THE ALABAMA RIVERS AND STREAMS NETWORK:

AN APPLIED, COOPERATIVE APPROACH TO AQUATIC SPECIES CONSERVATION

Geological Survey of Alabama
Special Publication 4

All cover photographs are by Patrick E. O’Neil unless otherwise stated.

Front cover:

Cypress Creek at Natchez Trace Parkway, Cypress Inn, Tennessee, October 25, 2023.

Back cover:

First row (from left)—Boat electrofishing, Weiss Bypass, Coosa River; Wade electrofishing, Choccolocco Creek, Coosa River.

Second row (from left)—Mill Creek, Cahaba River; Claiborne Lock and Dam on the Alabama River; Tombigbee River at Epps.

Third row (from left)—River Redhorse, Mulberry Fork, Black Warrior River; Crayfish burrow digging, Russell County, by Stuart W. McGregor; Cahaba Lily, Cahaba River.

Fourth row—(top left) Boat electrofishing catch, Choccolocco Creek, Coosa River; (bottom left) Electrofishing boat launch, Mulberry Fork, Black Warrior River; (center) Orangenacre Mucket, Alabama Aquatic Biodiversity Center, Marion, by Paul D. Johnson; (right) Key Cave, Tennessee River.

GEOLOGICAL SURVEY OF ALABAMA
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THE ALABAMA RIVERS AND STREAMS NETWORK: AN APPLIED, COOPERATIVE APPROACH TO AQUATIC SPECIES CONSERVATION

Special Publication 4

by

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Tuscaloosa, Alabama
2025

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December 3, 2025

The Honorable Kay Ivey
Governor of Alabama
Montgomery, Alabama

Dear Governor Ivey:

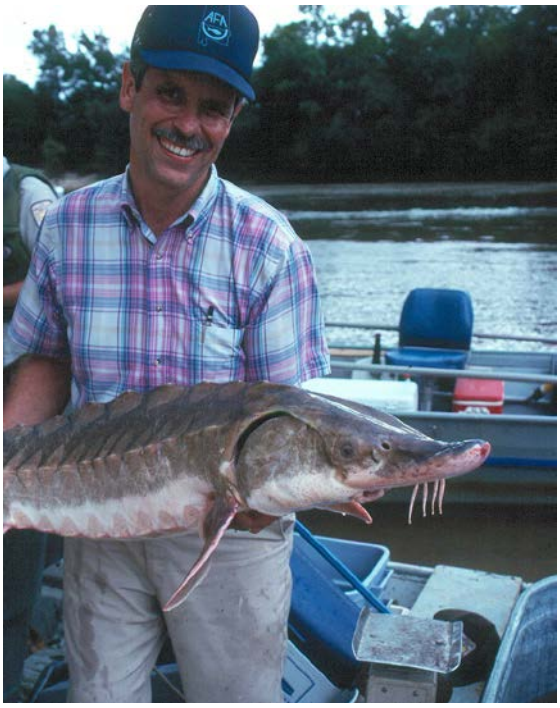
It is with pleasure that I make available to you this report entitled *The Alabama Rivers and Streams Network, An Applied Cooperative Approach to Aquatic Species Conservation*, by Patrick E. O'Neil, Rebecca A. Bearden, Jeffrey R. Powell, Paul D. Johnson, Stuart W. McGregor, Jennifer P. Grunewald, Cal C. Johnson, Daniel A. West, William J. Pearson, and Kellie W. Johnston, which has been published as Special Publication 4 by the Geological Survey of Alabama.

Alabama's aquatic resources rank at the top of all states regarding quantity, quality, and biodiversity. A recent count of Alabama's aquatic megafauna (fishes, bivalve mollusks, snails, and crayfishes) totals around 820 species, more than any of the surrounding Southeastern states. Around 310 of these species (38 percent) are considered imperiled and classified as extinct, extirpated, endangered, or threatened as species of highest or high conservation concern in Alabama. This large number of imperiled aquatic species reflects, in part, the current state of habitats and water resource quality in many Alabama watersheds and has significant regulatory implications to the state's economy if not addressed.

The Alabama Rivers and Streams Network (ARSN) is a group of agencies, industries, non-profits, individual landowners, academic institutions, and conservation organizations working together to implement "cooperative conservation" to improve water resource and habitat quality, educate the public about the benefits of good natural resource stewardship, and recover aquatic species to sustainable levels. This Special Publication discusses the origin of the Alabama Rivers and Streams Network, gives an overview and conservation status of biodiversity in the Southeast, and highlights several of the conservation initiatives and successes of network partners in Alabama.

Respectfully,

Berry H. (Nick) Tew, Jr.
State Geologist



IN MEMORIAM

Dr. Maurice F. "Scott" Mettee, Jr.

April 28, 1943 – January 10, 2026

The authors would like to dedicate Special Publication 4 to Dr. Maurice F. (Scott) Mettee, who passed on January 10, 2026, just before this report was published and printed. Scott was a tireless worker and dedicated ichthyologist and fisheries professional who contributed extensively to the conservation of Alabama's fishes. He started work at the Geological Survey of Alabama in 1975 and retired from that agency in 2009 after a 34-year career. Scott's work was extensive, encompassing studies on the biology and distribution of Alabama fishes, the restoration and recovery of endangered and threatened species, environmental studies associated with energy development in the state, and studies on fishes found in Alabama's larger rivers. A highlight of his career was publication in 1996 of the book "Fishes of Alabama and the Mobile Basin" with two colleagues. He worked cooperatively with government agencies, business, industry, universities, landowners, and the citizens of Alabama to promote the conservation of fishes and the environment. His passion and knowledge of natural history is celebrated, his giving personality is admired, his unrelenting demand to scientific standards is respected and appreciated, his mentorship is recognized widely, and his writing talent is a legacy to Alabama's aquatic science community and a gift to all who strive to protect Alabama's resources.

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ABBREVIATIONS AND ACRONYMS

Alphabetically arranged by “Abbreviation” column

Abbreviation	Term
AABC	Alabama Aquatic Biodiversity Center
ADCNR	Alabama Department of Conservation and Natural Resources
ADEM	Alabama Department of Environmental Management
ARRM	assessment, restoration, recovery, monitoring
ARSN	Alabama Rivers and Streams Network
ATtILA	analytical tools interface for landscape assessments
BCG	biological condition gradient
BEHI	bank erodibility and hazard index
BESI	bank erosion and susceptibility index
BMP	best management practice
Cawaco	Cawaco Resource, Conservation, and Development Council, Inc. (Cawaco RC&D)
CBD	Center for Biological Diversity
CWA	Clean Water Act of 1972
ESA	Endangered Species Act of 1973
FR	Federal Register
GIS	geographic information systems
GSA	Geological Survey of Alabama
HDG	human disturbance gradient
HDSS	high-definition stream survey
HUC	hydrologic unit code of USGS
IBI	Index of Biotic Integrity
kg	kilogram
km	kilometer
km^2	square kilometer
m	meter
m^3	cubic meter
mi	mile
mi^2	square mile
MRBC	Mobile River Basin Aquatic Ecosystems Coalition
NHD	National Hydrologic Dataset
NMFS	National Marine Fisheries Service
NRCS	Natural Resource Conservation Service
RC&D	Resource, Conservation, and Development Council
SARP	Southeast Aquatic Resources Partnership
SCA	stream crossing assessment methodology
SHC	Strategic Habitat Conservation
SHU	Strategic Habitat Unit
SOP	standard operating procedures manuals

ABBREVIATIONS AND ACRONYMS – continued

Alphabetically arranged by “Abbreviation” column

Abbreviation	Term
SRI	Sediment Risk Index
SRRU	Strategic River Reach Unit
SSA	species status assessment
SWAP	State Wildlife Action Plan
TMDL	total maximum daily load
TVA	Tennessee Valley Authority
U.S.	United States
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USGS-BRD	United States Geological Survey, Biological Resources Division
WFFD	Wildlife and Freshwater Fisheries Division of ADCNR
yd^3	cubic yard

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By

Patrick E. O'Neil, Rebecca A. Bearden, Jeffrey R. Powell, Paul D. Johnson, Stuart W. McGregor, Jennifer P. Grunewald, Cal C. Johnson, Daniel A. West, William J. Pearson, and Kellie W. Johnston

ABSTRACT

A recent count of Alabama's aquatic megafauna (fishes, bivalve mollusks, snails, and crayfishes) totals around 817 species, more than any of the surrounding southeastern states. Around 310 (38 percent) of these species are considered imperiled and classified as extinct, extirpated, endangered, threatened, or of high or highest conservation concern in Alabama. This large number of imperiled aquatic species reflects, in part, the current state of habitats and water resource quality in many Alabama watersheds. The presence of so many imperiled aquatic species is a general indicator of overall water resource health and could have unintended economic consequences if conservation activities are not continued at some fundamental level. Restoring and recovering Alabama's imperiled aquatic species is a daunting task that not any one agency, institution, or organization can solve alone and one that requires a multidisciplinary, collaborative, iterative, and adaptive approach to implementation.

The Alabama Rivers and Streams Network is a group of state, federal, and local agencies, industries, nonprofits, individual landowners, academic institutions, and conservation organizations working together to implement "cooperative conservation" to improve water resource and habitat quality, educate the public about the benefits of responsible natural resource stewardship, and recover aquatic species to sustainable levels. The network uses a conservation model built on the U.S. Environmental Protection Agency's nine elements approach for watershed management plans and the U.S. Fish and Wildlife Service's strategic habitat conservation approach for conserving wildlife populations and their habitats. The network's aquatic species conservation framework consists of eight essential elements: (1) working at a limited geographic scale that maximizes economic and human resources, (2) building cooperative and trusting relationships among participants, (3) valuing and respecting private landowner rights and encouraging their involvement in the process, (4) emphasizing watershed restoration and water resource protection, (5) identifying processes for habitat and species recovery, (6) balancing individual goals while allowing science to guide recovery decisions, (7) finding common ground where organization priorities, funding, and conservation needs align, and (8) providing educational outreach opportunities for all.

Employing these eight elements, the Alabama Rivers and Streams Network approach has yielded measurable success, including the following: precluding listing for 23 species and delisting of 6 species; reintroducing 16 species of mussels and 5 species of snails to targeted stream reaches; removing 5 large dams to restore natural flow conditions and connectivity; identifying over 700 stream-road crossings that limit species dispersal and cause sedimentation and potential structural issues; improving multiple methods for assessing biological responses, stream-road crossings, and water-quality and

habitat conditions; and engaging many stakeholders throughout Alabama and across the Southeast. As a result of work using this approach, water quality and aquatic habitat have improved in some watersheds over the past quarter of a century, evidenced by the upgraded conservation status for several imperiled aquatic species. This innovative and transformative approach is promising not only for future aquatic species conservation efforts but also for other initiatives addressing the intersection of conservation science and a growing human population.

INTRODUCTION

"*When we try to pick out anything by itself we find that it is bound fast by a thousand invisible cords that cannot be broken, to everything in the universe*." – *John Muir (1869)*

"We should preserve every scrap of biodiversity as priceless while we learn to use it and come to understand what it means to humanity." – *E. O. Wilson (1992)*

The importance of biodiversity and the preservation of biodiversity have been at the forefront of American conservation thought for centuries. Most people have a basic understanding of the need for plants and animals and for the sustenance they provide, but few people fully understand the ecological connections within biodiversity and how these connections are linked to the fundamental well-being of ecosystems and humans (for example, honeybees as pollinators for food production and honeybee venom as a potential treatment for some cancer cells).

The relationship of humans with nature is as complicated and complex as the connections that unite the two. Humans, by their ability to modify land and water at will, have systematically changed the earth's environment in ways that now threaten many of life's support systems. The concern that one species has the potential to permanently change the course of earth's processes at a rate that exceeds vast periods of geological time has led to an increased desire to better understand those complex connections and to possibly alter what could be a disturbing future outcome for all life on earth.

The rate of change caused by humans is most alarming for the earth's plant and animal species (Reid and others, 2019). NatureServe (2023) has estimated that 34 percent of plant species and 40 percent of animal species in the United States (U.S.) are at risk of extinction and that 41 percent of ecosystems are at risk of significant degradation or failure. Further, most of the imperiled animal species in the U.S. are aquatic, encompassing amphibians, selected reptiles, fishes, mussels, snails, and crayfishes. (Note: The term imperiled is common scientific language used throughout this report denoting rare and at-risk species and species found on state and federal protection lists.) Freshwater mussels and snails are the two most imperiled animal groups in the U.S., with 65 and 75 percent, respectively, of species classified as at risk (fig. 1). Regarding fishes, Burkhead (2012) determined that 57 taxa of freshwater fishes in North America have become extinct since 1898, with a modern extinction rate for fishes estimated to be 877 times greater than the natural extinction rate, which, calculated from the fossil record, is estimated to be about one species every 3 million years. Burkhead (2012) further proposed that the primary cause of imperilment and extinction in freshwater fishes is loss of habitat and introduction of nonindigenous species.

Alabama is at the heart of freshwater aquatic species rarity, with 85 species listed under the Endangered Species Act as either endangered or threatened (2 crustaceans, 52 mussels, 13 snails, 16 fishes, 1 amphibian, and 1 reptile) and an astonishing 45 aquatic species that once occurred in Alabama listed as extinct (8 mussels, 35 snails, and 2 fishes) (appendix A). Around 35 percent of the animals evaluated in the Alabama 2015 State Wildlife Action Plan (SWAP) (Alabama Department of Conservation and Natural Resources, 2015) were considered at risk (as determined by species having moderate, high, or highest risk of imperilment rankings). This included around 50 percent of the snail species, 69 percent of the mussel species, 50 percent of the crayfish species, and 21 percent of the fish species in Alabama (fig. 2). A

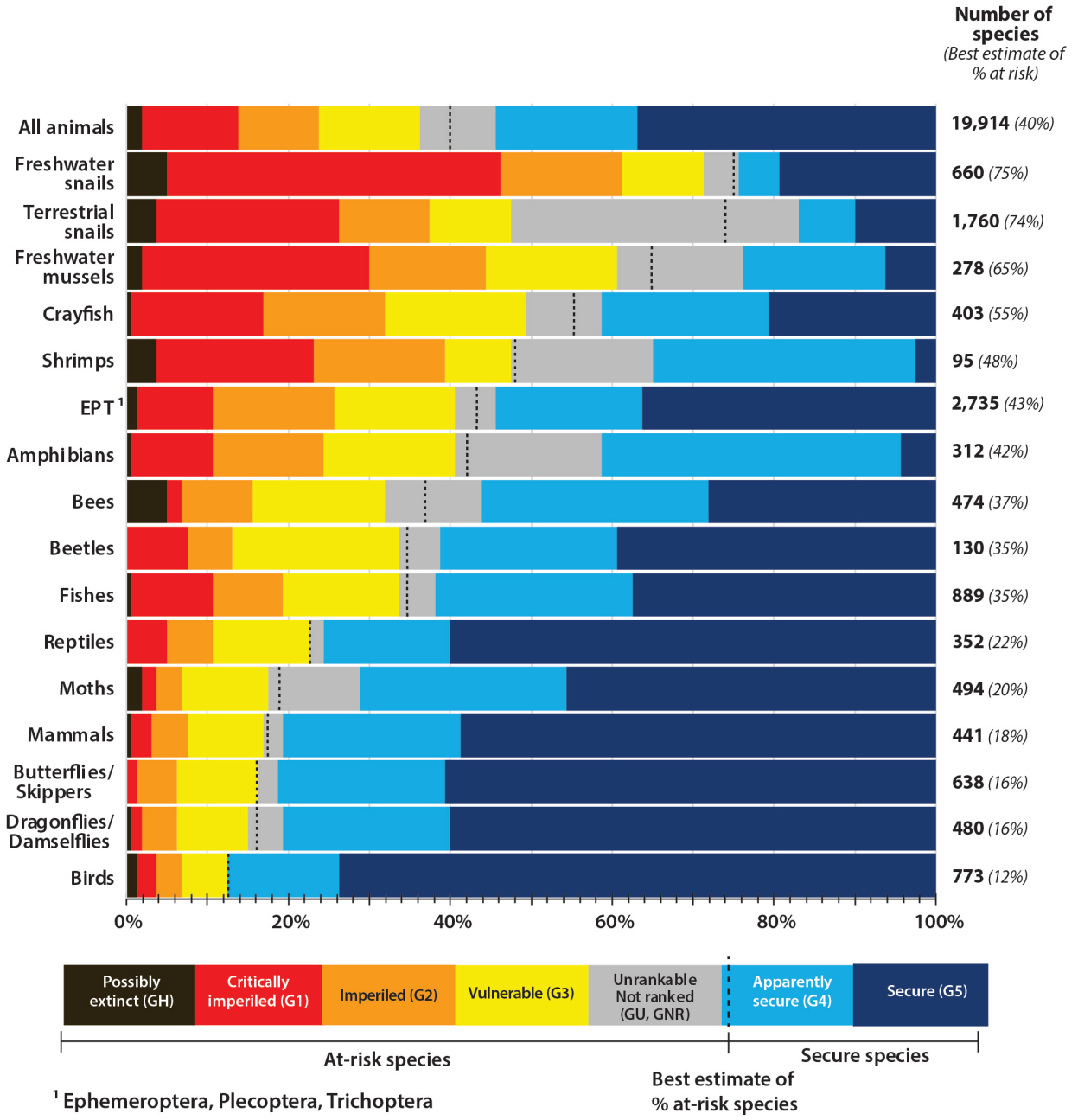


Figure 1.—Conservation status of animals in the United States (modified from NatureServe, 2023).

selection of Alabama's 800+ aquatic species of fishes, crayfishes, freshwater bivalve mussels, and freshwater snails with conservation statuses is depicted in figures 3 through 6.

Alabama's species rankings are a prime example of the relationship that has resulted from the intersection of aquatic biodiversity and a growing human population. Alabama's status as a biodiversity hotspot in need of conservation action can be understood by tracking changes, both natural and anthropogenic, to its landscape over time.

