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Viewing the Status of Virginia's Environment Through the Lens of Freshwater Fishes

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ABSTRACT

We summarize a range of topics related to the status of Virginia's freshwater fishes, their reflection of environmental quality, and their contribution to human wellbeing. Since 1994 the list of extant Virginia fishes has lengthened from 210 species to 227 species, mostly due to taxonomic reorganizations. Virginia's list of Species of Greatest Conservation Need currently contains 96 fish species, predominated by darters (32 species) and minnows (28 species). Increasing trends in species rarity and threats to fishes suggest that Virginia's aquatic environment is becoming less hospitable for fishes. Prevailing anthropogenic threats to fishes include agriculture, urban development, mineral extraction, forestry, and power generation; emerging threats include introduction of nonnative species and climate change. Agency assessments of Virginia's streams, rivers, and lakes indicate that over 40% of them are impaired and that dozens of these waterbodies have fishes that, if consumed by people, contain harmful levels of mercury and polychlorinated biphenyls. Multiple state agencies are responsible for managing Virginia's freshwaters and fishes to achieve objectives related to recreation, conservation, and environmental health. We close with a discussion of the challenges and opportunities associated with conserving Virginia's diverse fish fauna and identify several research, management, and outreach actions that may enhance conservation effectiveness.

INTRODUCTION

Freshwater fishes represent a substantial component of Virginia's rich natural heritage and are tightly interwoven into our economic, environmental, and cultural fabrics. With over 200 native species, Virginia's fish fauna far exceeds the average diversity among other states in the United States. One reason for this remarkable diversity is that the state is uniquely situated at the distributional crossroads of many southern, northern, eastern and western fish species. The importance of fishes to

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Virginians goes back centuries to connect with Native Americans and European colonists (McPhee 2002) but still holds true today, albeit in different ways. Whereas most early Virginians were connected to fishes primarily as a major source of food, most Virginians today are not. Instead, our main uses of freshwater fishes are related to recreation (e.g., sportfishing) and environmental monitoring. Of course, fishes are also an important source of natural beauty and knowledge for those who take the time to study them. In this paper, we focus on the insights that fishes offer regarding the condition of our precious water resources.

Fishes are excellent environmental monitors because they reflect conditions in the water bodies where they live; those conditions are strongly affected by how people use water and land nearby. Water bodies integrate environmental conditions in their watersheds and, in turn, fishes integrate the conditions of the water in which they live (Karr and Chu 1999). Ultimately, fishes' abilities to persist in a water body reflect the environmental conditions to which they are exposed. For example, human activities are shifting the spatial and temporal dynamics of the water cycle, accelerating the rates at which sediment and nutrients enter freshwaters, preventing some animals from migrating upstream and downstream, and altering river flooding patterns (Helfman 2007). Common practices that alter freshwater availability through time include building impoundments (especially those that regulate the release of water) and altering land cover. The many ways in which people use land and water affect water quality by altering a wide range of its physical, chemical, and biotic properties. Intensive uses of land and water, such as uses by large industries or many people, commonly diminish water quality. The regional and local status of freshwater fishes can teach us a lot about our performance as environmental stewards.

Below, we discuss a range of topics connecting Virginia's fishes to environmental quality and human wellbeing. We begin with a brief summary of ecological factors limiting fish distributions, then describe key recent changes to the state's fish fauna and its conservation status. We also devote considerable text to the prevailing anthropogenic threats to fishes and how fishes are used to measure stream health. We close with a summary of Virginia's regulatory framework germane to fish conservation and some thoughts on needs for fish conservation going forward.

FACTORS LIMITING FISH DISTRIBUTIONS

Well over 200 species of freshwater fish live among Virginia's water bodies, including streams, swamps, rivers, ponds, lakes and estuaries (Jenkins and Burkhead 1994; Figure 1). However, the particular species living in a water body vary greatly among locations, depending on a suite of factors that includes zoogeography, prevailing physicochemical conditions, dispersal abilities of fishes, interspecific interactions, and anthropogenic impacts. Many physicochemical factors collectively determine if a given water body is suitable for a given fish species, and each species has distinctive sensitivities to these factors. Further, these limiting factors vary naturally through space and time but can also be dramatically influenced by human uses of air, land, and water. Herein, we follow Jenkins and Burkhead (1994) and Jelks et al. (2008) in defining 'freshwater' fishes. This definition encompasses all fishes that commonly spend much of their life in fresh waters, including diadromous species.

Fishes are especially sensitive to water chemistry and temperature and most species have narrow ranges of chemistry and temperature under which they can thrive.

Chemical parameters such as pH, dissolved oxygen, nutrients, salinity, and a vast array of toxicants (e.g., metals, pesticides, chlorine) commonly limit fish distributions (Matthews 1998, Helfman 2007). Different tolerances to salinity distinguish most freshwater fishes from marine fishes but a few freshwater species, such as American Eel (*Anguilla rostrata*) and Striped Bass (*Morone saxatilis*), can adapt to very different ranges of salinity during certain life stages. Similarly, seasonally high or low water temperatures preclude coldwater or warmwater fishes, respectively, from occurring in certain water bodies.

In addition to being sensitive to properties of the water itself, fishes are also sensitive to the physical structure of water bodies, such as their size, slope, depth, movement, and bottom composition. Thus, species are differentially adapted to live and thrive in streams versus rivers, rivers versus lakes, rocky streams versus sandy streams, and other structural types of water bodies. Collectively, parameters of temperature, water chemistry, and physical structure are used to describe fish habitats; the availability of suitable habitat is a fundamental factor regulating species' distributions.

The types of habitat available to fishes can vary widely, so in turn the fish assemblages present at a locality also vary considerably among regions of Virginia. Each of the five physiographic provinces represented in Virginia (i.e., Appalachian Plateau, Ridge and Valley, Blue Ridge, Piedmont, and Coastal Plain) exhibit distinctive geology, topography, and land use, all of which promote distinctive arrays of habitat types and distinctive fish assemblages. Similarly, each of the ten major river drainages (i.e., Potomac, Rappahannock, York, James, Chowan, Roanoke, Peedee, New, upper Tennessee, and Big Sandy; see Jenkins and Burkhead 1994) is bounded by barriers to fish dispersal (e.g., ridge tops and ocean), which promote evolution of sibling species and differentiation among assemblages. Accounting for the various combinations of elevation (a surrogate for temperature), stream size, physiography, and river drainage, Virginia supports approximately 90 distinctive types of freshwater fish assemblage (Angermeier and Winston 1999).

Understanding natural patterns of habitat availability and fish distribution across Virginia is crucial to using fishes as a lens to interpret environmental quality. Readers interested in learning more about natural and anthropogenic factors that limit freshwater fish distributions, including patterns specific to Virginia, are encouraged to see Jenkins and Burkhead (1994), Matthews (1998), and Helfman (2007) for additional details.

