet).

**Operculum** – The gill cover of a fish.

**Osmogregulation** – The process by which an organism maintains the correct balance of salt and water in its tissues.

**Otoliths** – A structure of the inner ear of some animals, such as fish, that is made of calcium carbonate. It allows the animal to detect changes in orientation.

**Pectoral Fin** – Either of the anterior pair of fins attached to the pectoral girdle of fishes, corresponding to the forelimbs of higher vertebrates.

**Pelagic** – The open water area of a lake or reservoir.

**Pelvic Fin** – Either of a pair of lateral hind fins of fishes, attached to the pelvic girdle and corresponding to the hind limbs of higher vertebrates.

**pH** – A measure of the acidity or alkalinity of a solution on a scale of 1 to 14, with a value of 7 being neutral. Values less than 7 are acidic, and values greater than 7 are alkaline.

**Pharyngeal** – Throat area (between the head and the body cavity).

**Piscivore** – A fish eating animal.

**Pollutant** – Any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.

**Pseudobranchae** – A small patch of vascularized gill filaments attached to the inner region of the gill cover. Pseudobranchae are found in species of the Moronidae family.

**Pterygiophore** – A bone used to raise and lower rays and spines in the fins.

**Rays** – Soft, branched filaments used to stiffen fin tissue.

**Riparian** – Area of vegetation along a river or stream corridor that offers wildlife habitat and helps absorb runoff from the land during storm events, generally regarded as relatively narrow compared to a floodplain.

**Roe** – The eggs or the egg-laden ovary of a fish.

**Runoff** – That part of precipitation, snowmelt, or irrigation water that flows from the land into streams or other surface water, often carrying pollutants.

**Scute** – A large, thick scale or plate that has been adapted for body protection.

**Sediment** – Soil, sand, and minerals washed from land into water, usually after rain.

**Specialist** – Animal that requires a specific habitat or prey to survive, also generally referred to as an intolerant species.

**Species Richness** – The measure of an ecosystem's biodiversity, determined by counting the number of species in a given area, also known as species diversity.

**Spines** – Hard, boney-like filaments used to stiffen fin tissue.

**Stream Capture** – A phenomenon caused by geologic activity, whereby a stream leaves its own bed and flows down the bed of a neighboring stream.

**Subterminal Mouth** – Fishes with an upper jaw reaching slightly beyond the lower jaw.

**Superior Mouth** – Fishes with a lower jaw projecting beyond the upper jaw.

**Swim Bladder** – A gas-filled hollow organ lining the body cavity, used to help the fish maintain neutral buoyancy in the water.

**Terminal Mouth** – Fishes with jaws that are relatively even in length and meet at a point at the tip of the head.

**Thoracic** – The ventral surface behind the head of the fish, below the pectoral fin bases. The pelvic fins are sometimes located here.

**Threatened Species** – A species likely to become endangered in the immediate future.

**Ventral** – Bottom or underside of an organism.

**Weberian Apparatus** – A chain of small bones that connects the auditory system to the gas bladder of fishes, allowing the transmission of vibrations to the inner ear of some fish.

**Zoogeography** – The study of distribution patterns of animals and the processes that regulate their distribution.

**Study and Review Questions**

1. What ichthyologist described the majority of Virginia's fishes?
2. How many fish families and how many fish species are found in Virginia?
3. What system in fish is their primary means of sensing touch?
4. What are two life history strategies used by Virginia fishes?
5. What is the greatest threat to Virginia fishes and their habitats?
6. Name a federal or state threatened fish mentioned in this chapter.
7. Name a method used by biologists to study fish mentioned in this chapter.
8. Fisheries management occurs at the intersection of what three important dimensions of a fishery?

# Additional Resources


American Sportfishing Association. 2023. Economic Contributions of Recreational Fishing - Virginia. Available from https://asafishing.org/wp-content/uploads/2023/03/Virginia/2023_ASA_Senate_Handout_Digital_Virginia.pdf.