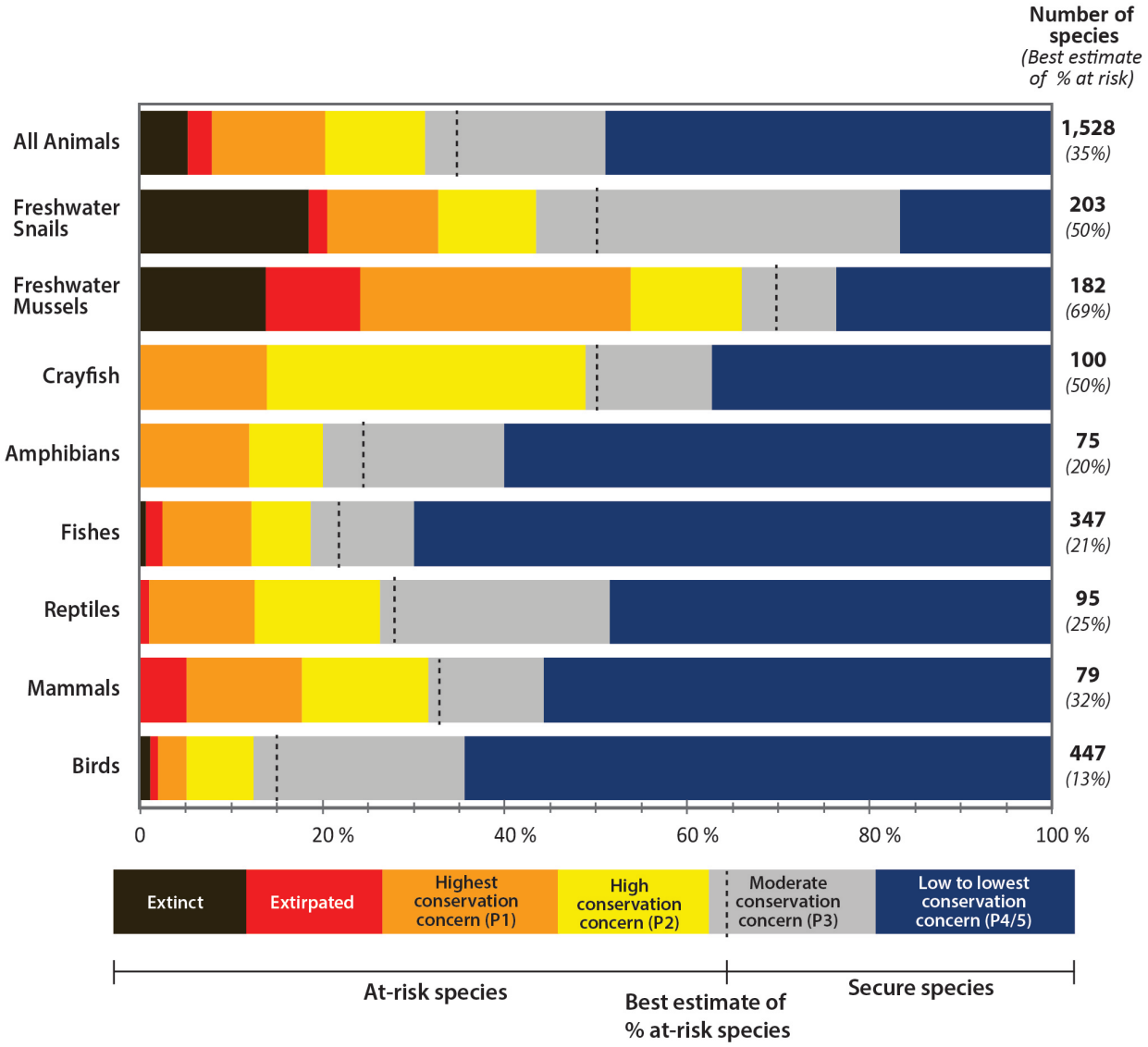


Figure 2.—Conservation status of animals in Alabama (data from Shelton-Nix, 2017).

Alabama is home to a surprising diversity of freshwater aquatic life forms, many seen nowhere else on the North American continent (Duncan, 2013). In general, scientists have attributed this regional hotspot of aquatic diversity to the interaction of several phenomena. The Southeastern landscapes have been relatively stable through recent geological time, having escaped the grinding of massive ice sheets and variation in sea level in some regions. The Southeast has a varied and diverse topography of sedimentary, metamorphic, and igneous landforms (fig. 7), all with differing chemical and physical natures that shape habitat, water quality, and availability of surface and groundwater.

The Southeastern climate has been reasonably stable during late Tertiary and Pleistocene times, classified as subtropical to temperate with moderate temperature extremes and consistent patterns of precipitation and water availability. The

Gulf Sturgeon *Acipenser desotoi* - threatened

Slackwater Darter *Etheostoma boschungi* - threatened

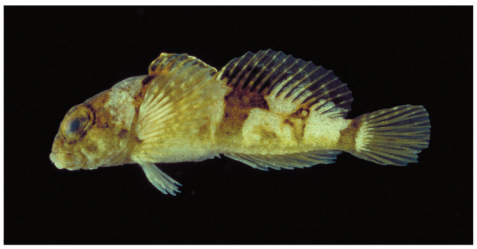
Watercress Darter *Etheostoma nuchale* - endangered

Trispot Darter *Etheostoma trisella* - threatened

Boulder Darter *Nothonotus wapiti* - endangered

Blue Shiner *Cyprinella caerulea* - threatened

Palezone Shiner *Miniellus albizonatus* - endangered



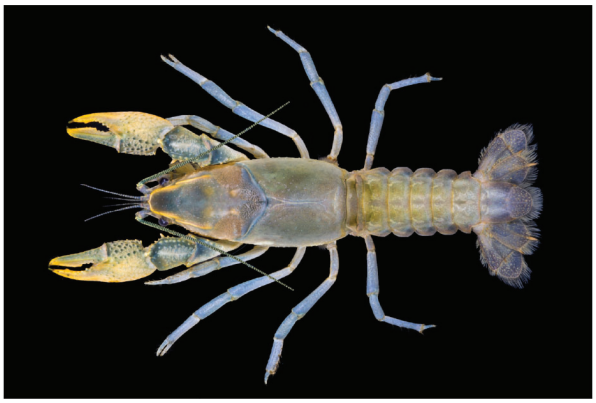
Pygmy Sculpin *Cottus paulus* - threatened

Spring Pygmy Sunfish *Elassoma alabamae* - threatened

Figure 3.—Examples of fish species occurring in Alabama, selected species with designated federal conservation status. Photos by Patrick O'Neil (Mettee and others, 1996).

Ambiguous Crayfish *Cambarus striatus*

Coosa River Spiny Crayfish *Faxonius spinosus*



Jackson Prarie Crayfish *Procambarus barbiger*

Vernal Crayfish *Procambarus viaeviridis*

Fireback Crayfish *Cambarus pyronotus*

Slenderclaw Crayfish *Cambarus cracens* - endangered

Figure 4.—Examples of crayfish species occurring in Alabama, selected species with designated federal conservation status. Photos by Guenter Schuster (Schuster and others, 2022).

Triangular Kidneyshell *Ptychobranchus greeni* - endangered

Coosa Moccasinshell *Medionidus parvulus* - endangered

Alabama Pearlshell *Margaritifera marrianae* - endangered

Alabama Lampmussel *Lampsilis virescens* - endangered

Finerayed Pigtoe *Fusconaia cuneolus* - endangered

Tapered Pigtoe *Fusconaia burkei* - threatened

Figure 5.—Examples of bivalve mollusk species occurring in Alabama, selected species with designated federal conservation status. Photos by Thomas Tarpley, Alabama Aquatic Biodiversity Center.

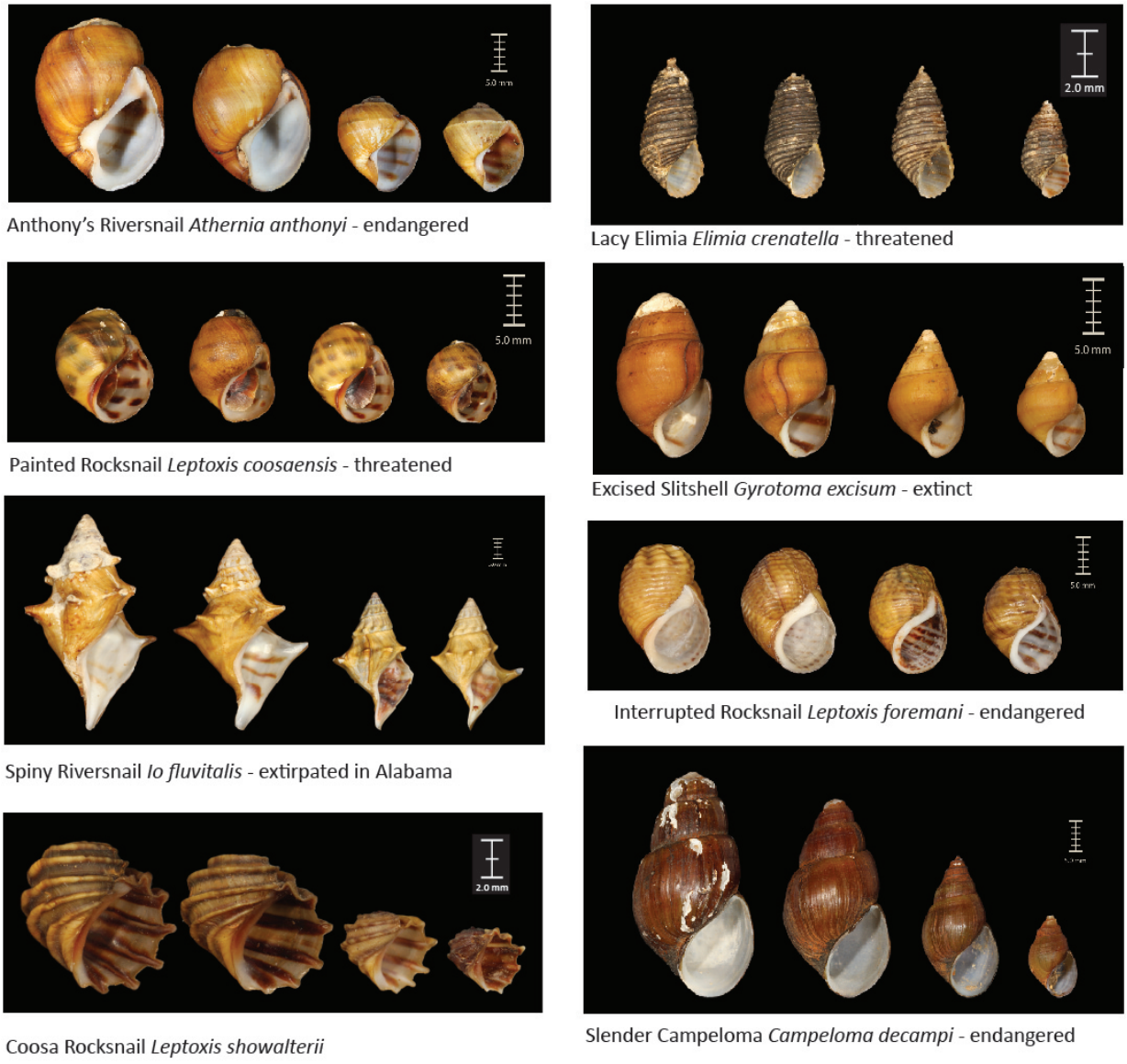


Figure 6.—Examples of gastropod mollusk species occurring in Alabama, selected species with designated federal conservation status. Photos by Thomas Tarpley, Alabama Aquatic Biodiversity Center.

presence of complex and varied landforms, the stable climate patterns and uniform presence of water throughout the region, and the stability of landforms through geologic time combine to build a vast diversity of aquatic habitats supporting a corresponding evolution of aquatic life adapted to these habitats. These conditions can be thought of as the Goldilocks Effect, describing the "just right" circumstances for biodiversity to flourish on land and in freshwater. Patterns of biodiversity differ among animal and plant groups across the U.S., as illustrated in figure 8 (Jenkins and others, 2015), with the Southeast a hotspot for amphibian, reptile, fish, and tree biodiversity and for endemic species within these groups. The Southeast, and Alabama in particular, is a priority region for biodiversity restoration and recovery (fig. 8).

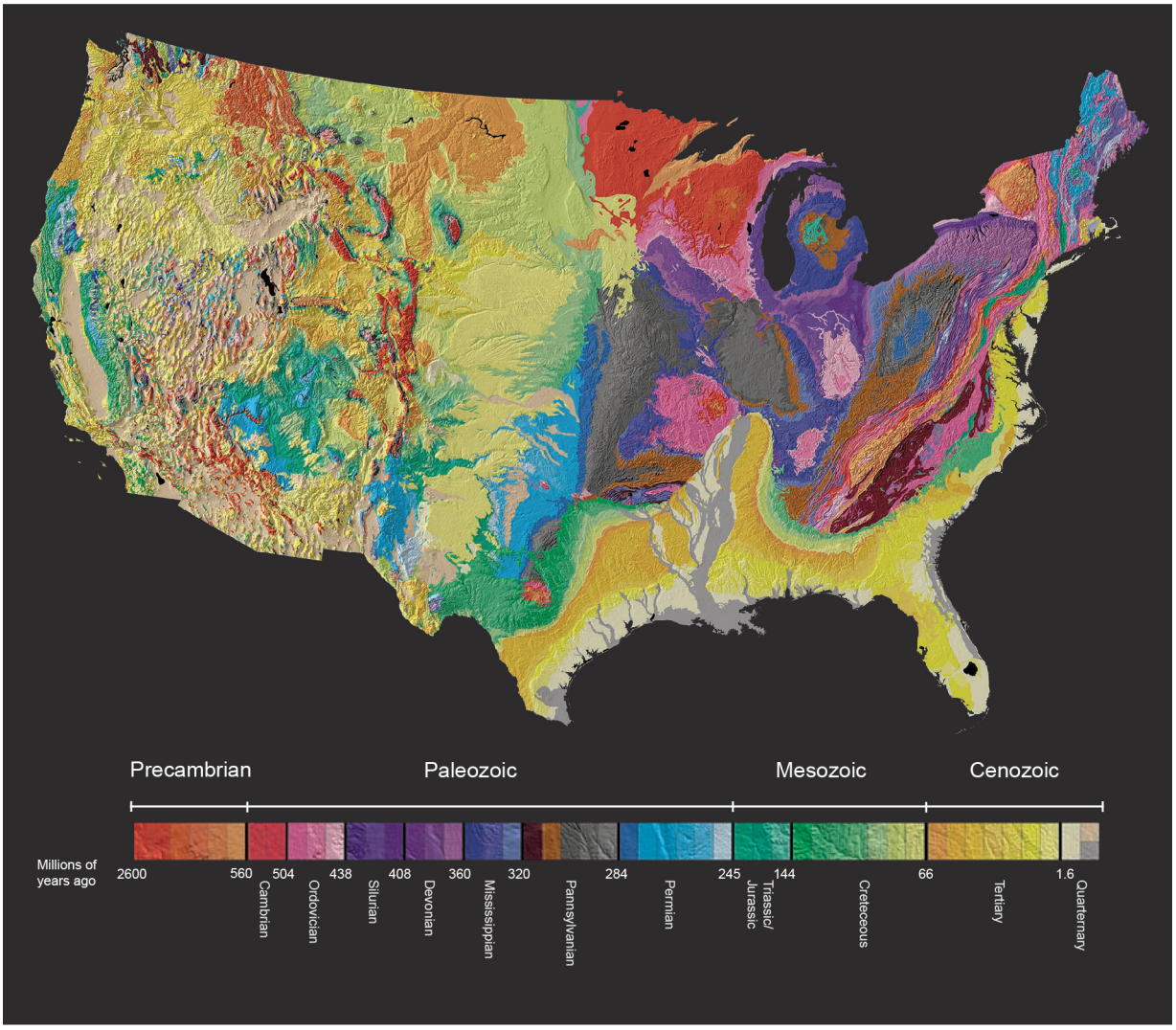


Figure 7.—Geology and terrain of the conterminous United States (modified from Vigil and others, 2000).

The freshwater megafauna species counts for Alabama and three surrounding states illustrate the considerable aquatic biological diversity of the Southeast in current times (table 1). Megafauna is defined as both vertebrate and invertebrate animals that are generally identifiable with the unaided eye and, for the purposes of this report, includes fishes, bivalve mussels, snails, and crayfishes. This distinction excludes aquatic insects and other small invertebrate groups, which comprise a species richness probably 50 to 100 times that of the megafauna, as well as reptiles and amphibians, some species of which are semi-aquatic. Alabama has a significantly higher aquatic megafauna count compared to the surrounding states of Mississippi, Tennessee, and Georgia. This is thought to be due in part to Alabama having a more diverse geological footprint drained by 10 unique river basins, several of which were isolated by sea level changes some 60 million years ago (Lacefield, 2013). Although all surrounding Southeastern states have localized aquatic biodiversity hotspots, no state has more species in the four aquatic megafauna groups than Alabama.