CHANGES IN VIRGINIA'S FISH LIST SINCE 1994

Over 20 years ago, Robert Jenkins and Noel Burkhead authored the seminal volume on the systematics, morphology, biology, habitat, and distribution of Virginia's freshwater fishes (Jenkins and Burkhead 1994). In that volume they provided a thorough summary account for each of the 210 species known to occur in Virginia waters, including chronologies of taxonomic reorganizations, introductions, and extirpations.

Many changes in Virginia's freshwater fish fauna have occurred since Jenkins and Burkhead's book was published, largely due to introductions, discoveries, and taxonomic reorganization. In short, the list of extant Virginia fishes has lengthened from 210 species and 230 taxa (i.e., species, subspecies, and undescribed forms) to 227 species and 235 taxa (Tables 1 and 2). Two species have been introduced: Northern Snakehead (*Channa argus)* and Blackside Dace (*Chrosomus cumberlandensis*). One

TABLE 1. List of freshwater fish families and species known from Virginia. The order is taxonomic. Scientific names are followed by common names. Numbers in parentheses indicate species counts. "*" indicates a species is extirpated or extinct. "**" indicates a species name is not officially recognized by the American Fisheries Society (Page et al. 2013).

Petromyzontidae – Lamprey (5)
Ichthyomyzon bdellium – Ohio Lamprey
Ichthyomyzon greeleyi – Mountain Brook Lamprey
Petromyzon marinus – Sea Lamprey
Lampetra aepyptera – Least Brook Lamprey
Lethenteron appendix – American Brook Lamprey

Acipenseridae – Sturgeon (2)
Acipenser brevirostrum – Shortnose Sturgeon
Acipenser oxyrinchus – Atlantic Sturgeon

Polyodontidae – Paddlefish (1)
Polyodon spathula – Paddlefish

Lepisosteidae – Gar (1)
Lepisosteus osseus – Longnose Gar

Amiidae – Bowfin (1)
Amia calva – Bowfin

Anguillidae – Eel (1)
Anguilla rostrata – American Eel

Clupeidae – Herring (6)
Dorosoma cepedianum – Gizzard Shad
Dorosoma petenense – Threadfin Shad
Alosa aestivalis – Blueback Herring
Alosa pseudoharengus – Alewife
Alosa mediocris – Hickory Shad
Alosa sapidissima – American Shad

Esocidae – Pike (4)
Esox lucius – Northern Pike
Esox masquinongy – Muskellunge
Esox niger – Chain Pickerel
Esox americanus americanus – Redfin Pickerel

Umbridae – Mudminnow (1)
Umbra pygmaea – Eastern Mudminnow

Cyprinidae – Minnow (73; *1 extirpated)
Cyprinus carpio – Common Carp
Carassius auratus – Goldfish
Ctenopharyngodon idella – Grass Carp
Notemigonus crysoleucas – Golden Shiner
Chrosomus tennesseensis – Tennessee Dace
Chrosomus oreas – Mountain Redbelly Dace
Chrosomus cumberlandensis – Blackside Dace
Chrosomus sp. cf. *saylori* – Clinch Dace**
Clinostomus funduloides – Rosyside Dace
Rhinichthys cataractae – Longnose Dace
Rhinichthys atratulus – Blacknose Dace
Rhinichthys obtusus – Western Blacknose Dace**
Campostoma anomalum – Central Stoneroller
Campostoma oligolepis – Largescale Stoneroller
Margariscus margarita – Allegheny Pearl Dace
Semotilus corporalis – Fallfish
Semotilus atromaculatus – Creek Chub
Exoglossum laurae – Tonguetied Minnow
Exoglossum maxillingua – Cutlip Minnow
Nocomis platyrhynchus – Bigmouth Chub
Nocomis micropogon – River Chub
Nocomis raneyi – Bull Chub
Nocomis leptocephalus – Bluehead Chub
Erimystax cahni – Slender Chub
Erimystax dissimilis – Streamline Chub
Erimystax insignis – Blotched Chub
Phenacobius mirabilis – Suckermouth Minnow
Phenacobius teretulus – Kanawha Minnow
Phenacobius crassilabrum – Fatlips Minnow
Phenacobius uranops – Stargazing Minnow
Hybopsis amblops – Bigeye Chub
Hybopsis hypsinotus – Highback Chub
Erimonax monachus – Spotfin Chub
Cyprinella labrosa – Thicklip Chub*
Cyprinella galactura – Whitetail Shiner
Cyprinella whipplei – Steelcolor Shiner
Cyprinella analostana – Satinfin Shiner
Cyprinella spiloptera – Spotfin Shiner
Luxilus coccogenis – Warpaint Shiner
Luxilus cerasinus – Crescent Shiner
Luxilus albeolus – White Shiner
Luxilus cornutus – Common Shiner
Luxilus chrysocephalus – Striped Shiner
Lythrurus lirus – Mountain Shiner
Lythrurus ardens – Rosefin Shiner
Lythrurus fasciolaris – Scarlet Shiner
Notropis rubellus – Rosyface Shiner
Notropis micropteryx – Highland Shiner
Notropis leuciodus – Tennessee Shiner
Notropis rubricroceus – Saffron Shiner
Notropis chiliticus – Redlip Shiner
Notropis atherinoides – Emerald Shiner
Notropis amoenus – Comely Shiner
Notropis photogenis – Silver Shiner
Notropis semperasper – Roughhead Shiner

TABLE 1. Continued.

Notropis volucellus – Mimic Shiner
Notropis spectrunculus – Mirror Shiner
Notropis stramineus – Sand Shiner
Notropis procne – Swallowtail Shiner
Notropis alborus – Whitemouth Shiner
Notropis bifrenatus – Bridle Shiner
Notropis chalybaeus – Ironcolor Shiner
Notropis altipinnis – Highfin Shiner
Notropis buccatus – Silverjaw Minnow
Notropis scepticus – Sandbar Shiner
Notropis sp. – Sawfin Shiner**
Hybognathus regius – Eastern Silvery Minnow
Pimephales promelas – Fathead Minnow
Pimephales vigilax – Bullhead Minnow
Pimephales notatus – Bluntnose Minnow

Catostomidae – Sucker (19; *1 extinct)
Carpiodes cyprinus – Quillback Carpsucker
Erimyzon sucetta – Lake Chubsucker
Erimyzon oblongus – Creek Chubsucker
Hypentelium nigricans – Northern Hog Sucker
Hypentelium roanokense – Roanoke Hog Sucker
Thoburnia rhothoeca – Torrent Sucker
Thoburnia hamiltoni – Rustyside Sucker
Moxostoma sp. – Brassy Jumprock
Moxostoma cervinum – Blacktip Jumprock
Moxostoma ariommum – Bigeye Jumprock
Moxostoma duquesnei – Black Redhorse
Moxostoma macrolepidotum – Shorthead Redhorse
Moxostoma breviceps – Smallmouth Redhorse
Moxostoma erythrurum – Golden Redhorse
Moxostoma carinatum – River Redhorse
Moxostoma anisurum – Silver Redhorse
Moxostoma collapsum – Notchlip Redhorse
Moxostoma pappillosum – V-lip Redhorse
Moxostoma lacerum – Harelip Sucker*
Catostomus commersoni – White Sucker