American Sportfishing Association. 2018. Sportfishing in North America: An Economic Engine and Conservation Powerhouse. Available from https://asafishing.org/wp-content/uploads/2019/02/Sportfishing-in-America-Revised-November-2018.pdf.

Bond, C.E. 1996. *Biology of Fishes*. Brooks/Cole, London.

Bryan , C.F. and D.A. Rutherford, editors. 1993. *Impacts on warmwater streams: guidelines for evaluation*, Second Edition. Southern Division, American Fisheries Society.

Bugas, Jr., P. E., C. D. Hilling, V. Kells, M. J. Pinder, D. A. Wheaton, and D. J. Orth. 2019. Field Guide to Freshwater Fishes of Virginia. Johns Hopkins University Press, Baltimore, MD.

EFISH: The Virtual Aquarium. Department of Fish and Wildlife Conservation, Virginia Tech. https://www.efish.fishwild.vt.edu.

Gilbert, C.R. and J.D. Williams. *National Audubon Society Field Guide to Fishes North America*. 2002. Chanticleer Press, Inc. New York, N.Y.

Hart, P.J.B. and J.D. Reynolds (eds). 2002. *Handbook of Fish Biology and Fisheries, Volume 1: Fish Biology*. Blackwell Publishing, Malden, Mass.

Helfrich, L.A., R.J. Neves, and J. Parkhurst. October 2003. *Sustaining America's Aquatic Biodiversity: Why Is Aquatic Biodiversity Declining?* Virginia Cooperative Extension publication 420-521. Available from https://www.pubs.ext.vt.edu/420/420-521/420-521.html.

Helfrich, L.A. and R.J. Neves. *Freshwater Fish Biodiversity and Conservation.* Virginia Cooperative Extension publication 420-525. Available from https://www.pubs.ext.vt.edu/420/420-525/420-525.html.

Hynes, H.B.N. 1970. *The Ecology of Running Water*. Liverpool University Press, Liverpool, England, U.K.

Jenkins, R.E. and N.M. Burkhead. 1993. *Freshwater Fishes of Virginia.* American Fisheries Society, Bethesda, Maryland.

Moyle, P.B., and J.J. Chach, Jr. 2003. *Fishes: An Introduction to Ichthyology*. Prentice Hall, Upper Saddle River, N.J.

Ney, J.J. and L.A. Helfrich. 2023. American Sportfishing Association. 2023. Economic Contributions of Recreational Fishing - Virginia. Available from https://asafishing.org/wp-content/uploads/2023/03/Virginia/2023_ASA_Senate_Handout_Digital_Virginia.pdf.

Richter, B.D., D.P. Braun, M.A. Mendelson, and L.L. Master. 1997. Threats to imperiled freshwater fauna. Conservation Biology 11:1081-1093.

Rohde, F.C., R.G. Arndt, D.G. Lindquist, and J.F. Parnell. *Freshwater Fishes of the Carolinas, Virginia, Maryland, and Delaware*. 1994. University of North Carolina Press, Chapel Hill, N.C.

Smith, C.L. 1994. *Fish Watching: An Outdoor Guide to Freshwater Fishes*. Cornell University Press, Ithaca, N.Y.

Waters, T.F. 1995. *Sediment in Streams: Sources, Biological Effects, and Control*. American Fisheries Society Monograph 7.

# Acknowledgments

This chapter was a major project of the Outreach Committee of the Virginia Chapter of the American Fisheries Society, a subunit of the American Fisheries Society, the world's oldest and largest organization promoting the scientific management of aquatic resources for the optimum use and enjoyment by the people of North America. A friendly review was provided by Don Orth. A major review was provided by Mike Pinder. Michelle Prysby compiled the edits for the 2025 update.

---

Visit our website: www.ext.vt.edu
Produced by Virginia Cooperative Extension, Virginia Tech, 2025



VT/0425/CNRE-73P (CNRE-188P)