The vast quantity of water resources serving as the template for Alabama's aquatic biodiversity were also critical to a growing

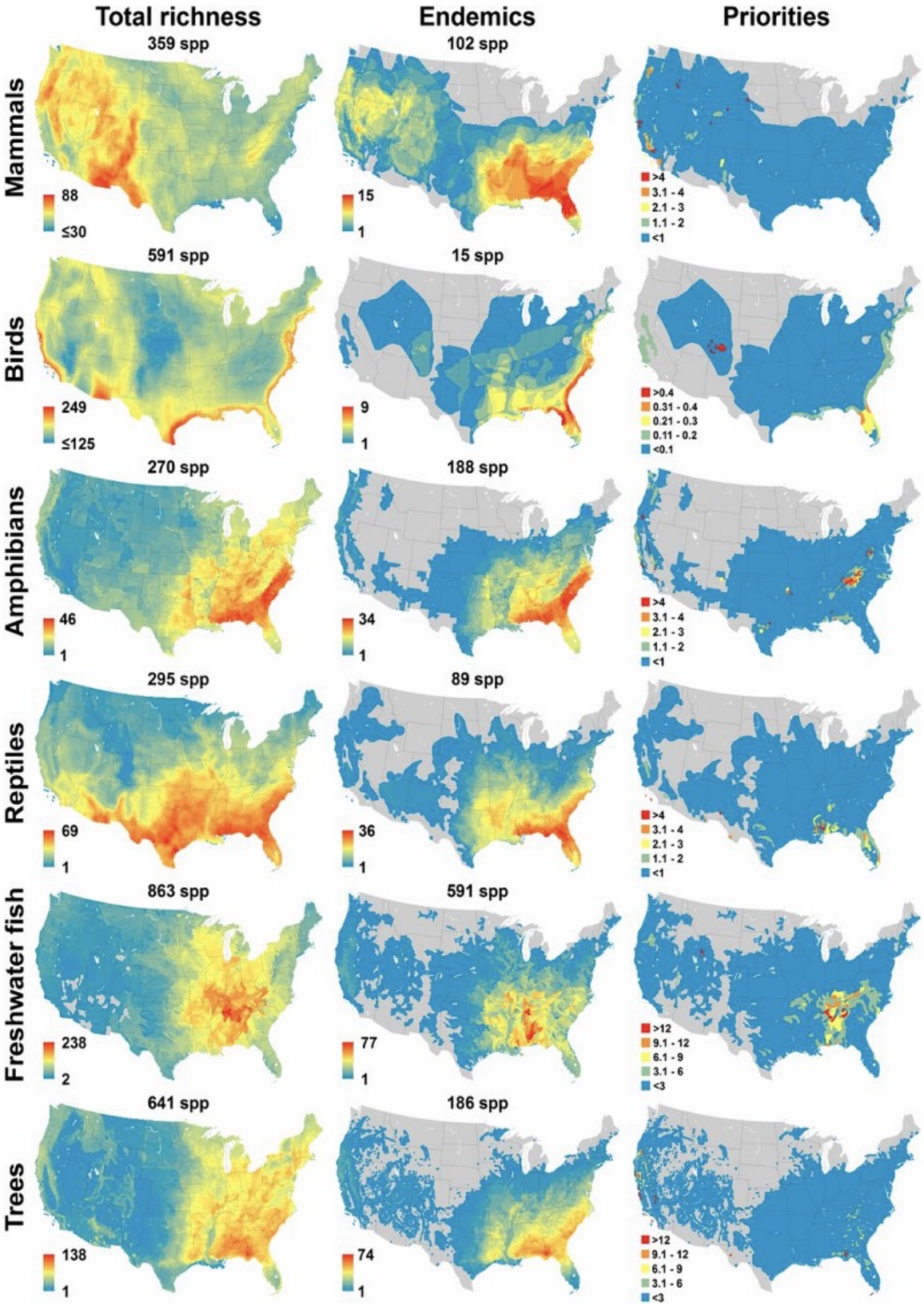


Figure 8.—Biodiversity of selected taxa in the conterminous United States and priority conservation areas for considered taxa groups (modified from Jenkins and others, 2015).

Table 1.—Counts of freshwater megafauna in Alabama and surrounding states.

Faunal group	Alabama	Tennessee	Georgia	Mississippi
Fishes	338	345	315	251
Freshwater mussels	181	132	127	103
Freshwater snails	198	99	84	67
Crayfishes	100	98	73	63
Totals	817	674	599	484

human population, as early Alabamians harnessed the power of water for trade and commerce. The ability to “capture” water was a necessity in earlier times to survive and thrive in the late nineteenth and early twentieth centuries. Dams serve many valuable purposes including power generation, flood control, water supply, and navigation, and harnessing the energy stored in impounded water has been extraordinarily important to Alabamians. Impoundments created by dams provided the energy to operate grist mills and sawmills in early years and to provide electricity throughout Alabama. Today, approximately 7.5 percent of electricity in the U.S. is generated at hydropower facilities on major rivers. Dams provide an important societal benefit by increasing capacity to store flood waters and by storing water for agricultural or industrial uses. Dams also improve commerce by increasing our ability to navigate and carry goods through inland waterways. Impoundments created by dams are also highly valued for aesthetics and the recreational opportunities they provide (Spadgenske, 2020).

In the early years of dam construction, little attention was given to the biological, water quality, and river flow concerns that are important now. In retrospect, large dams on main river channels have been implicated in one of the greatest extinction events of mollusks in modern history. In the early to mid-1900s, dams were built on the Coosa River to generate electricity for a growing population. Little was known at that time about the diversity and distribution of mussels, snails, and fish that were unique to Alabama. As the dams went up, the shallow, rocky sections of highly oxygenated rivers were transformed into deep lakes, changing the fundamental conditions of these rugged, wild rivers that once supported significant mollusk and fish biodiversity. By impounding water, dams altered the water chemistry and temperature profiles of rivers, transforming the biological community from that of flowing water to one of lake conditions. The entire food web was transformed because sunlight, the engine that drives life in these systems, could not reach the plants that provide food and produce oxygen. The crevices that formed among the boulders and bedrock in flowing water quickly filled with soft sediments and mud when the coursing waters were stopped. The snails, mussels, fish, and crayfish that evolved over hundreds of thousands of years in these free-flowing rivers were suddenly challenged beyond their capability to adapt. Some of these unique species, found nowhere else in the world, were either lost immediately or isolated to the point where they could no longer adequately reproduce (Spadgenske, 2020).

In addition to dams, waterway channelization, agriculture, and urban development have also altered the landscape with unfortunate consequences for aquatic species. Despite this decline, the numbers of remaining fish, crayfish, and mussel species in the southeastern U.S., when viewed at watershed scales (fig. 9), continue to reflect moderate to high aquatic species diversity. This diversity is closely linked to local geographies, climate, and water availability patterns, as well as the historical zoogeography discussed previously. The resulting aquatic biodiversity hotspots in Alabama provide challenging opportunities for conservation and recovery of imperiled species.

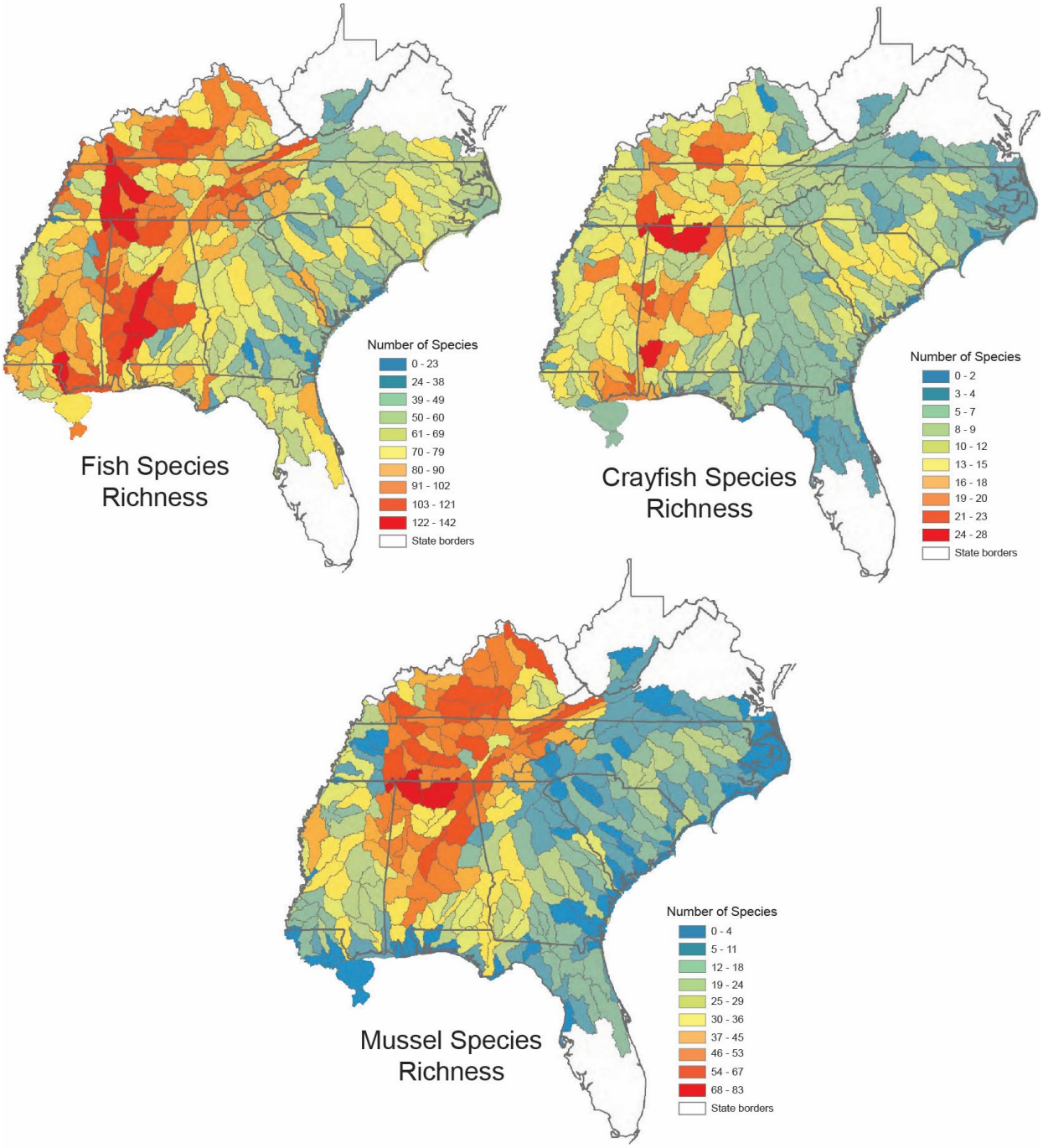


Figure 9.—Fish, crayfish, and mussel diversity in the southeastern United States mapped by HUC-8 watersheds (modified from Elkins and others, 2016).

Understanding both landscape and local factors affecting biodiversity is one of the many elements vital to the creation of a working roadmap for implementing effective conservation strategies to address imperilment and future extinction. A successful approach must also involve social science elements and include the following: balanced and calm thinking; economically viable solutions that meet societal needs, desires, and basic

stewardship principles; engaged science practitioners who understand and inform the issues and provide technically rigorous solutions to problems; and steady, sustained work with measured progress that is understood and accepted by the public. Balancing societal needs with well-informed decisions provides a solid foundation of responsible stewardship by aligning actions with environmentally ethical and moral approaches at a scale that works at the local level and is translatable across political and geographic borders to the larger watershed level. That stewardship fosters updated state water policies that protect instream flow, manage water withdrawals, and integrate biodiversity goals with water quality goals. All these approaches require integrating foundational knowledge about biodiversity and water resources with the political will to make conservation a priority.

This report describes an applied cooperative approach to conserving aquatic biodiversity in the southeastern U.S., one based on a simple concept that employs complex yet consistent strategies to successfully execute conservation acts and that can be modified to fit changing ecosystem and societal needs and desires. The approach is based in science, implemented and managed through networks of agency rules and regulations, and powered by human political, social, and relationship capital. This model approach is executed by the Alabama Rivers and Streams Network (ARSN), a group of federal, state, and local agencies, industries, nonprofits, individual landowners, academic institutions, and conservation organizations working together to implement "cooperative conservation" to improve water resource and habitat quality, educate the public about the benefits of good natural resource stewardship, and recover aquatic species to sustainable levels. The ARSN conservation model is built on the U.S. Environmental Protection Agency's (USEPA) nine elements approach for watershed management plans and the U.S. Fish and Wildlife Service's (USFWS) strategic habitat conservation approach for conserving wildlife populations and their habitats. The ARSN model employs the definition of "Strategic Habitat Units (SHUs)" and "Strategic River Reach Units (SRRUs)" to outline areas that harbor federally listed and state imperiled species and steers conservation work toward the assessment of required habitat components and work to remove potential threats. Adaptive in nature, this multidisciplinary approach is built to work with changing ecosystems that result from natural and human-induced alteration and to provide the mechanism to deliver creative, collaborative solutions from a diverse set of stakeholders.

ACKNOWLEDGMENTS

Work to restore aquatic imperiled species in the Tennessee, Mobile, Chattahoochee, and other river basins in Alabama takes the efforts of many scientists, land managers, private landowners and organizations committed to this task. To these individuals and organizations, we extend appreciation for their hard work and dedication. Current and retired participants in ARSN aquatic species conservation whom we wish to thank include:

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FOUNDATIONS OF THE ALABAMA RIVERS AND STREAMS NETWORK

The evolution of the ARSN conservation model, which merges watershed protection with aquatic species recovery and a sincere desire to work cooperatively with all parties and organizations, involves a history of leveraging federal legislation and legal action with attempts to unify disparate groups by establishing trust. This initiative has been successful because of ARSN's foundational values and operating principles: (1) working to develop trusting relationships with landowners and partners through good communication and straight talk, (2) finding common ground, (3) allowing for and embracing adaptive management, and (4) modifying goals and objectives to meet multiple stakeholder needs.

LEGISLATION

Two pieces of federal legislation laid the foundation for successful execution of the ARSN approach, the Clean Water Act (CWA) and the Endangered Species Act (ESA). While the CWA established the basic structure and regulations for protecting waters of the U.S., the ESA sought to identify, restore, and recover imperiled species. Successful combination of the two laws has been identified by ARSN as vital to efforts aimed at aquatic species recovery.

The foundational basis of the CWA was enacted in 1948 and was named the Federal Water Pollution Control Act. It was significantly reorganized and expanded with amendments in 1972 and named the "Clean Water Act." Under the CWA, the USEPA implemented pollution control programs, such as setting wastewater standards for industry, and developed national water quality criteria recommendations for pollutants in surface waters. Protecting and managing the water resource has the full weight of the CWA, and other state water protection programs administered through the Alabama Department of Environmental Management (ADEM) are available to improve the water resource. As the State Trustee for water under the CWA, ADEM regulates water quality using several programs and tools. The ADEM water quality program is closely aligned with restoration and recovery objectives of ARSN because work under this program includes those activities that directly affect aquatic organisms and their habitats such as surface water quality assessments, water quality standards, a biennial §305(b) report to Congress, the §303(d) list of impaired waters, and the total maximum daily load (TMDL) program. The TMDL program in Alabama began in earnest when a consent decree issued in 1998 paved the way for ADEM to establish TMDLs based on the 1996 §303(d) list of 115 water-quality impaired waterbodies in the state. This legal action led to significantly better results for both water quality and aquatic species in Alabama.

Imperiled species conservation took a significant step forward with passage of the ESA in 1973, one of the most historically significant pieces of conservation legislation ever passed by Congress. It charges the USFWS and the National Marine Fisheries Service (NMFS) with evaluating and listing species in immediate danger of becoming extinct (endangered) or likely to become endangered (threatened) in the near future, creates a nationally recognized list of these imperiled species, and works to restore and recover listed species through conservation actions. The USFWS is responsible for terrestrial and freshwater species including sea birds, manatees, polar bears, and anadromous fishes once they enter freshwater systems. The NMFS is responsible for marine wildlife and anadromous fishes including whales, seals, sharks, and corals. The ESA offers the public an opportunity to petition the USFWS or NMFS to evaluate and(or) list species that are documented as needing conservation action and requires all federal agencies to consult with the USFWS or NMFS if any of its operations directly, or indirectly, impact listed species. All these provisions have resulted in a powerful piece of conservation legislation that has been effective when properly implemented, yet at the same time

loathed in some circles because of its sometimes challenging requirements.

The merging of the ESA process with southeastern aquatic biodiversity is illustrated in table 2, in which the total number of all animal species listed by USFWS nationally, in Region 4, and in Alabama is compared by taxa group. Region 4 supports 37 percent of all animal species listed nationally, while Alabama supports 39 percent of Region 4's total. About 43 percent (fishes, mussels, and snails) of the national listed species are aquatic, 64 percent of Region 4's listed species are aquatic, and 76 percent of Alabama's listed species are aquatic, with the majority being bivalve mollusks. Two fish species, 8 freshwater mussel species, and an astonishing 35 freshwater snail species are considered extinct (appendix A).

Another way to display the relationship between southeastern aquatic biodiversity and the imperiled nature of this fauna is illustrated in figure 10, which maps the distribution of imperiled terrestrial and aquatic species that occur outside of protected areas such as national parks and forests, state parks, and other conservation-secured areas. Figure 10 illustrates where species with narrow ranges that fall outside of existing protected areas are concentrated and shows that the Southeast is an area of significant unprotected plant and animal biodiversity.

Hamilton and others (2022) suggested that, in general, freshwater animals occur in places with poorer landscape condition but with less exposure to climate change impacts and suggested that habitat restoration is an important conservation strategy for this group of organisms. These researchers further quantified the number of plant, vertebrate, freshwater invertebrate, and pollinator species in areas of unprotected biodiversity importance and found that 65.9 percent were located on private lands, 26.9 percent on federal lands, 4.6 percent on state lands, and 2.8 percent on local government properties. The Southeast will continue to be an active area of work to evaluate and possibly list imperiled species, with conservation efforts expanding the definition of "land protection" to include restoration of flow dynamics, riparian vegetation restoration and protection, dam and barrier removal, and improved water quality (Hamilton and others, 2022).

Despite federal protections, regulations, and the overall strength of the CWA and ESA, there is still significant harm to species, as witnessed by shrinking distribution ranges and declining population numbers. Aquatic species are particularly vulnerable due to their geographically very limited available habitat, the significant quantities of polluted runoff aquatic habitats receive from the entire landscape and permitted discharges of effluents, and the significant hydromodification of rivers and stream habitats by dams and channelization. This situation, combined with the super high

Table 2.—Counts of federally listed species within terrestrial and freshwater animal groups for the United States, U.S. Fish and Wildlife Service Region 4, and Alabama as of 2024.