Ictaluridae – Catfish (15)
Ictalurus furcatus – Blue Catfish
Ictalurus punctatus – Channel Catfish
Ameiurus catus – White Catfish
Ameiurus platycephalus – Flat Bullhead
Ameirus brunneus – Snail Bullhead
Ameiurus natalis – Yellow Bullhead
Ameiurus nebulosus – Brown Bullhead
Ameiurus melas – Black Bullhead
Noturus flavus – Stonecat
Noturus gilberti – Orangefin Madtom
Noturus insignis – Margined Madtom
Noturus gyrinus – Tadpole Madtom
Noturus flavipinnis – Yellowfin Madtom
Noturus eleutherus – Mountain Madtom
Pylodictis olivaris – Flathead Catfish

Salmonidae – Trout (3)
Salvelinus fontinalis – Brook Trout
Salmo trutta – Brown Trout
Onchorynchus mykiss – Rainbow Trout

Percopsidae – Trout-Perch (*1 extripated)
Percopsis omiscomaycus – Trout-perch*

Aphredoderidae – Pirate Perch (1)
Aphredoderus sayanus – Pirate Perch

Amblyopsidae – Cavefish (1)
Chologaster cornuta – Swampfish

Atherinidae – Silverside (1)
Labidesthes sicculus – Brook Silverside

Fundulidae – Killifish (5)
Fundulus heteroclitus - Mummichog
Fundulus diaphanus – Banded Killifish
Fundulus rathbuni – Speckled Killifish
Fundulus catenatus – Northern Studfish
Fundulus lineolatus – Lined Topminnow

Poeciliidae – Livebearer (1)
Gambusia holbrooki – Eastern Mosquitofish

Gasterosteidae – Stickleback (1)
Gasterosteus aculeatus – Threespine Stickleback

Cottidae – Sculpin (10)
Cottus bairdi – Mottled Sculpin
Cottus caeruleomentum –Blue Ridge Sculpin
Cottus baileyi – Black Sculpin
Cottus cognatus – Slimy Sculpin
Cottus sp. – Holston Sculpin**
Cottus sp. – Clinch Sculpin**
Cottus sp. – Bluestone Sculpin**
Cottus carolinae – Banded Sculpin
Cottus kanawhae – Kanawha Sculpin
Cottus girardi – Potomac Sculpin

Moronidae – Temperate Bass (3)
Morone americana – White Perch
Morone saxatilis – Striped Bass
Morone chrysops – White Bass

Centrarchidae – Sunfish (20)
Ambloplites rupestris – Rock Bass
Ambloplites cavifrons – Roanoke Bass
Acantharchus pomotis – Mud Sunfish
Centrarchus macropterus – Flier
Pomoxis annularis – White Crappie

TABLE 1. Continued.

Pomoxis nigromaculatus – Black Crappie
Enneacanthus obesus - Banded Sunfish
Enneacanthus gloriosus – Bluespotted Sunfish
Enneacanthus chaetodon – Blackbanded Sunfish
Micropterus dolomieu – Smallmouth Bass
Micropterus punctulatus – Spotted Bass
Micropterus salmoides – Largemouth Bass
Lepomis gulosus – Warmouth
Lepomis cyanellus – Green Sunfish
Lepomis auritus – Redbreast Sunfish
Lepomis megalotis – Longear Sunfish
Lepomis marginatus – Dollar Sunfish
Lepomis macrochirus – Bluegill
Lepomis gibbosus – Pumpkinseed
Lepomis microlophus – Redear Sunfish

<u>Percidae – Perch (50; *1 extirpated)</u>
Sander vitreus vitreus – Walleye
Sander canadensis – Sauger
Perca flavescens – Yellow Perch
Percina sciera – Dusky Darter
Percina oxyrhynchus – Sharpnose Darter
Percina burtoni – Blotchside Logperch
Percina rex – Roanoke Logperch
Percina caprodes – Logperch
Percina bimaculata – Chesapeake Logperch*
Percina williamsi – Sickle Darter
Percina maculata – Blackside Darter
Percina notogramma – Stripeback Darter
Percina gymnocephala – Appalachia Darter
Percina peltata – Shield Darter
Percina nevisense – Chainback Darter
Percina crassa – Piedmont Darter
Percina roanoka – Roanoke Darter
Percina evides – Gilt Darter
Percina aurantiaca – Tangerine Darter
Percina copelandi – Channel Darter
Ammocrypta clara – Western Sand Darter
Etheostoma cinereum – Ashy Darter
Etheostoma swannanoa – Swannanoa Darter
Etheostoma variatum – Variegate Darter
Etheostoma kanawhae – Kanawha Darter
Etheostoma osburni – Candy Darter
Etheostoma blennioides – Greenside Darter
Etheostoma zonale – Banded Darter
Etheostoma simoterum – Snubnose Darter
Etheostoma tennesseense – Tennessee Darter
Etheostoma stigmaeum – Speckled Darter
Etheostoma jessiae – Blueside Darter
Etheostoma longimanum – Longfin Darter
Etheostoma podostemone – Riverweed Darter
Etheostoma nigrum – Johnny Darter
Etheostoma olmstedi – Tessellated Darter
Etheostoma vitreum – Glassy Darter
Etheostoma camurum – Bluebreast Darter
Etheostoma chlorobranchium – Greenfin Darter
Etheostoma rufilineatum – Redline Darter
Etheostoma denoncourti – Golden Darter
Etheostoma acuticeps – Sharphead Darter
Etheostoma vulneratum – Wounded Darter
Etheostoma caeruleum – Rainbow Darter
Etheostoma flabellare – Fantail Darter
Etheostoma humerale – Chesapeake Fantail Darter
Etheostoma brevispinum – Carolina Fantail Darter
Etheostoma percnurum – Duskytail Darter
Etheostoma serrifer – Sawcheek Darter
Etheostoma fusiforme – Swamp Darter
Etheostoma collis – Carolina Darter

<u>Sciaenidae – Drum (1)</u>
Aplodinotus grunniens – Freshwater Drum

<u>Channidae – Snakehead (1)</u>
Channa argus – Northern Snakehead

species, Clinch Dace (*Chrosomus sp.* cf. *saylori*), was newly discovered, while 15 species emerged from taxonomic reorganizations (Table 2; Robert Jenkins, personal communication).