Faunal group	U.S. listings	USFWS Region 4 listings	Alabama listings
Mammals	80	19	6
Birds	108	23	4
Reptiles	50	28	10
Amphibians	39	10	3
Fishes	141	54	16
Freshwater mussels	124	103	52
Freshwater snails	51	18	13
Insects	97	10	1
Arachnids	11	1	0
Crustaceans	30	8	2
Totals	731	274	107

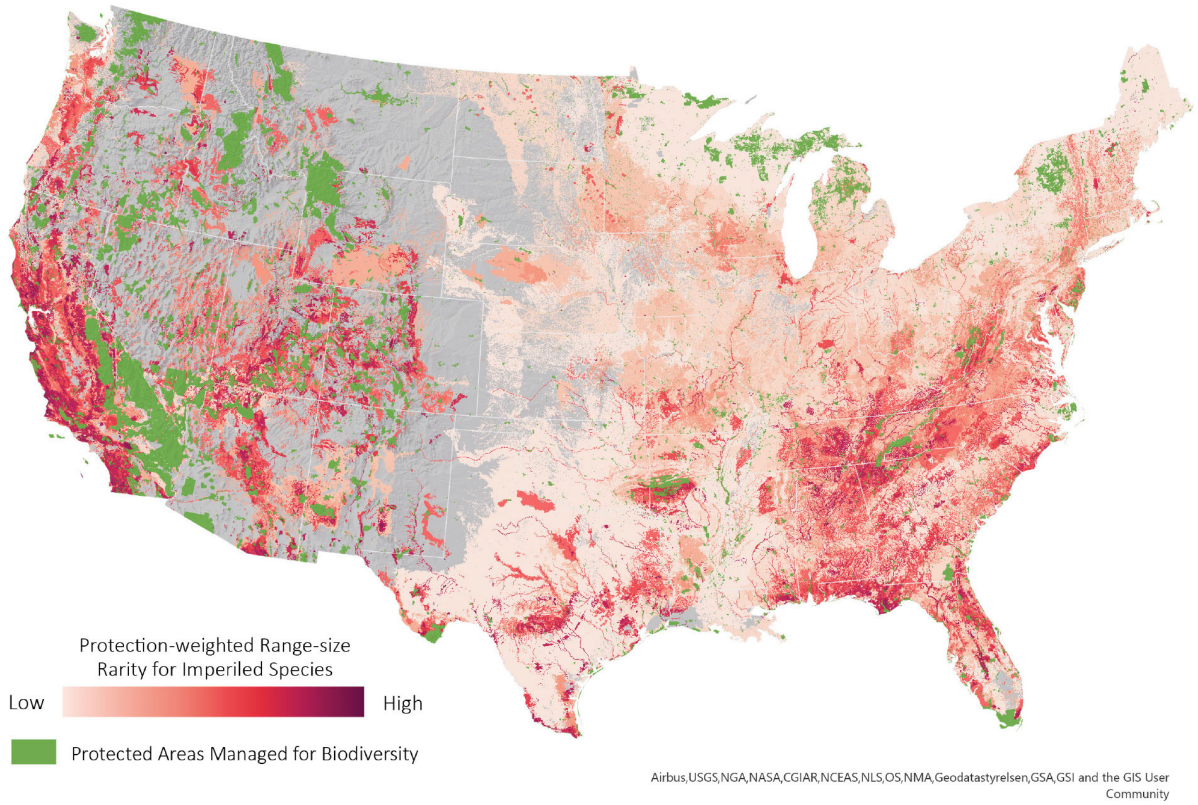

Figure 10.—Map of biodiversity importance displaying the distribution of imperiled species found outside of existing protected areas (used with permission of NatureServe Network, 2024, all rights reserved).

aquatic biodiversity and preponderance of private landownership in the Southeast, leads to significant conservation challenges and relies on the regulatory backing of the ESA, CWA, and the states to adequately address those challenges.

RECOVERY PLAN FOR THE MOBILE RIVER BASIN AQUATIC ECOSYSTEM

The original seeds of the ARSN germinated during a contentious period of time to describe, list, and attempt recovery of the Alabama Sturgeon from 1991 to 2000 (appendix B). In addition to the regulatory pathway that included the actions and documents required by the ESA to fulfill the regulatory requirements of listing, there was the science and social pathway that included all comments, scientific investigations, surveys, and legal challenges to the listing. This flurry of listing activity naturally led to significant legal challenges by utilities, river associations, paper industries, barge companies, and others who saw the action as a significant deterrent to their business operations with the potential to close Mobile basin rivers to all commerce. These organizations and businesses were organized under the name “Alabama-Tombigbee Rivers Coalition.” The confrontation between the Coalition and regulators was intense and attacked the listing along several fronts, including scientific, regulatory, and social, through the media. These early battles over the science behind the Alabama Sturgeon and the process to list the sturgeon under the ESA led to a polarized environment, threatening the possibility of constructive conservation actions for the species. Fortunately, representatives from several of the parties involved in this conflict came together to form the Mobile River Basin Aquatic Ecosystem Coalition (MRBC) in June 1996. This group of businesses, agencies, and conservation organizations assisted in

preparation of what eventually became the recovery plan for a suite of rare Mobile River basin species (USFWS, 2000) and addressed the potential listing of the Alabama Sturgeon (table 3).

These regulatory machinations were the beginning of some appearance of cooperative conservation for aquatic species in Alabama; the Alabama Sturgeon was simply the match that lit the fuse for starting the process, which led to the discussion, which led to a process of cooperative conservation action for the Alabama Sturgeon. The bigger challenge for the MRBC was how to deal with a large suite of imperiled aquatic species, including several fish and mussel species, that either formerly occurred or currently occur in low numbers throughout the Mobile River basin. After several years of meetings, discussion, and review, the final recovery plan for a subset of Mobile River basin listed species was published in 2000 (USFWS, 2000). This document (Recovery Plan for Mobile River Basin Aquatic Ecosystem—the "recovery plan") was the sole recovery plan for 22 aquatic species—4 fish, 11 mussel, and 7 snail (table 3).

The MRBC had essentially stopped working as a team by 2005, around which time two significant cooperative conservation actions were underway. First, since 2003, the Geological Survey of Alabama (GSA) had been working to develop the statewide Index of Biotic Integrity (IBI) biological monitoring tool that was envisioned as a standardized method for evaluating the biological condition of streams based on the fish community. By design, the IBI team was a cooperative

Table 3.—Federally listed aquatic species that were covered exclusively by the Mobile River Basin Aquatic Ecosystem recovery plan (USFWS, 2000).

Scientific name	Common Name	Status*
Scaphirhyncus suttkusi	Alabama Sturgeon	E
Etheostoma scotti	Cherokee Darter	T
Etheostoma etowahae	Etowah Darter	E
Percina aurolineata	Goldline Darter	T
Medionidus acutissimus	Alabama Moccasinshell	T
Medionidus parvulus	Coosa Moccasinshell	E
Pleurobema furvum	Dark Pigtoe	E
Hamiota altilis	Fine-lined Pocketbook	T
Hamiota perovalis	Orange-nacre Mucket	T
Pleurobema perovatum	Ovate Clubshell	E
Epioblasma othcaloogensis	Southern Acornshell	E
Pleurobema decisum	Southern Clubshell	E
Pleurobema georgianum	Southern Pigtoe	E
Ptychobranchus greenii	Triangular Kidneyshell	E
Epioblasma metastriata	Upland Combshell	E
Lioplax cyclostomaformis	Cylindrical Lioplax	E
Lepyrium showalteri	Flat Pebblesnail	E
Elimia crenatella	Lacy Elimia	T
Leptoxis taeniata	Painted Rocksnail	T
Leptoxis plicata	Plicate Rocksnail	E
Leptoxis ampla	Round Rocksnail	T
Tulotoma magnifica	Tulotoma Snail	E

*E-endangered, T-threatened (status at the time of Mobile River Basin Aquatic Ecosystem recovery plan in 2000)

venture of state agencies (GSA, ADEM, and the Alabama Department of Conservation and Natural Resources, Wildlife and Freshwater Fisheries Division (ADCNR-WFFD)) working jointly to collect the necessary field data for IBI development. Secondly, the USFWS and the newly formed Alabama Clean Water Partnership were working to reengage partners and rebuild relationships with river industry users, private landowners, and agencies to implement the conservation actions identified in the recovery plan (USFWS, 2000).

In 2004, the USFWS published in the Federal Register (69 FR 40084) their intent to designate critical habitat for 11 mussel species in the Mobile River basin. After publication of the multi-species recovery plan in 2000, the MRBC became inactive. However, publication of this rule in the Federal Register, essentially an ecosystem plan, breathed new life into the cooperative conservation process in Alabama. A more organized effort to address imperiled aquatic species conservation in Alabama began in 2006 when staff at USFWS and GSA began to revive the functions and operations of the defunct MRBC. Meanwhile, leadership at the USFWS and the U.S. Geological Survey (USGS) were beginning to reassess their thinking about rare species conservation. Working jointly through the National Ecological Assessment Team, they adopted an approach termed strategic habitat conservation (SHC) (fig. 11), a holistic approach to conserving wildlife and plant populations and their

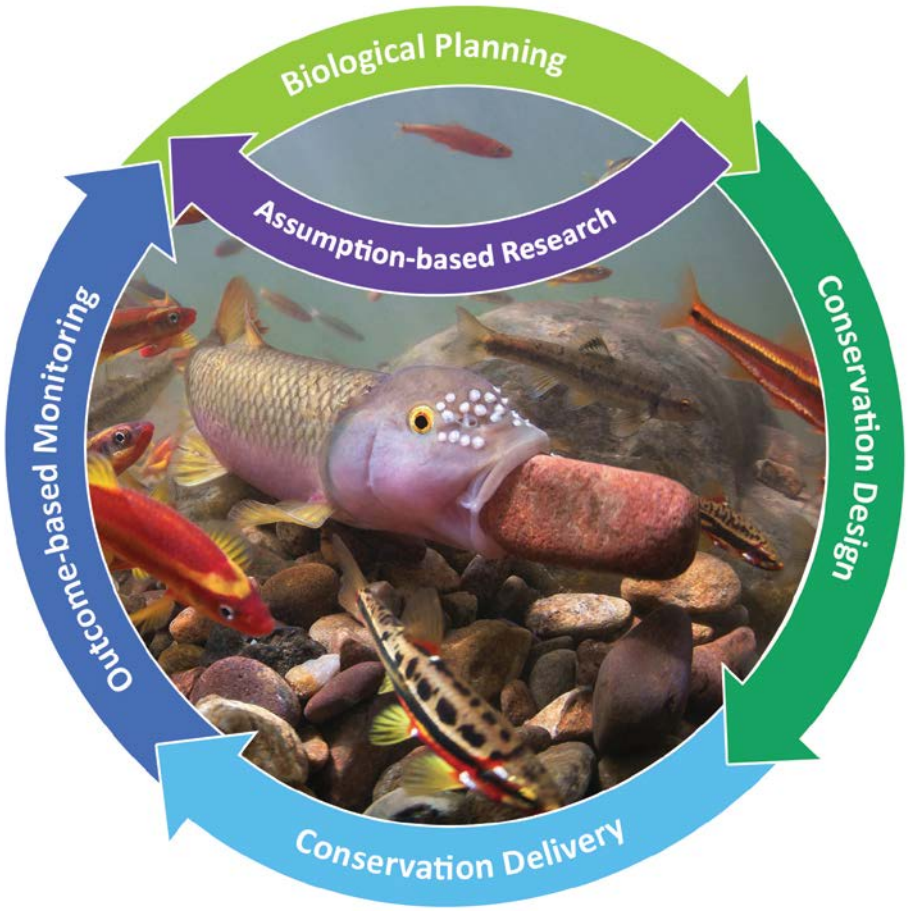

Figure 11.—The U.S. Fish and Wildlife Service's logo for the strategic habitat conservation model (modified from USFWS, 2024). Photo used with permission of Issac Szabo.

habitats that aims to maximize the return on investments of conservation dollars (National Ecological Assessment Team, 2006). Many imperiled wildlife and plant species were suffering from the effects of habitat loss, habitat degradation, and invasive species, and it was determined that these stressors would be best addressed by working across a broad region (= watersheds for aquatics) rather than within the boundaries of refuges or other managed areas.

Building upon the newly published ESA critical habitat spatial framework for the 11 mussel species and the remaining foundation of the old MRBC relationships, the USFWS, GSA, ADCNR, and Alabama Clean Water Partnership began to envision cooperative species conservation more broadly. They incorporated the concepts and methods of the watershed approach advocated by the USEPA for water quality management and the SHC approach of USFWS for restoring and managing fish and wildlife to form the reimagined cooperative conservation approach. This new direction was envisioned as a partnership, or network, of agencies, industries and businesses, academic institutions, and landowners to facilitate imperiled species restoration and recovery as needed. The name of the new organization, the Alabama Rivers and Streams Network (ARSN), reflected its desire to be a communication tool (network) among members and its desire to focus on species conservation in rivers and streams of the state, centering on habitat and water resources restoration. An ARSN logo (fig. 12) was created reflecting these principles.

RECOGNITION FOR A NEW STRATEGY

Another significant event in the evolution of ARSN was the filing of a legal petition, in what has come to be known as the “megapetition,” to the USFWS by the Center for Biological Diversity (CBD) to list 404 aquatic, riparian, and wetland species in the southeastern United States as threatened or endangered under the ESA (CBD, 2010). In their letter dated April 20, 2010, addressed to Ken Salazar, Secretary of the Interior, Gary Locke, Secretary of Commerce, and Cindy Dohner, USFWS Region 4 Director, the CBD acknowledged that “Defendants [USFWS] recognize that a multi-species, ecosystem approach to their listing responsibilities under the ESA will assist them in better analyzing the common nature and magnitude of threats facing ecosystems, help them in understanding the relationships among imperiled species in ecosystems, and be more cost-effective than a species-by-species approach to listing responsibilities.” The CBD megapetition acknowledged that the Mobile River basin multi-species recovery plan (USFWS, 2000) ecosystem strategy to species conservation was a desirable way to proceed

Figure 12.—The logo for the Alabama Rivers and Streams Network, a species conservation organization.

in their view, particularly when there were so many imperiled aquatic species, as is the case in Alabama and the Southeast.

In 2002, ADCNR began their first State Wildlife Action Plan (SWAP) effort, a comprehensive state conservation plan that serves as a roadmap for conserving aquatic and wildlife species, resulting in a series of documents cataloging animal species and their conservation status in Alabama (ADCNR, 2025; Mirarchi, 2004; Mirarchi, Bailey, Garner, and others, 2004; Mirarchi, Bailey, Haggerty, and others, 2004; and Mirarchi, Garner, and others, 2004). Also during this time, plans for the population restoration and conservation of freshwater mollusks of the Mobile River basin (the "mollusk plan") was prepared by the Mobile River Basin Mollusk Restoration Committee (2010), a group of mollusk taxonomists and conservation professionals from the USFWS, ADCNR-WFFD, GSA, USGS Biological Resources Division (USGS-BRD), universities, and others. The goal of these mollusk plans was not to replace species recovery plans, but to provide an organized framework for the restoration of freshwater mollusk resources and their ecological functions to appropriate reaches of the Mobile River basin through the reintroduction and controlled propagation of priority imperiled mollusks. The mollusk plans prioritized conservation and propagation activities for imperiled mollusks in the Mobile River basin and Tennessee River drainage and provided guidelines for resource managers and recovery partners. The mollusk plan was not a legal document and did not replace or supersede any published recovery plans for listed mollusks; rather, it was a set of directions and priorities for culture and propagation of mollusks at the newly created Alabama Aquatic Biodiversity Center (AABC) located near Marion in Perry County, Alabama, a facility that was established in 2005 and began mollusk reintroductions in 2010. The AABC would soon lead the way in mollusk propagation and subsequent reintroduction of mollusks into streams statewide.

ALABAMA RIVERS AND STREAMS NETWORK PROCESS

The new watershed/ecosystem strategy gaining traction in the conservation realm necessitated a multidisciplinary tactic by merging the watershed approach advocated by the USEPA for nonpoint source water quality restoration with the strategic habitat conservation approach of USFWS for restoring and managing fish and wildlife.

Because watershed plans provide an analytic framework for managing efforts both to restore water quality in degraded areas and to protect overall watershed health, the USEPA determined the elements needed for developing watershed management plans (USEPA, 2008, 2013), which provided a beginning foundation to cultivate the ARSN framework for better and more effective imperiled species conservation. The USEPA developed nine minimum elements to help watershed stakeholders address some of the more common pitfalls experienced in watershed plans, particularly those for impaired waters. The USEPA's nine elements approach (outlined below) has many beneficial points that are applicable to species recovery:

1. Identify sources and causes of pollution.
2. Estimate pollutant loading into the watershed and the expected load reductions.
3. Describe management measures that will achieve load reductions and target critical areas.
4. Estimate amounts of technical and financial assistance and the relevant authorities needed to implement the plan.
5. Develop an information/education component.
6. Develop a project schedule.
7. Describe the interim, measurable milestones.
8. Identify indicators to measure progress.
9. Develop a monitoring component.

Implementing the nine essential elements of watershed plans takes place through five fundamental steps: (1) building partnerships, (2) characterizing the watershed, (3) determining water-quality goals and identifying solutions, (4) designing a program to implement

the watershed plan, and (5) measuring progress and adjusting the plan.

Complementing the USEPA watershed management plan approach, the USFWS SHC approach focused on conserving wildlife and plant populations and their habitats by working across watersheds with engaged stakeholders through adaptive management. The SHC approach emphasizes:

- Working at larger landscape (watershed) scales;
- Working with partners (other agencies, tribes, universities, private landowners) to leverage resources, jointly address shared concerns, and maximize the effectiveness of conservation actions;
- Using science-based conservation planning and design;
- Setting measurable goals; and
- Applying adaptive management principles, which is a systematic approach to assessing the effectiveness of conservation actions with outcome-based monitoring so conservation measures can be adjusted and improved over time.

From these foundations, the ARSN model took shape under the principles of cooperating partnerships; a common restoration goal, which is the water resource; the need to make progress in restoring and recovering the many listed aquatic species in Alabama; and working to develop trusting relationships among landowners and partners through good communication, straight talk, and working as honest brokers.

By merging the major components of watershed management (USEPA's nine elements) with those of SHC, the stage was set to construct an integrated means to implement aquatic species conservation in Alabama and the Mobile River basin—regions of very high aquatic biodiversity. The resulting ARSN aquatic species conservation framework consists of eight elements that included the capacity for adaptation:

1. Limit the geographic scope of restoration plans and attempt to work in smaller watersheds or unique river reaches.
2. Build cooperative relationships among participants and work through neutral partnerships to identify areas of need, coordinate funding, and provide opportunities for reporting results.
3. Value the importance of the private landowner in the Southeast.
4. Place emphasis on restoration of the water resource.
5. Have a process for accomplishing recovery:
   a. Assess
   b. Restore
   c. Recover
   d. Monitor
6. Let science guide the process and decision making as appropriate.
7. Find projects of opportunity.
8. Provide opportunities for cooperator and landowner training and education.

LIMIT THE GEOGRAPHIC SCOPE OF RESTORATION PLANS

Because securing ample funding, personnel, and support for conservation can be a challenge, it becomes necessary to limit the geographic footprint of conservation to areas where the available resources and expended effort results in tangible gains for the greatest number of species. Due to the diverse aquatic habitats across the Mobile, Tennessee, and coastal river drainages, the founding organizers of ARSN decided that focusing on species with designated critical habitat would be a good start at narrowing the geographic scope of recovery. Using the EPA's watershed evaluation and assessment protocols as a guide, it was decided to delineate a watershed area from the most downstream point of officially designated ESA critical habitat for aquatic species. Once a watershed (unit) is established, then land and water protective measures can be implemented, resulting in improved aquatic habitat and water quality and eventually improving the biological status of listed species. These designated watersheds define a strategic habitat unit (SHU). Designated SHUs support one or more listed aquatic species and delineate a narrowed geographic area to better focus available human and monetary

resources for conservation. The ARSN has also designated strategic river reach units (SRRUs) to capture smaller yet unique reaches of larger rivers that support imperiled species. Three generations of the SHU-SRRU map have been produced for cooperators and network members to plan their activities and were developed with input from the USFWS, GSA, and ADCNR-WFFD (O'Neil and others, 2008; Wynn and others, 2012; Wynn and others, 2018).

DEFINITION OF A STRATEGIC HABITAT UNIT AND A STRATEGIC RIVER REACH UNIT

Strategic habitat and river reach units are those watersheds and river segments of *exceptional ecological significance* that support *viable, healthy aquatic habitats and populations of imperiled species* and that provide suitable opportunities for *restoration and recovery actions*.

EXCEPTIONAL ECOLOGICAL SIGNIFICANCE

Waters of exceptional ecological significance have superior physical, chemical, and biological values beyond the ordinary necessary for sustaining typical ecological functions and processes. These waters may include any combination of least or minimally impaired abiotic and biotic components. The abiotic components include such things as productive and high-quality physical habitat, water quality regimes that fully support ADEM's water-use classification, and unimpaired or minimally impaired stream flows. The biotic components include the presence of imperiled aquatic species, unique biodiversity, and biotic communities of good to excellent quality.

VIABLE AND HEALTHY AQUATIC HABITAT

Healthy habitat is key to aquatic species recovery and encompasses the physical, chemical, and hydrological environment within which species grow, survive, and reproduce. A suitable definition of "healthy habitat" comes from 69 FR 40083, which describes the primary constituent elements of Mobile River basin mussel critical habitat as follows:

- Geomorphologically stable stream and river channels and banks.
- A flow regime (i.e., the magnitude, frequency, duration, and seasonality of discharge over time) necessary for normal behavior, growth, and survival of all life stages of mussels and their fish hosts in the river environment.
- Water quality conditions including temperature, pH, hardness, turbidity, oxygen content, and other chemical characteristics necessary for normal behavior, growth, and viability of all life stages.
- Sand, gravel, and(or) cobble substrates with low to moderate amounts of fine sediment, low amounts of attached filamentous algae, and the presence of other physical and chemical characteristics necessary for normal behavior, growth, and viability of all aquatic life stages.

POPULATIONS OF IMPERILED SPECIES

Imperiled species are those that are listed under the ESA as endangered, threatened, or candidate or that are considered species of high to highest conservation need by the states as discussed in SWAPs.

RESTORATION AND RECOVERY ACTIONS

Restoration actions are those activities that physically repair damaged aquatic habitat or adjacent riparian habitat (e.g., by restoring eroding stream banks); eliminate barriers to the movement of aquatic animals (e.g., by removing unneeded dams or replacing a perched culvert); impede sediment movement to a stream or reduce land erosion through application of a best management practice (BMP); enhance water quality through BMPs and improved discharge requirements (e.g., in urban areas by controlling stormwater runoff, in agricultural areas by implementing soil management practices, in silvicultural areas by following streamside management zone and stream crossing guidelines); restore natural patterns of stream hydrology (e.g., by removing dams and channelized sections of streams); and prevent artificial depletion of surface water flow (e.g., by managing surface and groundwater withdrawals). Recovery actions for imperiled species include activities to culture and reintroduce imperiled populations; surveys to locate new populations and confirm

the viability of known and historic populations; studies to understand taxonomic relationships of natural populations; and studies to define ecological, physiological, and toxicological needs and limits.

STRATEGIC HABITAT UNIT AND STRATEGIC RIVER REACH UNIT MAPS

The first SHU map, published as GSA Special Map 247 (O'Neil and others, 2008) included 24 SHUs and two SRRUs in the Mobile River basin delineated based on ESA-designated critical habitat of 11 mussel species published in 2004 (fig. 13). The second version of the SHU map, published as GSA Special Map 248 (Wynn and others, 2012), extended the SHU/SRRU concept beyond the Mobile River basin to include additional watersheds and river reaches in other areas of Alabama and in selected contiguous watersheds whose rivers and streams flow either into or out of Alabama (fig. 14). These additional watersheds and SHU boundaries outside of Alabama in the second version were included to extend the ARSN conservation process to entire watersheds regardless of political boundaries. The third version of the SHU map, published as GSA Special Map 248-B (Wynn and others, 2018), expanded on this concept of entire watershed inclusion and delineated additional SHUs and SRRUs, bringing the total to 46 SHUs and 14 SRRUs (fig. 15). The Tennessee USFWS Ecological Services office, working in

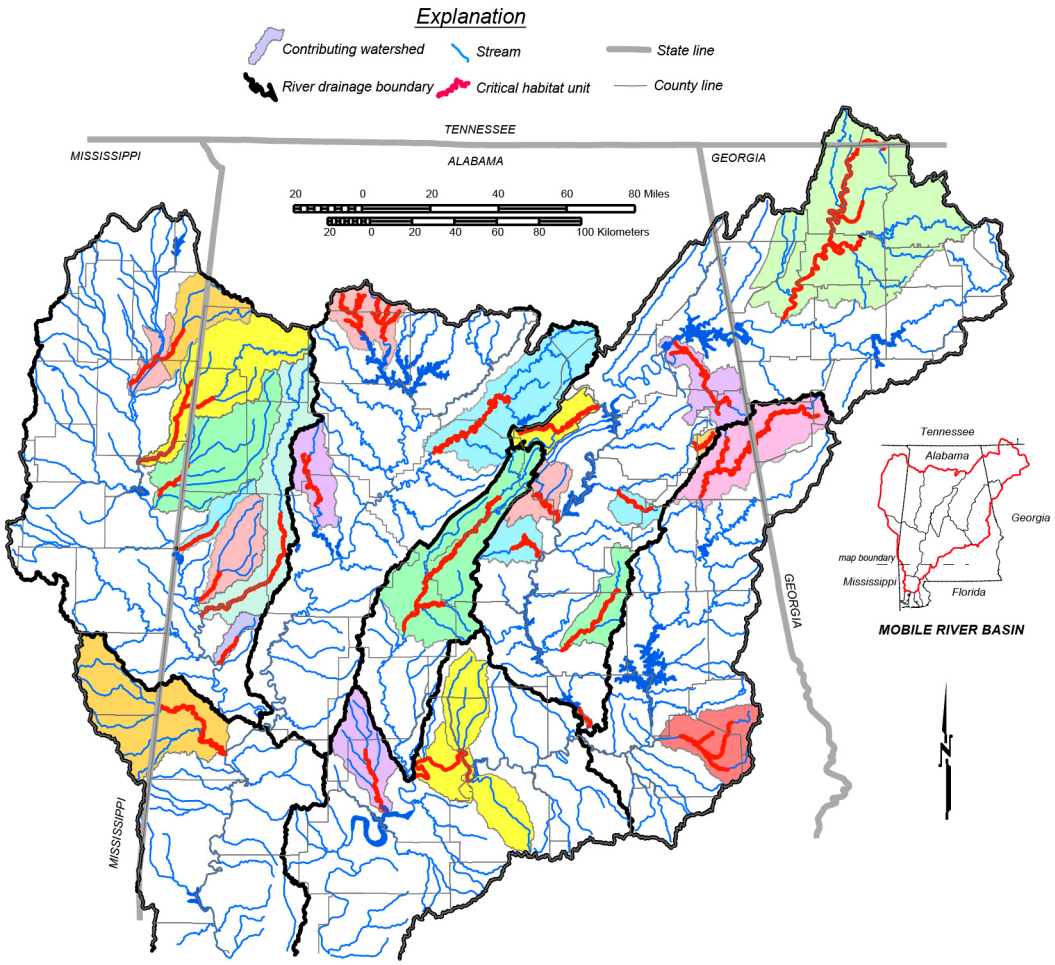

Figure 13.—Critical habitat units for threatened and endangered mussels in the Mobile River basin of Alabama and adjoining states, Strategic Habitat Unit map version one (modified from O'Neil and others, 2008).

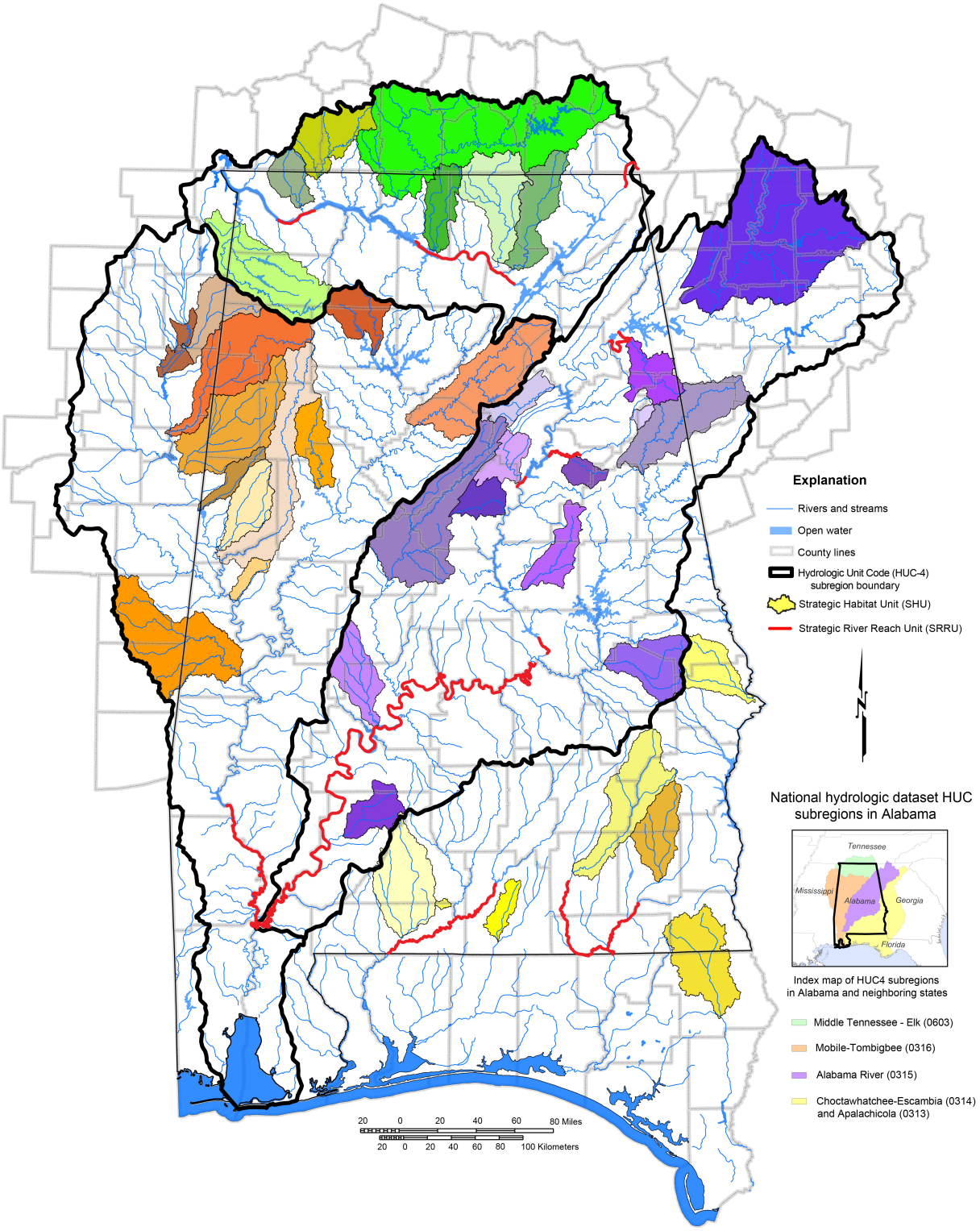

Figure 14.—Strategic habitat and river reach units for aquatic species of conservation concern in Alabama and adjoining states, Strategic Habitat Unit-Strategic River Reach Unit map version two (modified from Wynn and others, 2012).

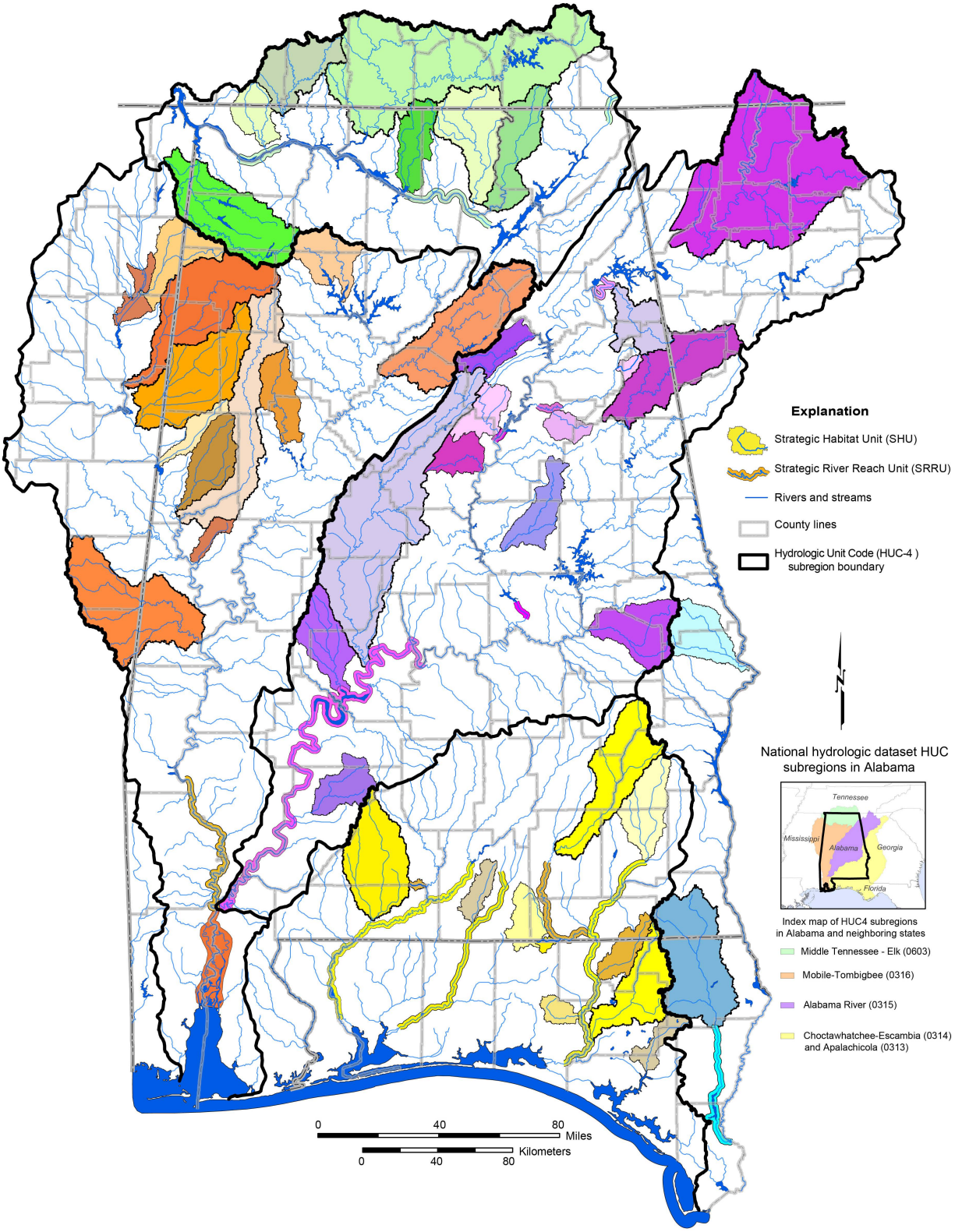

Figure 15.—Strategic habitat and river reach units for aquatic species of conservation concern in Alabama and adjoining states, Strategic Habitat Unit-Strategic River Reach Unit map version three (modified from Wynn and others, 2018).

conjunction with the Alabama Ecological Services office and the Tennessee Valley Authority (TVA), has extended the ARSN SHU concept into Tennessee for conservation activities for a suite of freshwater mussel species; workers in Mississippi and Georgia have used the SHU map to help prioritize species conservation activities; and federal and state agencies have used the SHU concept and maps to assist their natural resource conservation functions and activities. The ADCNR in its 2015 Alabama SWAP chose to use the ARSN SHU concept in the aquatic conservation section of the plan.

Concurrently with the publication of GSA Special Map 248-B, the ARSN produced a supporting spreadsheet identifying the occurrence of known imperiled species in SHUs and SRRUs (Wynn and others, 2018), their federal ESA status, and their conservation status as designated by state fish and game agencies for Alabama, Florida, Mississippi, Tennessee, and Georgia for SHUs extending into these states. A sample of the information in the spreadsheet is shown in table 4. The phylogenetic relationships and systematic status of many aquatic species occurring in SHUs and SRRUs is constantly under evaluation, and as such, the SHU-species matrix is updated at times regarding the most current taxonomic names and species conservation status consistent with the most recent SWAP.

BUILD A COOPERATIVE PARTNERSHIP AND MEANINGFUL RELATIONSHIPS

Cooperative partnerships are the absolute first action item when working toward species restoration. Whether conservation is happening on public or private lands, honest and forthright communication and partnering with other institutions and individuals is fundamental. The ARSN can be thought of as a shopping list of potential cooperators and partners for species conservation efforts (see listing in appendix C). The ARSN partners each have unique staff skills, agency and business missions and goals, and access to resources that any one partner working alone would find difficult to have under one roof. Another important role of ARSN is to provide a neutral forum for cooperators to meet, plan, discuss, and execute recovery projects. Typically, business and industry are at times requested by USFWS or the state to consider imperiled species in their business decisions and operations under conservation laws and regulations. Having a neutral partnership as part of the ARSN model facilitates these kinds of interactions/discussions and can lead to positive species recovery outcomes.

The Alabama Clean Water Partnership provided early ARSN administrative support services for a few years until it was disbanded. Currently, Cawaco Resource Conservation & Development Council, Inc. (Cawaco), a nonprofit 501(c)3 organization, provides administrative and project support for ARSN conservation projects. Resource, Conservation, and Development Councils were organized based on the premise that local people, working together, can cooperatively address local issues and opportunities that enhance quality of life. Cawaco plans and supports activities that increase the conservation of natural resources, improve local economies, and provide for human development. It is actively involved in management of multi-county, cross-jurisdictional projects and partnerships.