A few miscellaneous changes in the fish list are also noteworthy. First, Jenkins and Burkhead (1994) included "Smallfin Redhorse" (*Scartomyzon robustus)* in their book, but Robust Redhorse (*Moxostoma robustum*) was subsequently rediscovered and described, which invalidated the name "Smallfin Redhorse". As a result, "Smallfin Redhorse" is now called Brassy Jumprock (*Moxostoma sp.),* an undescribed species occurring in the PeeDee drainage. Second, we added Mummichog (*Fundulus heteroclitus)* to our list because it has a high tolerance to varying salinities and often

Table 2. List of freshwater fish species new to Virginia since the publication of Jenkins and Burkhead (1994), along with reasons for their addition.

Scientific name	Common name	Reason
Channa argus	Northern Snakehead	Introduced
Moxostoma breviceps	Smallmouth Redhorse	Elevated subspecies of *M. macrolepidotum*
Moxostoma collapsum	Notchlip Redhorse	Split from *M. anisurum*
Cottus caeruleomentum	Blue Ridge Sculpin	Split from *C. bairdi*
Cottus kanawhae	Kanawha Sculpin	Elevated subspecies of *C. carolinae*
Campostoma oligolepis	Largescale Stoneroller	Elevated subspecies of *C. anomalum*
Chrosomus sp. cf. *saylori*	Clinch Dace	New discovery
Chrosomus cumberlandensis	Blackside Dace	Introduced
Lythrurus fasciolaris	Scarlet Shiner	Elevated subspecies of *L. ardens*
Notropis micropteryx	Highland Shiner	Elevated subspecies of *N. rubellus*
Notropis specticus	Sandbar Shiner	New discovery
Rhinicthys obtusus	Western Blacknose Dace	Elevated subspecies of *R. atratulus**
Lepomis marginatus	Dollar Sunfish	New discovery
Etheostoma brevispinum	Carolina Fantail Darter	Elevated subspecies of *E. flabellare*
Etheostoma denoncourti	Golden Darter	Split from *E. tippecanoe*
Etheostoma humerale	Chesapeake Fantail Darter	Elevated subspecies of *E. flabellare*
Etheostoma jessiae	Blueside Darter	Elevated subspecies of *E. stigmaeum*
Etheostoma tennesseense	Tennessee Darter	Elevated from *E. simoterum*
Percina bimaculata	Chesapeake Logperch	Elevated subspecies of *P. caprodes*
Percina nevisense	Chainback Dater	Elevated from *P. peltata*

* - not yet accepted by American Fisheries Society

occurs in tidal freshwaters. Jenkins and Burkhead (1994) briefly discussed this species but omitted it from their list. Third, Dollar Sunfish (*Lepomis marginatus*) has been collected in Virginia since the late 1980s; it is presumably native, though rare and restricted in its range. Because this species was first discovered in Virginia as Jenkins and Burkhead (1994) was going to press, its account was omitted.

Our fish list also includes four species that are completely extinct (Harelip Sucker [*Moxostoma lacerum*]) or judged to be extirpated from Virginia: (Trout-perch [*Percopsis omiscomaycus*], Chesapeake Logperch [*Percina bimaculata*], and Thicklip Chub [*Cyprinella labrosa*]). The latter three species still occur in other parts of their historic ranges.

SPECIES DISTRIBUTIONS AMONG FAMILIES AND RIVER DRAINAGES

The distribution of Virginia's fish species among its 26 families mirrors that of the rest of the eastern United States. The most diverse families by far are Cyprinidae (minnows; 73 species) and Percidae (perches; 50 species), with Catostomidae (suckers), Ictaluridae (catfishes), Cottidae (sculpins), and Centrarchidae (sunfishes) also contributing 10-20 species each (Table 1).

The distribution of fish species among Virginia's ten major river drainages varies greatly, depending on drainage area, diversity of habitat types, and connection to the speciose Mississippi River basin. Drainages with larger area, more habitat types, and fluvial links to the Mississippi River tend to support more species than drainages with opposing features. The upper Tennessee drainage supports the most fish species (120), while the Peedee drainage supports the least (27; Table 3). Ranks of drainages, with respect to fish species numbers, are similar for total species versus native species. Native species predominate the faunas of most drainages. Exceptions include the New and Potomac drainages, where 51% and 32%, respectively, of the extant fish species are introduced (Table 3).

CONSERVATION STATUS OF VIRGINIA FISHES

The U.S. Fish and Wildlife Service (USFWS) and the Virginia Department of Game and Inland Fisheries (VDGIF) recognize 22 fish species as being significantly imperiled and have conferred protective status to those species (Table 4). A species is designated as "endangered" if it is currently in danger of extinction throughout all or a significant portion of its range. A "threatened" species is likely to become endangered within the foreseeable future (see http://www.fws.gov/endangered/laws-policies/index.html). All ten species with federal protective status also have state status. These designations aim to protect individual fish, their populations, and their habitat from harm. To assist with protecting habitats, the VDGIF maintains a database of Threatened and Endangered Species Waters, which includes locations where imperiled species have been documented.

Imperilment and eventual extinction do not occur randomly across fish species. Rather, species with certain traits are more likely to become imperiled than others. Among Virginia's fishes, traits that predispose species to imperilment include a) diadromy (i.e., use of freshwater and marine habitats during sequential phases of life history), b) small range of suitable physiographies or stream sizes, and c) food and habitat specialization (Angermeier 1995). Every species listed in Table 4 exhibits one or more of these traits. Most of Virginia's imperiled fishes are darters (nine species) or minnows (seven species; Table 4).

In addition to monitoring and protecting imperiled species, VDGIF also has developed a comprehensive wildlife conservation strategy – or Wildlife Action Plan (WAP) – for all Virginia wildlife, including fishes (VDGIF 2005). The plan is based on input from partners, stakeholders, and citizens, and aims to anticipate and prevent imperilment. The WAP summarizes information on a) locations, abundances, and habitat requirements of species; b) threats to species and habitats; c); potential management actions to conserve species; and d) research, survey, and monitoring needs. Expert biologists for each major taxon developed a list of Species of Greatest Conservation Need (SGCN), then assigned those species to one of four tiers reflecting degrees of conservation need: critical (Tier 1), very high (Tier 2), high (Tier 3), and moderate (Tier 4). These tiers enable managers to prioritize threats to species and associated conservation actions based on conservation need. The WAP was initially developed in 2005, then revised in 2015 to reflect updated knowledge of status and threat (http://www.bewildvirginia.org/wildlife-action-plan/draft/).

The SGCN list currently contains 96 fish species, predominated by darters (32 species) and minnows (28 species), the most diverse taxa in Virginia freshwaters.

TABLE 3. Numbers of total fish species, native species, and percentage of introduced species for each of the ten major river drainages in Virginia.