VALUE THE IMPORTANCE OF THE PRIVATE LANDOWNER IN THE SOUTHEAST

Private land ownership in the United States varies from state to state, with individuals and corporations owning approximately 60 percent of the land; in total 77 million people own 1.3 billion acres of private land (American Geographical Society, 2023). Additionally, 63 percent of privately owned lands are farms and ranches, while 32 percent are forests. It is reported that 95.1 percent of Alabama land is in private ownership followed by federal ownership at 3.1 percent and state/other ownership at 1.8 percent (Headwater Economics, 2019). Private ownership in the states surrounding Alabama is 91.8 percent for Mississippi, 90.3 percent for Tennessee, 91.9 percent for Georgia, and 73.7 percent for Florida. Recent information from the Alabama Forestry Commission (2024) places the amount of privately owned lands in Alabama at around 93 percent.

Table 4.—Example of information as provided in the Strategic Habitat Unit (SHU) species matrix.

Species		Conservation status [1]						Middle Tennessee-Elk (0603) subregion									
								Bear Creek	Tennessee River-Wilson Dam tailwater	Cypress Creek	Shoal Creek	Elk River	Limestone, Piney, Beaverdam Creeks	Tennessee River-Guntersville Dam tailwater	Flint River	Paint Rock River	Tennessee River-Nickajack Dam tailwater
Scientific name	Common name	USFWS	Alabama	Florida	Georgia	Mississippi	Tennessee	1	2	3	4	5	6	7	8	9	10
Mussels																	
Actinonaias ligamentina	Mucket		P1			S1, LE	S4	H	H			H		H		X	H
Actinonaias pectorosa	Pheasantshell		P1				S4									X	
Alasmidonta marginata	Elktoe		P1				S4									X	
Alasmidonta triangulata	Southern Elktoe		P1	R, BV	S1, E												
Alasmidonta viridis	Slippershell Mussell		P1												X	X	H
Amblema neislerii	Fat Threeridge	E		FE, R, BV	S1, E												
Anodonta hartfieldorum	Cypress Floater		P3	BV		S3S4											
Anodontoides radiatus	Rayed Creekshell		P2	BV	S2, T	S2											
Cumberlandia monodonta	Spectaclecase	E	P1				S2S3		X			H		X			
Cyprogenia stegaria	Fanshell	E	P1				S1, E		X			H		H			H
Dromus dromas	Dromedary Pearlymussel	E	Ex				S1, E	H	H				H	H			H
Elliptoideus sloatianus	Purple Bankclimber	T	P1	FT, R, BV	S2, T												
Elliptio arca	Alabama Spike		P1		S1, E	S1S2	S2										
Elliptio arctata	Delicate Spike		P2	BV	S2, E	S1, LE	S2										
Elliptio chipolaensis	Chipola Slabshell	T	P1	FT, R, BV													

Table 4.—Example of information as provided in the Strategic Habitat Unit (SHU) species matrix—continued.

Species		Conservation status [1]						Middle Tennessee-Elk (0603) subregion									
								Bear Creek	Tennessee River-Wilson Dam tailwater	Cypress Creek	Shoal Creek	Elk River	Limestone, Piney, Beaverdam Creeks	Tennessee River-Guntersville Dam tailwater	Flint River	Paint Rock River	Tennessee River-Nickajack Dam tailwater
Scientific name	Common name	USFWS	Alabama	Florida	Georgia	Mississippi	Tennessee	1	2	3	4	5	6	7	8	9	10
Elliptio dilatata	Spike		P1			S1, LE			X		H	H	H	X	H	X	H
Elliptio purpurella	Inflated Spike		P1	R, BV	S2, T												
Epioblasma ahlstedti	Duck River Dartersnapper		Ex					H	H		H						
Epioblasma brevidens	Cumberlandian Combshell	E	P1			S1, LE	S1, E	X	H					H			H
Epioblasma capsaeformis	Oyster Mussel		Ex		SX		S1, E		H			R	H		H	H	H
Epioblasma penita	Southern Combshell	E	P1		SX	S1, LE											
Epioblasma triquetra	Snuffbox	E	P1			S1, LE	S3	H	H			X		H	H	X	H

[1] **Conservation status abbreviations**

X-present, **H**-historic, **R**-reintroduced

USFWS E-endangered, T-threatened

Alabama: P1-highest conservation concern, P2-high conservation concern, P3-moderate conservation concern, Ex-extirpated.

Florida: SL-state listed taxa, R-rare, BV-biologically vulnerable, FE-federal endangered, FT-federal threatened.

Georgia: S1-critically imperiled, S2-Imperiled, SX-presumed extirpated, E-endangered, T-threatened.

Mississippi: S1-critically imperiled, S2-Imperiled, S3-Rare or uncommon, S4-widespread, apparently secure, LE-listed endangered.

Tennessee: E-endangered, S1-critically imperiled, S2-imperiled, S3-vulnerable, S4-apparently secure.

An interesting dilemma regarding species diversity and conservation in general is that most protections for species are generally found in the large areas of publicly owned land out West while the biodiversity hotspots are found in the Southeast, where most land is privately held. A major tool for conservation on private lands is easements, but data suggest that much of the southern lands under easements are not ideally positioned for biodiversity conservation (Jenkins and others, 2015). Endemic species-rich states in the Southeast (Tennessee, Kentucky, North Carolina, South Carolina, Mississippi, Alabama, and Georgia), which make up 10.7 percent of the total land area in the conterminous states, collectively contain only 7.8 percent of the conservation easement area.

Implementing federal regulations, like the ESA and CWA, on federal properties is a more straightforward process when the regulator is the regulated and owns the land. Managing species and water quality on private property is a different process because it requires the willingness of landowners to implement successful conservation practices such as easements. As such, effective imperiled species conservation work in Alabama requires that organizations must work cooperatively with landowners and adaptively manage their conservation desires with the landowner desires.

PLACE EMPHASIS ON RESTORING THE WATER RESOURCE

The ESA can be a lightning rod for controversy stemming from poorly communicated conservation goals, overzealous staff attempting to force regulatory requirements onto landowners, landowners distrustful of government operations, and poor education concerning the imperiled species of concern. While it may be easier to garner public support for well-known species, like the symbol of our country, the Bald Eagle, an endangered snail living in a geographically restricted area may prove more difficult. Because so much of the imperiled Southeast aquatic biodiversity is poorly known by the public, it is necessary to translate the biological/ecological need for conservation to another embodiment of the need. That need is simply the “water resource.” Everyone understands the need for and desire for clean and wholesome water resources. If the focus of species conservation can be expressed into a focus to improve, manage, and conserve water resources, then a good water outcome will directly translate to a good imperiled species outcome.

Karr and Yoder (2004) hypothesized the five major contributors to the biological condition of water resources (fig. 16): habitat structure, energy source, biotic factors, chemical variables, and flow regime. These five factors translate their impacts to biological condition in varied ways, some direct (dissolved oxygen content) and some indirect (eutrophication through excessive nutrients). In almost all cases, the flow regime (water) can be considered the master variable to the other four factors affecting biological condition. As such, focusing species restoration efforts on aspects of the water resource (i.e., repairing habitat, improving water quality improvement, reducing sediment and nutrients, improving stream flow and connectivity in stream channels, and improving watersheds) will positively affect the condition of imperiled species. Restoration may require augmentation or reintroduction of species to their original habitats if they are severely depleted, but this usually takes place after watershed/ecological factors are restored to some level of normal function.

HAVE A PROCESS FOR ACCOMPLISHING RECOVERY

The USEPA’s nine steps for watershed management plans and the USFWS’s SHC approach both contain elements of problem discovery, issue restoration, and monitoring. The ARSN has synthesized several of these concepts into what is known as the ARRM steps—assessment, restoration, recovery, monitoring. These steps complement the SHC process outlined in figure 11.

ASSESSMENT

Project planning efforts involve the collection of water quality and streamflow data, habitat assessments, species-specific surveys and genomic studies, biological

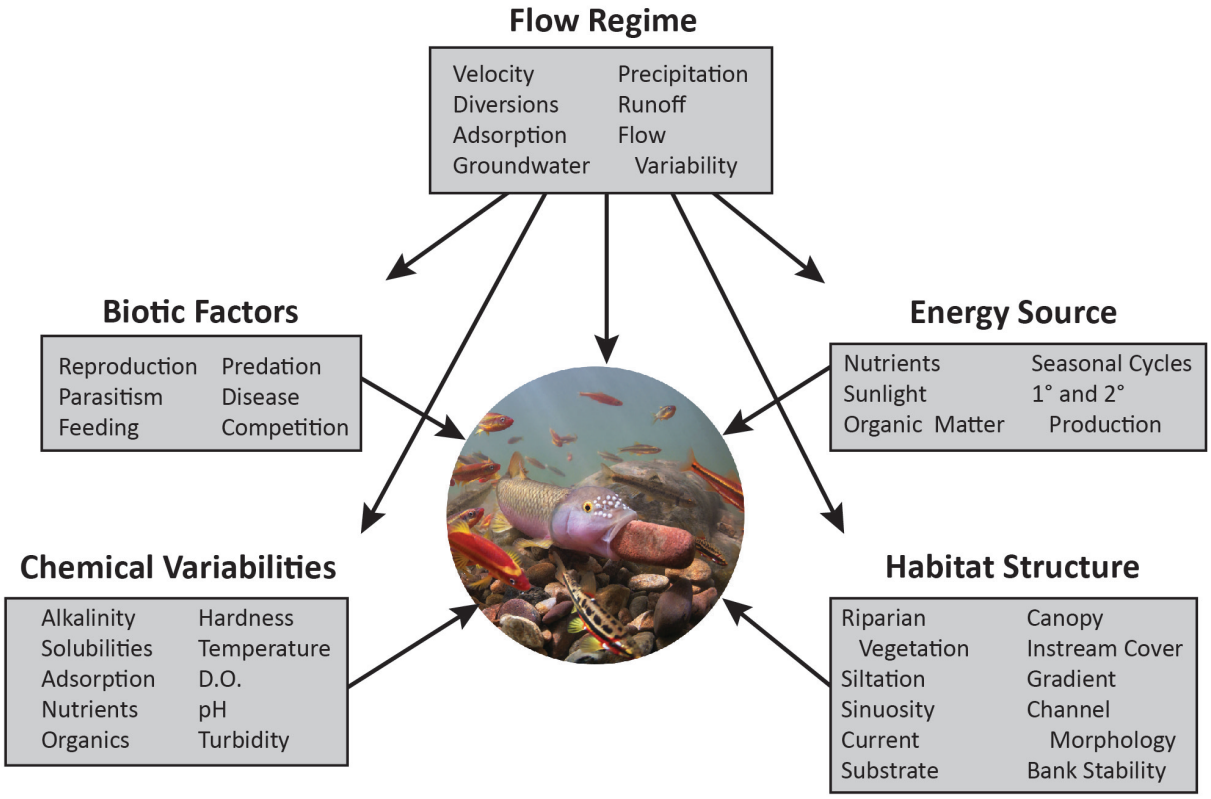

Figure 16.—Ecological components that affect aquatic biological condition (modified from Karr and Yoder, 2004).

condition surveys using benthic macro-invertebrate or fish IBI methodologies, land cover/land use analyses, threat assessments, and geographic information system analyses of landscape data to identify issues affecting listed species and to locate potential projects to alleviate these issues. The data are often compiled into a watershed- or species-focused report for distribution. This data provides an opportunity for ARSN partners to focus efforts and funding where there is landowner consent for on-the-ground projects.

RESTORATION

Project implementation activities include habitat renovation by repairing stream banks, removing barriers to fish migration, and restoring natural stream riparian cover. Water quality restoration can include applying nonpoint source BMPs to improve water quality in urban and agricultural areas, working with forest management companies to better apply and implement forestry BMPs, enhancing streamside management zones, converting impervious surfaces to pervious surfaces to better manage storm water runoff, and working with state water quality agencies to improve point source pollution permitting. Restoration of natural river and stream flows and improving aquatic organism passage have been accomplished by removing old and dangerous dams and working with utilities to provide more natural river flows downstream of their projects.

RECOVERY

Conservation delivery efforts are those administrative actions of federal and state agencies to implement the requirements of federal and state fish and wildlife law. These kinds of activities include conducting species status assessments, reviewing project plans, serving as liaison to business and industry regarding listed species, completing ESA

consultations by USFWS, reintroducing and(or) augmenting populations, and working on issues related to listed species. The USFWS defines the process of recovery as "working with partners to conserve the ecosystems upon which endangered species and threatened species depend, developing and maintaining conservation programs for these species to improve their status to the point that ESA protection is no longer necessary for survival."

Recovery planning for federally listed species includes various strategies and participation by partners to be successful. Measurable and objective criteria are developed as targets for each species to be considered "recovered" alongside activities necessary to reach those goals, such as life history studies, water quality improvements, species reintroductions, or removal of barriers to aquatic organism passage.

MONITORING

Outcome-based monitoring activities include assessing species' populations for size, health, recruitment, and stability with occasional measurements of water quality or biological condition to track long-term trends. Monitoring also entails working with industries to track potential future impacts to listed species and working with other groups and agencies to alleviate actions that are likely harmful to listed species.

LET SCIENCE GUIDE THE PROCESS

Adherence to basic scientific principles and methods provides the credibility needed to have successful species conservation. The ARSN partners have a high level of scientific expertise and technical proficiency in habitat assessment, biological monitoring, hydrology, natural history, aquatic science, limnology, environmental engineering, water quality, culture of mollusk and fish species, genomic analysis, geographic information systems (GIS) technology, water policy, and CWA and ESA regulations. Individuals with these skill sets contribute to the ARSN approach of interdisciplinary watershed science so urgently needed to conserve southeastern aquatic biodiversity.

FIND PROJECTS OF OPPORTUNITY

Another distinct objective of ARSN is that partners should work to find projects where several agencies, businesses, and landowners can work jointly and cooperatively for restoration. As an example, if a SHU contains listed mussels that occur in the main creek channel and sediment and(or) nutrients are causing water quality issues and the stream is listed on the state's §319 list of impaired water bodies, then CWA dollars and ESA dollars would be available to work on the problem. If fish migration barriers are present because of old dams or perched culverts, then the USFWS Partners for Fish and Wildlife program dollars are available. If landowners in the watershed have working forests and are amenable to conservation programs, then Natural Resource Conservation Service (NRCS) dollars are available for qualifying practices. If agricultural lands are in the watershed, then Farm Bill conservation dollars are available for qualifying practices. Having listed species in a watershed can lead to better control of pollution sources when several programs work cooperatively to provide funding to resolve problems.

PROVIDE OPPORTUNITIES FOR TRAINING AND EDUCATION

Other important goals of ARSN are to provide education opportunities for landowners and businesses about the ESA and presence of imperiled species in their respective geographic areas of concern, provide contacts for other agencies and individuals that may assist with their project, and provide knowledge about the ecological and economic values of species and the importance of maintaining functional aquatic systems.

The annual ARSN meeting is a forum for providing updates concerning species restoration to partners. Agencies provide briefs about assessment and monitoring activities in SHUs and SRRUs, results of aquatic species surveys, recent progress on culture and reintroduction of species, and regulatory and management issues affecting listed species. These meetings are also a time for researchers to present their work about

imperiled species' behavior, life history, and systematics. Business and industry also participate and update ASRN partners about ongoing projects in their business footprints and how their work to comply with ESA regulations is proceeding. The meeting is also used to discuss upcoming research and activities related to SHUs, as well as emerging technologies for environmental monitoring, and to present novel ways to collect, manage, and analyze data.

In-field technical training is also provided to partners to better standardize methods and teach environmental assessment tools. Past events and classes have concerned fish, mollusk, and crayfish identification; habitat assessment fundamentals; how to conduct biological assessments; status of urban darters in Jefferson County; and stream ecology demonstrations for landowners and loggers. Other instructional opportunities may involve assisting businesses and industries in conducting field days, aquatic plant identification and habitat assessment workshops, and training relating to boating and electrofishing techniques and safety considerations.

ALABAMA RIVERS AND STREAMS NETWORK ACHIEVEMENTS

Integrating the eight elements of the ARSN aquatic species conservation framework, ARSN partners have made substantial progress toward implementing effective conservation programs in Alabama. Building cooperative relationships among participants, working through neutral partnerships to identify areas of need, coordinating funding and providing opportunities to accomplish recovery, and emphasizing restoration of the water resource have been especially vital for successful species recovery.

POWER OF PARTNERSHIPS

The ARSN approach has provided a working example of how the framework unites multiple stakeholders by establishing common ground. Both the private sector and government agencies have benefited from its structure.

The recent purchase by Toyota-Mazda of a significant part of Beaverdam Spring complex in north Alabama assured that the manufacturing plant footprint would have the least possible impact on the habitat of the Spring Pygmy Sunfish, a federally listed threatened fish species. The conservation actions of Toyota-Mazda have led to perhaps the best long-term conservation solution for the species given that the land surrounding Beaverdam Spring was experiencing rapid urban growth, which would have been more damaging to the Beaverdam Spring complex. Assurances and financial commitments to conservation of the Spring Pygmy Sunfish and Beaverdam Spring by Toyota-Mazda have resulted in a win-win for business and aquatic conservation in this region of Alabama.

Additionally, agencies such as the NRCS have used the SHU/SRRU map (Wynn and others, 2018) to prioritize areas for monitoring and put conservation dollars on the ground. The SHU map satisfies many obligations federal agencies have for consulting USFWS should listed species occur on a property of interest. When two or more groups can agree on a SHU in which to work, then the conservation results are boosted by orders of magnitude.

The power of ARSN partnerships has been recognized the last few years. In 2020, ARSN received the "Water Conservationist of the Year" award at the Annual Alabama Wildlife Federation's Governor's Conservation Achievement Awards ceremony, and in April 2024, Martha Williams, Director of the U.S. Fish and Wildlife Service, visited several stream barrier and road crossing restoration projects in the east Alabama watershed of Little Canoe Creek, St. Clair County (fig. 17). Director Williams (holding the sign in fig. 17) was accompanied by staff of the Alabama Ecological Services field office of USFWS, Region 4, USFWS staff, ARSN partners who worked on these projects, local government officials, and field staff of landowner Manulife/John Hancock Financial Services. The theme of cooperative conservation action was emphasized throughout the day as the key to successful restoration projects to benefit imperiled species, and ARSN was highlighted as a model for success.