Drainage	Total species	Native species	% Introduced
Potomac	100	68	32.0
Rappahannock	80	66	17.5
York	76	57	25.0
James	107	80	25.2
Chowan	93	82	11.8
Roanoke	116	98	15.5
Peedee	24	18	25.0
New	89	44	50.6
Upper Tennessee	120	97	19.2
Big Sandy	51	39	23.5

Between 2005 and 2015, 45 species changed status, including those added or removed from the list and those changing tiers; the status of 62 species remained the same (Table 5). The number of Tier I species increased 55% in the 2015 assessment while the number of Tier II species decreased 40%. During the 2015 re-assessment, the most common justification for removing a species from the SGCN list or shifting it to a lower-need tier was the committee of experts' judgment (based on available data) that its abundance or number of locality occurrences had increased (11 species). Other justifications included a) the species was peripheral to Virginia waters (six species) and b) revisions in taxonomy or native range (two species). Conversely, the most common justification for adding a species to the SGCN list or shifting it to a higher-need tier was a judgment that the species' abundance or number of locality occurrences had decreased (14 species). Other justifications included a) threats to the species were increasing (six species) and b) revisions in taxonomy (five species). Even as we learn more regarding life history and distribution for several species (Argentina et al. 2013, Starnes et al. 2014, White and Orth 2014), the overall increasing trends in species' rarity and threats suggest that Virginia's aquatic environment is becoming less hospitable for fishes.

ANTHROPOGENIC THREATS TO VIRGINIA FISHES

A wide range of human activities can directly or indirectly harm freshwater fishes by impairing their reproduction, survival, or growth. The most pervasive and impact-

TABLE 4. Legal protective status for 21 fish species in Virginia. FE=Federal Endangered; FT=Federal Threatened; FP=Federal Proposed; SC=Federal Species of Concern (not a legal status); SE=State Endangered; ST=State Threatened. "WAP tier" refers to designations of conservation need in Virginia's Wildlife Action Plan: I=critical; II=very high; III=high; and IV=moderate. Tiers do not confer legal status (see VDGIF 2005). Blank entries indicate no status.

Common Name	Scientific name	Federal status	State status	WAP tier
Atlantic Sturgeon	*Acipenser oxyrinchus*	FE	SE	I
Blackbanded Sunfish	*Enneacanthus chaetodon*		SE	I
Carolina Darter	*Etheostoma collis*		ST	II
Duskytail Darter	*Etheostoma percnurum*	FE	SE	I
Emerald Shiner	*Notropis atherinoides*		ST	IV
Golden Darter	*Etheostoma denoncourti*	SC	ST	II
Greenfin Darter	*Etheostoma chlorobranchium*		ST	I
Orangefin Madtom	*Noturus gilberti*	SC	ST	II
Paddlefish	*Polyodon spathula*		ST	IV
Roanoke Logperch	*Percina rex*	FE	SE	II
Sharphead Darter	*Etheostoma acuticeps*		SE	I
Shortnose Sturgeon	*Acipenser brevirostrum*	FE	SE	I
Sickle Darter	*Percina williamsi*		ST	I
Slender Chub	*Erimystax cahni*	FT	ST	I
Spotfin Chub	*Erimonax monachus*	FT	ST	I
Steelcolor Shiner	*Cyprinella whipplei*		ST	III
Tennessee Dace	*Chrosomus tennesseensis*		SE	I
Variegate Darter	*Etheostoma variatum*		SE	I
Western Sand Darter	*Ammocrypta clara*		ST	IV
Whitemouth Shiner	*Notropis alborus*		ST	II
Yellowfin Madtom	*Noturus flavipinnis*	FT	ST	I

TABLE 5. Status summary of Virginia fish species in the Wildlife Action Plan (WAP; VDGIF 2005). The WAP assigns each Species of Greatest Conservation Need to one of four tiers: I=critical; II=very high; III=high; and IV=moderate. Assignations were determined by expert fish biologists. The WAP was initially developed in 2005, then revised in 2015. Entries are numbers of species.

Status	2005	2015
Tier I	11	17
Tier II	15	9
Tier III	18	18
Tier IV	53	50
Total	97	94
Added	--	10
Need increased	--	16
Removed	--	13
Need decreased	--	6
Unchanged	--	62

prone of such activities, such as intensive uses of land and water, are performed for economic benefits (Czech 2000, Czech et al. 2000). As human populations and their resource consumption continue to increase, so will the magnitude of anthropogenic impacts, which could ultimately threaten the existence of many fish species (Burkhead 2012). Natural and anthropogenic factors interact to limit the success of individual fish, which translates into effects on population persistence and assemblage composition. The hundreds of potential anthropogenic impacts on fishes can be categorized as those that affect water quality, habitat structure, flow regime, energy and food dynamics, and biotic interactions (Karr et al. 1986). Any intensive use of water or land is likely to shift one or more of these categories away from natural conditions, thereby altering a fish species' ability to thrive. To the extent that human activities make an aquatic environment less suitable for the fishes naturally occurring there, that activity can be considered a threat to fishes.

The most common economic activities that threaten fishes in Virginia include agriculture, urban development, mineral extraction (especially coal mining [Stauffer and Ferreri 2002, Hill and Chambers 2014]), forestry, and power generation (Tables 3.19 and 3.23 in VDGIF [2005]). Notably, these activities occur primarily on land upslope of water bodies, as opposed to in the water bodies themselves (an exception is hydropower generation). The most harmful by-products of these activities, which typically flow downslope into streams, include a) excessive fine sediment (i.e., clay and silt), b) excessive nutrients (i.e., nitrogen and phosphorus), and c) industrial toxins (e.g., synthetic organics, herbicides, and insecticides) (Tables 3.19 and 3.21 in VDGIF [2005]). Some economic activities also involve direct structural changes to water bodies, such as channelizing streams, hardening shorelines, and building dams or culverts; other activities directly manipulate flow regimes, such as reducing overall discharge or increasing temporal variation in discharge. Such changes often lead to decreases in habitat suitability and/or increases in habitat fragmentation for fishes (Helfman 2007). The threats described above have been common in Virginia for decades and instrumental in causing fish imperilment. For example, impacts of agriculture, urban development, coal mining, forestry, dams, and industrial pollution were all cited in 1995 as contributing to the decline of one or more of the following State-Endangered species: Sharphead Darter (Smogor et al. 1995a) and Tennessee Dace (Smogor et al. 1995b). Furthermore, impacts stemming from urban development and industrial pollution seem likely to expand in the foreseeable future, as urbanization continues its rapid growth around northern Virginia, Richmond, Norfolk, Virginia Beach, and Lynchburg and along interstate highways 95 and 64 (VDGIF 2005).

Anthropogenic threats to, and impacts on, aquatic biota may interact in complex ways. First, a single source (e.g., urban development) can cause multiple impacts mediated via adverse effects on water quality, habitat structure, flow regime, energy and food dynamics, and/or biotic interactions (Wheeler et al. 2005). For example, some effects of urbanization may be direct and obvious, such as fish kills from point-source industrial effluents, whereas other effects may be indirect and obscured, such as reduced population abundance resulting from impaired reproduction, growth, and survival due to stressful flow and temperature regimes and excessive fine sediment. Second, multiple sources of biotic impact can interact to exacerbate their respective impacts on fishes. For example, effects of urbanization and climate change are likely to interact synergistically, so that impacts on Virginia fish populations are greater than if only one of the two sources were contributing (Nelson et al. 2009). Finally, anthropogenic impacts typically accrue and manifest over a range of spatiotemporal frames. Unfortunately, the protocols conventionally used by state and federal agencies to assess environmental impacts largely ignore large-scale, long-term impacts of activities such as road building and urban development, which often impose serious impacts on aquatic ecosystems (Angermeier et al. 2004).

Another pervasive threat to native freshwater biota that has garnered much attention by researchers and managers over the past few decades is the introduction of nonnative species, including parasites, predators, and competitors. Historically, fishes were most commonly introduced via government-sanctioned stocking (e.g., for sport-fishing or biocontrol) but fish introductions due to aquarium release, bait release, and escape from aquaculture are now more prevalent in the mid-Atlantic region of the U.S. (Lapointe et al. 2016). Recent examples germane to Virginia fishes include a) *Anguillicola crassus*, a parasitic nematode that originated in Asia but now infects swim-bladders of American Eel in much of its range (Barse and Secor 1999); b) Northern Snakehead (*Channa argus*), a large piscivorous fish that originated in Asia but now occurs in the Potomac and Rappahannock river drainages (Odenkirk and Owens 2005); and c) Variegate Darter (*Etheostoma variatum*), which is State-Endangered in Virginia but was illegally introduced into streams of the New River drainage in West Virginia, where it seems to be supplanting Candy Darter (*Etheostoma osburni*) (Switzer et al. 2007). Candy Darter is endemic to the New River drainage and a Tier 1 species on Virginia's SGCN list. If Variegate Darter spreads or is introduced to streams supporting Candy Darter in Virginia, Candy Darter may become increasingly imperiled.

Introductions of nonnative fishes are common across the United States (Nico and Fuller 1999, Rahel 2000), including Virginia, but their general severity as a risk to native biota, as well as how to manage them, are still debated (Leprieur et al. 2009, Gozlan et al. 2010). In some cases, ecological and/or economic impacts are clearly significant (Vitule et al. 2009) but standard methods for quantifying impact are lacking (Lapointe et al. 2012a). Managing introduced fishes is complicated by great variation in the propensity for particular species to become invasive and in the susceptibility of particular ecosystems to invasion. Across river basins of the Mid-Atlantic region of the United States, which includes Virginia, the number of nonnative fish species is positively correlated with colonization (i.e., propagule) pressure and range in elevation (Lapointe et al. 2012b). Montane basins in the Mid-Atlantic region have more nonnative species, in part due to their greater habitat heterogeneity induced by the widespread lentic habitats formed by impoundments.

As is the case for other anthropogenic threats to fishes, most introductions of nonnatives stem from widespread economic activities (Ericson 2005, Hulme 2009). The two main pathways by which nonnative fish species have been introduced into Virginia waters are both linked to recreational fishing: a) authorized stocking of gamefishes by state fisheries managers to enhance fishing opportunities and b) unauthorized release by anglers of game and bait fishes (Jenkins and Burkhead 1994). The former pathway has become less common in recent decades while the latter pathway has become more common (Lapointe et al. 2016). Some introduced species (e.g., Redbreast Sunfish, *Lepomis auritus,* now in the upper Tennessee drainage) originate from other waters in Virginia, while others originate from other states (e.g., Blue Catfish, *Ictalurus furcatus*) or other continents (e.g., Brown Trout, *Salmo trutta*). In any case, recreational fishing is a widespread, popular activity. According to a USFWS survey, 8% of Virginia residents fished in 2011 for a total of 9367 person-days (including saltwater fishing), spending $2.6 billion (USFWS 2012). Social demand for fishing opportunities is especially high in and around Virginia's growing urban centers (Villamagna et al. 2014). Thus, as these areas continue to grow, so will the threat of additional nonnative introductions for native fishes.

State and federal agencies are developing regulations to reduce the threats posed by introductions of nonnative species. In 2003, the Virginia General Assembly passed §29.1-570, the Nonindigenous Aquatic Nuisance Species (NANS) Act to control snakehead fishes (Channidae) and exotic mussel species (VDGIF 2011). This law empowers VDGIF to control, eradicate, or prevent the introduction or spread of NANS. These are defined in Virginia code (§29.1-571) as nonindigenous freshwater species "whose presence in state waters poses or is likely to pose a significant threat of harm to (i) the diversity or abundance of any species indigenous to state waters; (ii) the ecology stability of state waters; or (iii) the commercial, industrial, agricultural, municipal, recreational, aquacultural, or other beneficial uses of state waters." The General Assembly also approved creation of the Virginia Invasive Species Council, which includes representatives from eight state agencies and is responsible for coordinating state activities regarding invasive species. The VDGIF regularly assesses emerging threats associated with species likely to be introduced, then considers potential regulatory actions. For example, they recently prohibited the importation and sale of Oriental Weatherfish (*Misgurnus anguillicaudatus*), which is known to be invasive in neighboring states (http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=498). However, because commercial pathways of fish introduction often cross state boundaries, effective regulation of nonnative introductions must be based on interstate cooperation (Environmental Law Institute 2007).

Climate change is an over-arching, impending threat to some freshwater ecosystems but its potential impacts have not been examined explicitly for most Virginia fishes. Recent analysis indicates that stream temperatures in Virginia are increasing, on average, about 0.028 °C per year (Rice and Jastram 2015). However, water temperature can vary considerably across a watershed, as it is mediated by a complex suite of processes and factors such as riparian vegetation and subsurface flow (Johnson 2004) and groundwater inputs (Dugdale et al. 2015, Snyder et al. 2015). Thus, the severity and extent of impacts on Virginia fishes due to climate change remain largely unassessed.

Three main forms of climate-change impact seem likely. First, warming water temperatures, which directly influence fish growth, development, reproduction, and survival (Hester and Doyle 2011), are likely to reduce the extent and connectivity of suitable habitat for coldwater and coolwater fishes over the long term. Published analyses of these impacts on Virginia fishes have focused on salmonids (Clark et al. 2001, Flebbe et al. 2006, Hester and Doyle 2011,). However, any species unable to move along stream/river corridors to find suitable habitat during climatic shifts may be threatened with local or regional extirpation (Poff et al. 2001). Second, projected increases in frequencies of severe weather patterns, such as floods and droughts, would favor species especially tolerant of such events. Third, to the extent that climate change promotes conditions stressful to fishes, the new stresses may interact synergistically with preceding stresses (e.g., from urbanization [Nelson et al. 2009]) to drive some populations to extinction. Overall, projected changes in land use and climate are likely to be especially harmful to fish species that have small geographic ranges, ecological specialization, a requirement for flowing water, or migratory behavior (Poff et al. 2001). These traits are common among Virginia fishes, especially darters.