Figure 17.—Alabama Rivers and Streams Network partners inspecting a newly installed road crossing on April 19, 2024. The old crossing was blocking access to upstream breeding habitat of the Trispot Darter in the Big Canoe Creek watershed in St. Clair County, Alabama.

SPECIES LISTING AND RECOVERY

While the growing number of partners is one testament to the success of conservation efforts, the ARSN approach has also yielded measurable achievements in the aquatic species recovery arena through the pathways formed by the ESA. The USFWS plays the lead role in the species listing and recovery process by administering the regulatory functions of the ESA. The first stage of listing a species occurs when the USFWS is officially petitioned (fig. 18) to list a species and is supported by species surveys, threat assessments, and other studies to determine if the species qualifies for listing (appendix D). If a decision is made that a candidate species warrants listing, then a very specific regulation-driven listing process is followed that includes a species status assessment, public notifications of USFWS actions, and development of recovery plans and conservation actions (appendix D). Due in part to the proactive nature of ARSN and the implementation of ongoing recovery efforts and collaborative partnering opportunities of the ARSN, several species have been removed completely from the ESA (delisted) and one has improved enough to be downlisted (appendix D).

The purpose of the ESA is to provide a means to conserve the ecosystems upon which endangered and threatened species depend and to provide a program for the conservation of such species. The ESA directs all federal agencies to participate in conserving these species through the Section 7 Consultation process involving Sections 7(a)1 and 7(a)2 of the ESA. Section 7(a)1 charges federal agencies (including the USFWS when implementing its authorities outside of the ESA) to carry out programs within their authorities to advance the recovery of endangered and threatened species (appendix D). This obligation is species specific and is triggered when a species is listed under the ESA.

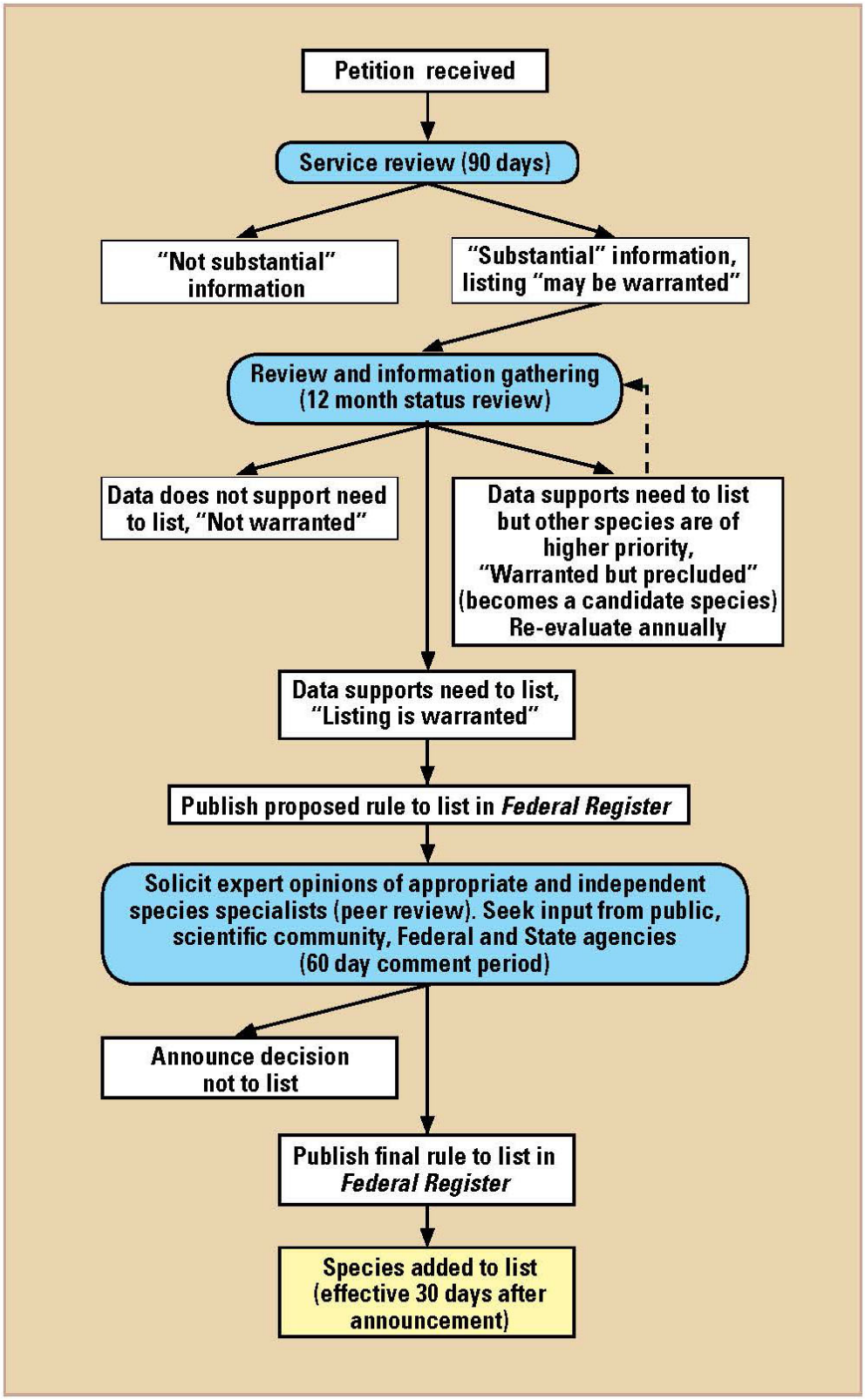

Figure 18.—The petition process for listing a species through the U.S. Fish and Wildlife Service under the Endangered Species Act (USFWS, 2016a).

To guide the ESA listing decision process, the USFWS also employs the use of the species status assessment (SSA) framework (fig. 19), an analytical approach developed to deliver foundational science for informing all ESA decisions (USFWS, 2016b; appendix D). An SSA is a focused, repeatable, and rigorous scientific assessment. The results of an SSA are better assessments, improved and more transparent and defensible decision making, clearer and more concise listing documents, and increased engagement by species experts outside of the USFWS. The SSA does not result in a decision for listing or not listing, but rather provides the biological information and scientific analysis foundation in support of listing decisions and other activities of the ESA (USFWS, 2016b). The SSA framework is a relatively new activity (2016) of the listing process and is also applied to the recovery and reclassification process. An SSA is in essence a biological risk assessment to aid decision makers who must use the best available scientific information to make policy decisions. The SSA provides decision makers with a scientifically rigorous characterization of species status that focuses on the likelihood that the species will sustain populations within its ecological settings, factoring in key uncertainties into that characterization.

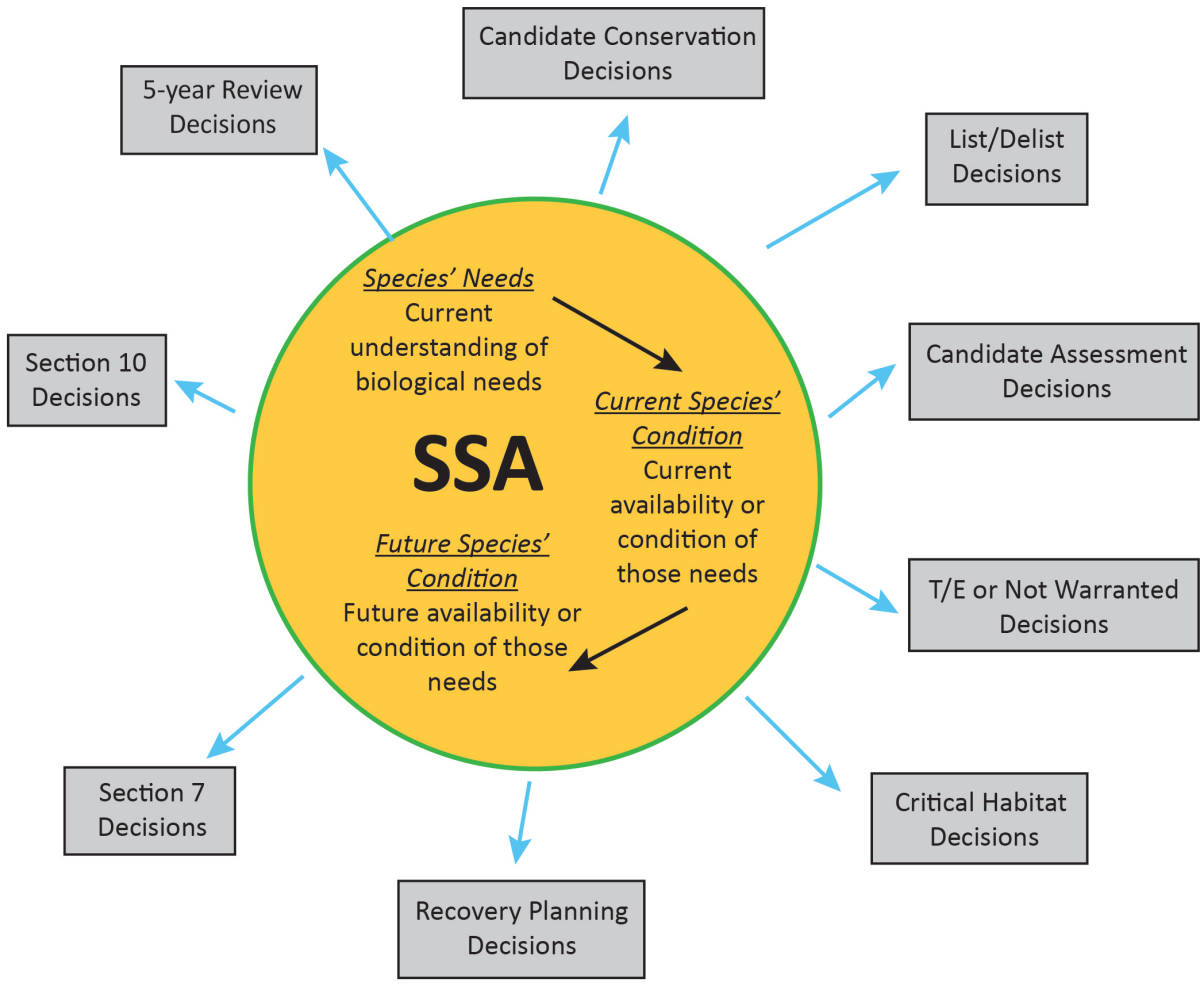

Figure 19.—Species status assessment framework and functions of the Endangered Species Act that it supports (modified from USFWS, 2016b).

MOLLUSK REINTRODUCTIONS

Through 2023, the USFWS has listed 81 species of mollusks and fish as threatened or endangered in Alabama's watersheds (table 2, appendix A). To address the conservation needs of these species, efforts by the ADCNR began to fulfill the ecological need for mollusk restoration in the Mobile River basin. Retrofit of a closed federal hatchery, located at the state fish hatchery in Marion, Alabama, from fish culture to mollusk culture began in late 2005 and was completed in late 2010. Named the Alabama Aquatic Biodiversity Center (AABC), a dedication ceremony took place in 2010, and the first batch of mussels were reintroduced to Alabama waters that same year. A fish culture facility was completed at the AABC in 2016 to focus on recovery of small-bodied fishes and to culture host-fish for mussel propagation. The AABC facilities constitute the largest state nongame recovery program of its kind in the United States with a mission to promote the conservation and restoration of rare freshwater species in Alabama waters and in turn restore the ecological functions in Alabama's waterways. The facilities at the AABC encompass 13,875 square feet of space under roof, a 5,525-square-foot outdoor culture field, a 4,300-square-foot administration building with office and laboratory space, and approximately 30 surface acres of aquaculture ponds (Outdoor Alabama, 2023).

Introducing mollusks into streams and waterways promotes water-quality improvements by removing pathogens and sediment through the water-filtering activities of mussels. These filter feeders process many gallons of water per day, removing bacteria and suspended solids, and expiring clear water back into the stream. An individual mussel can filter over 12 gallons of water per day, and in healthy ecosystems throughout the Southeast, freshwater mollusks historically numbered in the hundreds of millions, providing significant, free water pollution removing capacity. Since 2010, the AABC has developed propagation protocols for 30 federally listed mussel species and nine listed aquatic snail species.

From 2010 to 2024, the AABC programs have transformed over 1,500,000 individual mussels and reintroduced over 158,000 one- to two-year-old cultured mussels (17 species, 11 federally listed) and 133,265 six-month-old cultured snails (5 species, 3 federally listed) back to rivers and streams (fig. 20). Over this 14-year period, the top three mussel species

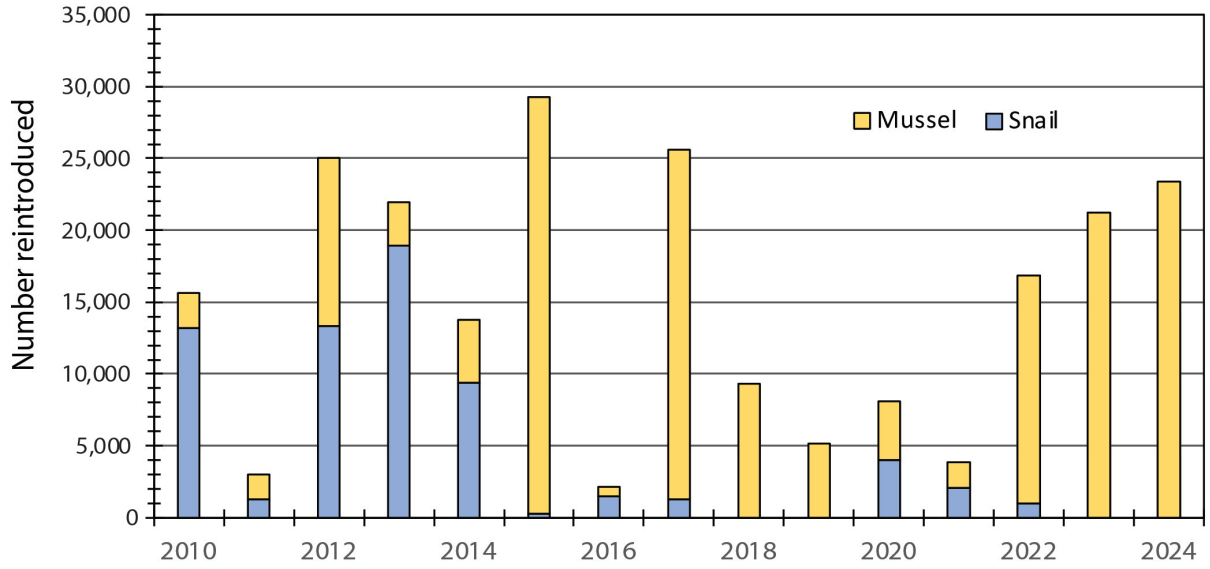

Figure 20.—Mollusk reintroductions into Alabama rivers and streams annually from 2010 to 2024 (data from Alabama Aquatic Biodiversity Center).

stocked into Alabama waters were the Alabama Lampmussel (*Lampsilis virescens*), 50,876 individuals, Alabama Rainbow (*Cambarunio nebulosa*), 34,170 individuals, and the Orangenacre Mucket (*Hamiota perovalis*), 31,032 individuals (fig. 21). The top two snail stockings were the Plicate Rocksnail (*Leptoxis plicata*), 67,110 individuals, and the Spotted Rocksnail (*Leptoxis picta*), 56,749 individuals. Snail and bivalve mollusk reintroductions have taken place in several streams of the Mobile River basin and Tennessee River drainage since 2010 (table 5).

In addition to river and stream stockings, over 21,000 juvenile mussels have been provided to agencies and universities for stocking and research purposes including the U.S. Forest Service; USFWS; Mississippi Department of Wildlife, Fisheries and Parks; Louisiana Department of Wildlife and Fisheries; Tennessee Wildlife Resources Agency; Virginia Department of Wildlife Resources; Georgia Department of Natural Resources; Auburn University; University of Alabama; University of Mississippi; University of Michigan; North Carolina State University; University of Georgia; and the USGS National Water Quality Laboratory in Columbia, Missouri.

DAM REMOVALS

One of the eight elements of the ARSN framework places emphasis on restoration of the water resource, including restoring connectivity to waterways. From an ecological perspective, ARSN has logged remarkable results following removal of unwanted dams and reconnection of rivers and streams.

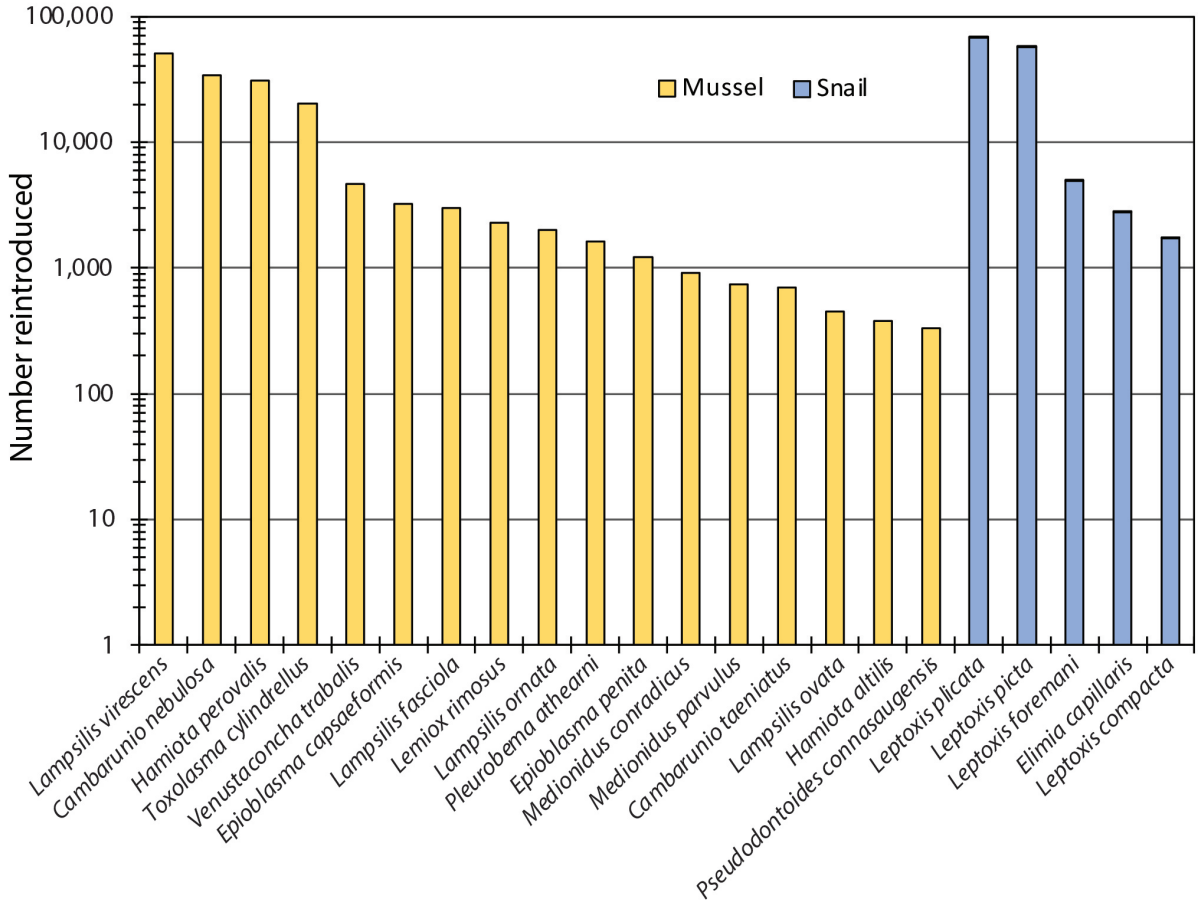

Figure 21.—Mollusk reintroductions into Alabama rivers and streams from 2010 to 2024 arranged by species (data from Alabama Aquatic Biodiversity Center).