USE OF FISHES TO ASSESS WATERBODY HEALTH

Fishes are widely used across the United States to assess anthropogenic impacts on streams, rivers, and lakes. Extensive knowledge of fish species' ecological traits provides insight into how human-induced environmental changes lead to shifts in population abundance and assemblage composition (Frimpong and Angermeier 2010). This knowledge has been used to develop assessment protocols that enable water resource managers to distinguish between the variation in environmental conditions that occur naturally from place to place and the variation caused by human impacts (Karr et al. 1986, Smogor and Angermeier 1999). Such fish assemblage-based protocols, along with protocols to assess water and sediment (physicochemical) quality, are used by many state agencies, including the Virginia Department of Environmental Quality (VDEQ), to monitor stream health. However, although VDEQ began collecting fish assemblage data for its statewide assessment of streams in 2008, the indexes it plans to use to summarize the data are still in draft form (Jason Hill, VDEQ, personal communication). Thus, assessment results are not publically available.

VDEQ also monitors stream health via probabilistic sampling of benthic macroinvertebrates in selected water bodies. Macroinvertebrate responses to stream conditions are germane to fishes because a) the vast majority of Virginia fishes primarily eat macroinvertebrates at some point during their life cycle (Jenkins and Burkhead 1994) and b) the two groups respond similarly to some anthropogenic impacts (Karr and Chu 1999). VDEQ's Probabilistic Monitoring Program is designed to answer questions about statewide and regional water quality. This program sampled over 250 sites from 2007 to 2012 for the 2014 assessment report. Based on that report, most water quality parameters met applicable water quality criteria, but 43.5% of the stream miles sampled exhibited sub-par biological conditions (http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/ProbabilisticMonitoring/ProbMon2014.pdf). The top three causes of biological impairment seem to be streambed sedimentation (39.7%), habitat disturbance (19.7%) and total phosphorus (17.1%), all of which can adversely affect fishes. These percentages have changed only slightly since 2008, when 45.1% of the stream miles sampled exhibited biological impairment and the same top three causes accounted for impairment in 44.6%, 17.1%, and 15.9%, respectively, of stream miles (http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/ProbabilisticMonitoring/ir08_Pt2_Ch2.4_Freshwater_ProbMon.pdf).

Another measure of a stream's health is how safe it is for people to eat the fish that live there. VDEQ and Virginia Department of Health (VDH) monitor levels of selected toxins (e.g., mercury and polychlorinated biphenyls [PCBs]) in tissues of selected fish species. These toxins pose health risks to people who eat them, especially pregnant and nursing women and young children (http://www.vdh.virginia.gov/Epidemiology/dee/PublicHealthToxicology/Advisories/). VDH maintains lists of fish-consumption advisories for Virginia, which indicate that fish taken from a particular body of water may contain harmful levels of toxins in certain fish species. At any given time, dozens of advisories may be in force. For example, on 26 April 2015, each major river drainage was represented by three (New) to nine (Potomac) water bodies with consumption advisories. Across Virginia waters, PCBs were the most common toxin in fish tissue.

Statewide temporal trends in contaminant levels in fish tissues are difficult to assess because the locations and numbers of sites, species, and individual fish sampled vary greatly among years. In 2013 (the most recent data available at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/FishTissueMonitoring/FishTissueResults.aspx), VDEQ found total PCB concentrations in fish tissues to exceed the VDH level of concern (50 ppb) in one to eight species in six waterbodies; Roanoke River had eight contaminated species. In contrast, the 2008 data indicated that total PCB concentrations exceeded the VDH level of concern in one to seven species in 42 waterbodies; Chopawamsic Creek had seven contaminated species. Differences between years cannot be interpreted as trends because sampling effort for PCBs in fish tissue was much greater in 2008 than in 2013, reflecting budget cuts to VDEQ's fish-tissue monitoring program (Jason Hill, VDEQ, personal communication). Further, the PCB sampling was distributed across different areas in 2008 versus 2013. The 2008 fish samples were collected mainly in the York River drainage and small coastal drainages plus selected sites in the James and Potomac river drainages, but the 2013 samples were collected mainly in the Rappahannock, Dan, and Roanoke river drainages.

VIRGINIA'S REGULATORY FRAMEWORK GERMANE TO FISH CONSERVATION

VDGIF is responsible for the management of inland fisheries, wildlife, and recreational boating for the Commonwealth of Virginia. Department policy for "conserving, protecting, replenishing, propagating and increasing the supply of game birds, game animals, fish and other wildlife of the Commonwealth" is set by its Governor-appointed Board under Code of Virginia §29.1-103. VDGIF is authorized to create regulations governing the taking, possession, and sale of "wild animals and birds and freshwater fish, and of endangered species of any form of wildlife." Thus, VDGIF regulates all issues related to the harvest, capture, importation, imperilment, and recovery of fish species. Regulations and resolutions are proposed by VDGIF staff to the Board based on perceived management needs and accompanied by sound biological justification. After a public comment period, the Board may adopt, modify, or reject proposed regulations while conferring with the VDGIF Director.

VDGIF manages all game and nongame fishes in Virginia's freshwaters. Gamefish populations are managed for the recreational enjoyment of its citizens through maintenance of wild populations and stocking of hatchery-produced fishes; most stocked fishes are trouts. Harvest regulations are used to prescribe fees for fishing licenses and permits, creel limits, capture methods, and fishing seasons. Nongame fish species are managed to provide harvestable bait for anglers and fish for personal possession (e.g., in an aquarium), while maintaining viable wild populations. Many introduced species have caused or have the potential to cause negative impacts to the Commonwealth's environment and economy. For those nonnative species determined to be too predatory or otherwise undesirable, VDGIF regulates them through the issuance of special permits to import, possess, or sell. Special permits are now required for 25 fish taxa (Table 6). In 1972, the Virginia General Assembly passed the Virginia Endangered Species Act, which allowed VDGIF to adopt the federal list of threatened and endangered species. Conservation and recovery efforts aimed at federally protected species are coordinated with the USFWS through Section 6 of the U.S. Endangered Species Act. A list of state-endangered species was first developed by VDGIF in 1987 (Terwilliger 1991) and is periodically updated (Table 4). VDGIF initiates and pursues conservation and recovery of these species as well.

CONSERVATION NEEDS FOR VIRGINIA FISHES

As threats to fishes become increasingly extensive and intensive, the need for effective conservation strategies and tactics will become more pressing. In our view, three main types of actions need greater support to enhance conservation effectiveness: research, management, and outreach. The main actors in these efforts will continue to be VDGIF and USFWS but other state and federal agencies will often be crucial partners. Research generates new knowledge to inform management and outreach. Most species on the SGCN lists remain poorly studied and lack sufficient funding for conservation. Key research needs for these species include studies to a) clarify exactly where species are (and are not), b) describe basic life history and habitat associations,

TABLE 6. List of nonnative fish taxa for which a special permit is needed to import, possess, or sell in Virginia. "spp." refers to all species of a genus or family.

Scientific name	Common name
Catastomidae	
Ictiobus bubalus	Smallmouth Buffalo
I. cyprinellus	Bigmouth Buffalo
I. niger	Black Buffalo
Channidae	
Channa spp.	(all snakeheads)
Parachanna spp.	
Characidae	
Pygopristis spp	(all piranhas)
Pygocentrus spp.	
Rooseveltiella spp.	
Serrasalmo spp.	
Serrasalmus spp.	
Taddyella spp.	
Cichlidae	
Tilapia spp.	Tilapia
Clariidae spp.	Air-breathing catfishes
Cobitidae	
Misgurnus anguillicaudatus	Oriental Weatherfish
Cyprinidae	
Aristichythys nobilis	Bighead Carp
Ctenophargyngoden idella	Grass Carp
Cyprinella lutrensis	Red Shiner
Hypophthalmichthys molitrix	Silver Carp
Mylopharyngodom piceus	Black Carp
Scardinius erythrophthalmus	Rudd
Tinca tinca	Tench
Gobiidae	
Neogobius melanostomus	Round Goby
Proterorhinus marmoratus	Tubenose Goby
Percidae	
Gymnocephalus cernuus	Ruffe
Synbranchidae	
Monopterus albus	Swamp Eel

c) document species' responses to selected anthropogenic impacts, d) develop reliable methods to track changes in distribution and abundance, and e) quantify the connection and value of healthy waters and fish communities to people. Previous experience in Virginia indicates that wise investment in targeted research can yield important findings that make species management more cost-effective (Rosenberger and Angermeier 2003, Roberts et al. 2008, Roberts et al. 2013).

The list of affordable and politically viable management actions that can be implemented to advance fish conservation is not long. The main field-based actions include those aimed at habitat restoration, such as a) re-vegetating riparian zones to stabilize stream banks and b) breaching (or removing) dams and replacing perched road culverts to facilitate fish passage. For a few species (e.g., Yellowfin Madtom [*Noturus flavipinnis*], Roanoke Logperch [*Percina rex*], and Blackbanded Sunfish [*Enneacanthus chaetodon*]), reintroductions may also be feasible if suitable, unoccupied habitat is available within their historic range. Because most Virginia water bodies drain private land, all these field-based actions require substantial partner collaboration to be successful. A management tool used to make this possible is the nonessential experimental population (NEP) designation provided by the U.S. Endangered Species Act. The NEP designation allows an endangered species to be reintroduced into its unoccupied, historic range while not subjecting federal agencies to activities that may jeopardize the species under Section 7 of the Act. Furthermore, accidental or incidental take is allowed by legal activities (i.e., agriculture, recreation, forestry) under a NEP designation. Governmental and non-profit organizations are currently moving forward to reintroduce Yellowfin Madtom into the North Fork Holston River, via a NEP designation (Conservation Fisheries, Inc. 2015). Finally, key regulatory actions to support conservation include restricting bait-harvest for narrowly distributed species (e.g., Tennessee Dace, *Chrosomus tennesseensis*) and reducing risks of further species introductions. Because these actions are politically difficult to implement and because such regulations impinge on some recreational and/or commercial activities, they too need substantial public support to be successful.

An important tactic for garnering political support for fish conservation is public outreach. Fish biologists have a central role and responsibility in engaging a range of publics regarding conservation (Angermeier 2007). Outreach messages that warrant delivering repeatedly include a) how healthy fishes are analogous to clean water and contribute to human wellbeing and b) what people can do individually to enhance water quality and fish conservation. One innovative outreach method currently being used in Virginia is the training of citizens to become naturalists through the Virginia Master Naturalist Program (VMNP). Many VMNP courses adopt a holistic approach with emphasis on aquatic species. After graduation, each naturalist must volunteer in nature-related roles to continue her/his certification. Since 2006, over 1,300 volunteers have contributed over 417,900 hours toward conservation efforts. In this manner, the public gains a long-term appreciation for aquatic ecosystems and becomes more likely to advocate for their protection. Another valuable outreach program used by some states is Trout in the Classroom, a collaboration between Trout Unlimited and state wildlife agencies. This program uses hands-on experiences to teach students about the water quality and habitat conditions required for fish growth and survival. Lastly, the display of native fish species at public aquariums is an excellent way to educate large numbers of citizens in a fun, comfortable setting. For many Virginians, seeing these species in a controlled environment may be the first and only opportunity to learn about native fishes and the importance of clean water to both people and fishes.

Although the number of freshwater species formally protected in the southeastern United States, including Virginia, probably underrepresents those in actual need of protection (Jelks et al. 2008), establishing legal protection is highly contentious, requires substantial resources, and can be counter-productive. In 2010, the Center for Biological Diversity (CBD) petitioned the USFWS to list 404 aquatic, riparian, and wetland species as federally threatened or endangered (http://www.biologicaldiversity.org/programs/biodiversity/1000_species/the_southeast_freshwater_extinction_crisis/index.html). To date, only one of those species, Alabama shad (*Alosa alabamae*), has been reviewed for protective listing; it was ultimately rejected. While such listings are necessary to protect some fishes, listings do not necessarily aid species recovery. For some people, "endangered" species have negative connotations such as government intrusion, impeding of progress, and trampling of private property rights (personal observations, Olive and Raymond 2010). These stigmas may impede rather than advance species recovery. Thus, for a species that can be propagated in captivity and for which suitable, but unoccupied, habitat is available, conservation may be more effective if it is not formally listed as imperiled. For example, Candy Darter, endemic to the New River drainage, is on the CBD's 2010 list. Because the species occurs primarily on U.S. Forest Service lands in Virginia, VDGIF has been able to develop a collaborative partnership to protect the species without assigning it a formal protective status. For waters occupied by Candy Darter, this partnership has facilitated a) elimination of stocking brown trout (a potential predator), b) purchase of significant, nearby private parcels, and c) research on the species' life history and habitat associations. Future research will continue to inform reintroduction efforts for this species. In the case of Candy Darter, it is unclear if formal protective status would make its conservation more effective.

People are more likely to value and become emotionally attached to animals they frequently see, such as birds (Messaris 1994, Czech and Krausman 1999). Because fishes live underwater where they are difficult for people to see, fishes often do not receive the attention they deserve unless being targeted for sport, food, or bait. Unknown by most, there is a remarkable diversity of freshwater fishes in Virginia that present a seemingly endless variety of colors, shapes, and behaviors. To bring more citizen attention and connection to fishes, we suggest more effort is needed to encourage the public to observe them in the wild (Monroe et al. 2009). Fish observation platforms, snorkeling field trips, and fish-related educational signage near waterbodies are but a few ideas that might promote the conservation of this unique and under-appreciated taxon.

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