Table 5.—Streams in which mollusks and snails have been reintroduced by the Alabama Aquatic Biodiversity Center in Alabama and Tennessee from 2010 to 2022.

Scientific name	Common Name	Status [1]	River or Stream [2]
Mollusks:			
Cambarunio nebulosus	Alabama Rainbow	under review	1, 2, 3, 5, 8
Cambarunio taeniatus	Painted Creekshell	AL P2	16
Epioblasma capsaeformis	Oyster Mussel	E	17
Epioblasma penita	Southern Combshell	E	10, 12
Hamiota altilis	Finelined Pocketbook	T	6
Hamiota perovalis	Orangenacre Mucket	T	1, 9
Lampsilis fasciola	Wavyrayed Lampmussel	AL P3	16, 21
Lampsilis virescens	Alabama Lampmussel	E	13, 15, 17, 18, 19
Lampsilis ornate	Southern Pocketbook	AL ngcn	8
Lampsilis ovata	Pocketbook	AL ngcn	20
Lemiox rimosus	Birdwing Pearlymussel	E	17
Medionidus conradicus	Cumberland Moccasinshell	PE	3
Medionidus parvulus	Coosa Moccasinshell	E	11
Pleurobema athearni	Canoe Creek Clubshell	E	4
Pseudodontoides connasaugensis	Alabama Creekmussel	AL P2	5, 6, 8
Toxolasma cylindrellus	Pale Lilliput	E	13, 14, 15, 16, 17
Venustaconcha trabalis	Cumberland Bean	E	17
Snails:			
Leptoxis coosaaensis	Painted Rocksnail	T	7
Leptoxis compacta	Oblong Rocksnail	PE	10,
Leptoxis foremani	Interrupted Rocksnail	E	8
Leptoxis picta	Spotted Rocksnail	under review	10
Leptoxis plicata	Plicate Rocksnail	E	1
Elimia capillaris	Spindle Elimia	AL P1	8

[1] Federal: E–endangered, T–threatened, PE–provisional endangered.
Alabama: P1–priority 1, P2–priority 2, P3–priority 3, ngcn–non greatest conservation need.

[2] List of rivers and streams in which mollusks and snails have been reintroduced:

River System	Stream number and name
Black Warrior River system	1. Locust Fork
	2. Blackburn Fork
	3. Turkey Creek
Coosa River system	4. Big Canoe Creek
	5. Choccolocco Creek
	6. Little River
	7. Coosa River downstream of Jordan Dam
	8. Coosa River-bypass channel/Terrapin Creek
	9. Tallatchee Creek
Cahaba River system	10. Cahaba River main channel
	11. Little Cahaba River (lower tributary)
Tombigbee River system	12. Bull Mountain Creek
Tennessee River drainage	13. Bear Creek
	14. Duck River (TN)
	15. Elk River (TN)
	16. Limestone Creek
	17. Paint Rock River
	18. Sequatchie River (TN)
	19. Shoal Creek (AL and TN)
	20. Flint River

Removing unwanted and non-serviceable dams has immediate restoration value for aquatic species by reconnecting former fish migration routes, allowing host fishes to resume interactions with mussels to transport glochidia, and restoring flows to a more natural and seasonally predictable ecological hydrograph. Perhaps more importantly are safety and liability issues attached to unwanted and abandoned dams. Between 2004 and 2024, conservation organizations and agencies have removed six significant dam barriers in Alabama, and several more are on the list for removal soon. Over 1,000 miles of stream and river habitat have been returned to a natural flow status, allowing fish and mussel species access to historic spawning habitat and improving water quality conditions.

MARVEL SLAB 2004

Removal of the Marvel Slab on the Cahaba River in 2004 was one of the first large dam removals in Alabama, marking the first time a dam was removed in the state for stream restoration and conservation reasons. The dam—6 feet tall, 210 feet long, and 24 feet wide (fig. 22)—was constructed in northern

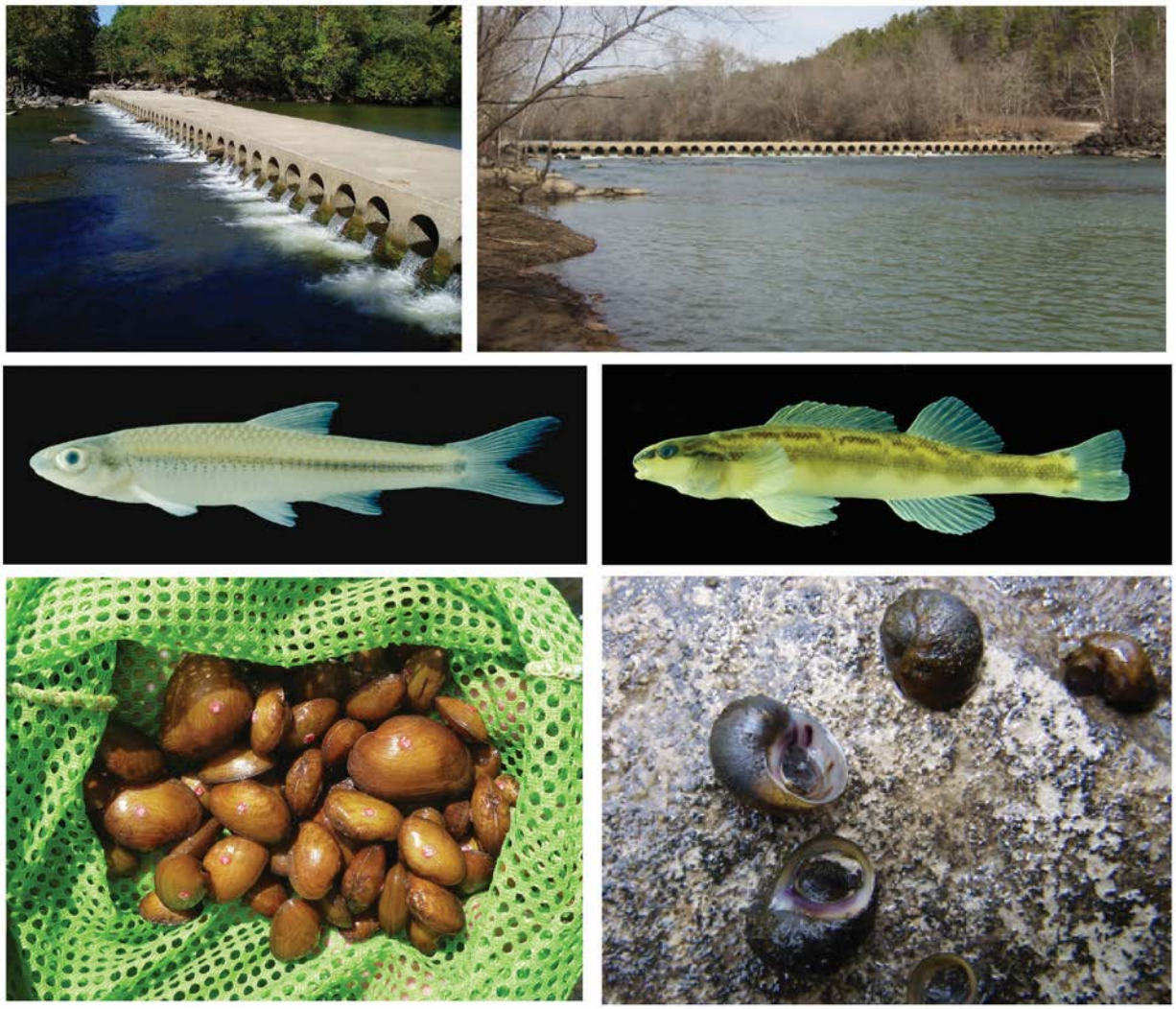

Figure 22.— Photographs of federally listed mussel and fish species occurring at the old Marvel Slab site in the Cahaba River, Shelby County, Alabama. Clockwise from top left: Marvel Slab depicting the extreme perched condition of the culverts, the full width of the Marvel Slab (pre removal) across the Cahaba River, Goldline Darter, Round Rocksnail, Southern Combshell, and the Cahaba Shiner.

Bibb County to allow coal and logging trucks a shorter route to cross the Cahaba River. It was a giant slab of concrete with 46 culverts, each 3 feet in diameter, for water passage. These culverts were perched 4 feet or more above the downstream river surface, effectively blocking fish migration during seasonal periods. The removal work was sponsored by and partially funded by the U.S. Army Corps of Engineers, with additional funds from the World Wildlife Fund, The Nature Conservancy, the Cahaba River Society, USFWS, and the ADCNR. Eight agencies, coordinated and led by the Alabama Chapter of The Nature Conservancy, along with conservation groups and landowners along the river, worked to complete the project.

By improving habitat in the Cahaba River that these animals need to survive, the project aided in the recovery efforts for nine species of fish and mollusks protected under the ESA. More than 131 species of fish and more than 75 species of freshwater mussels and snails have been observed through time in the Cahaba, including 5 fish and 11 mollusk species protected under the ESA.

As part of the ESA section 7 process to minimize the harm to mussels and freshwater snails while the dam was being removed, scientists and technicians spent three days transplanting the animals from the slab footprint. They hand-picked thousands of snails and mussels from the bottom of the river, counting, identifying, and then transporting them upstream away from the dam removal site. Within two years after the dam was removed, upstream snail densities improved by orders of magnitude (fig. 23), rare fishes migrated upstream, and mussels returned to habitats previously vacated. Bennett and others (2015) reported likely new upstream records for five fish species—the Skygazer Shiner (*Miniellus uranoscopus*), River Redhorse (*Moxostoma carinatum*), Southern Sand Darter (*Ammocrypta meridiana*), Freckled Darter (*Percina lenticula*), and River Darter (*Percina shumardi*). These findings have reinforced the view that dam removals can result in restored mollusk populations and migration routes for fishes.

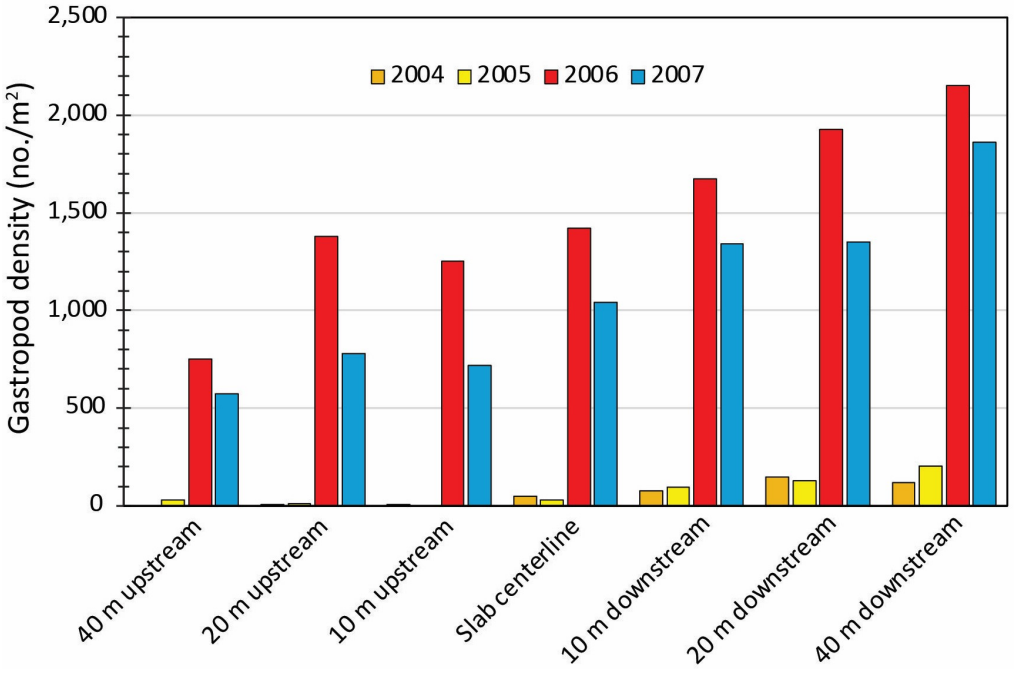

Figure 23.—Gastropod density at the Marvel Slab footprint in the Cahaba River, Shelby County, Alabama, following removal of the dam in 2004 (modified from Johnson and others, 2013).

SHADOW LAKE DAM 2012

The endangered Vermillion Darter (*Etheostoma chermocki*) was for many years only known to occur in the Turkey Creek watershed in and around the community of Pinson, Alabama. The downstream extent of its range was defined by Turkey Creek Falls, which forms at the boundary between the Warrior Basin and Birmingham-Big Canoe Valley physiographic districts. The upstream limit of distribution was a barrier known as Shadow Lake Dam (fig. 24). Because the distribution of the Vermillion Darter was so restricted, efforts were undertaken to remove Shadow Lake dam and provide opportunity to expand the range of the Vermillion Darter further upstream in Turkey Creek. Post-dam removal monitoring has confirmed the darter has migrated upstream well past the old dam footprint and established residency in the formerly impounded section of Turkey Creek.

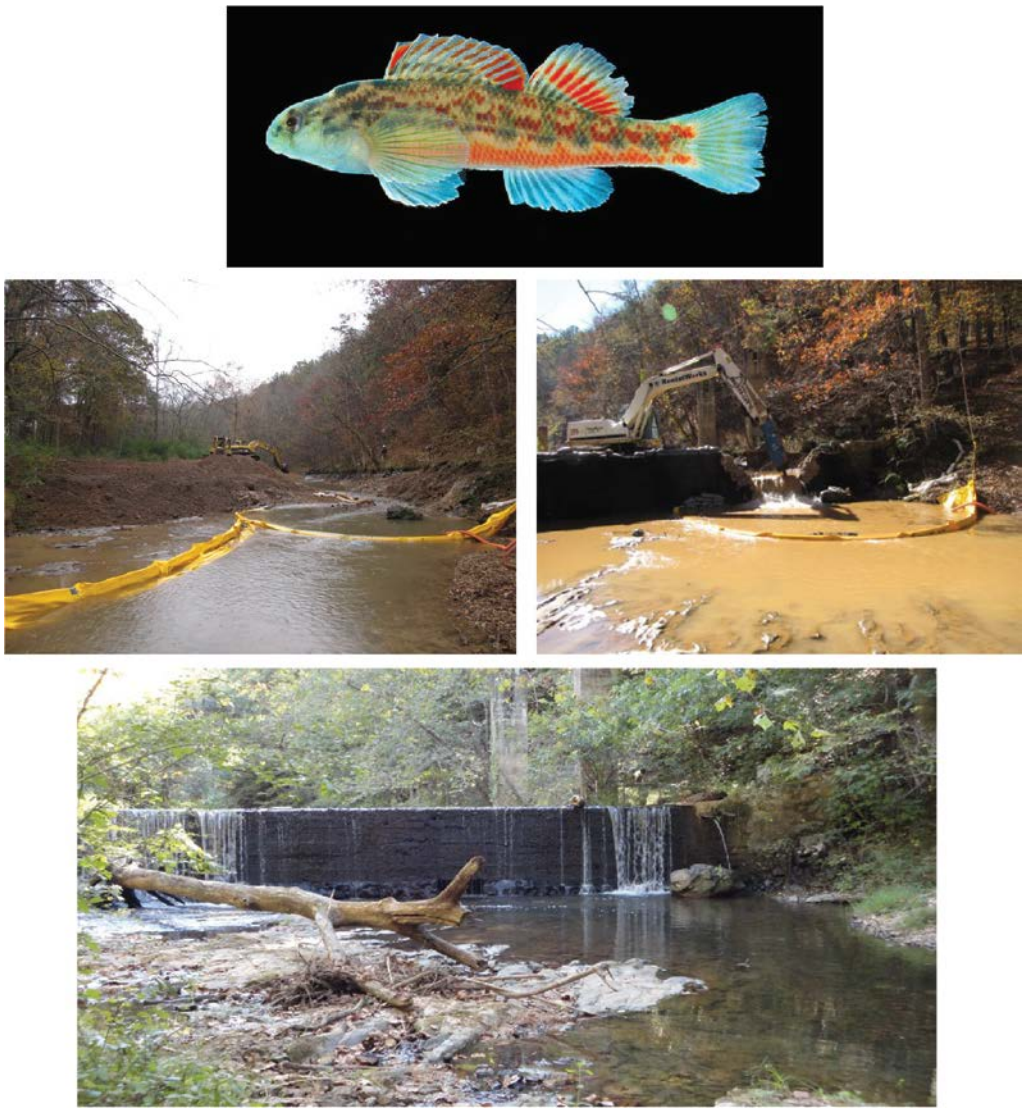

Figure 24.—Removal of the Shadow Lake dam on Turkey Creek near Pinson, Jefferson County, Alabama. Clockwise from top: the endangered Vermillion Darter that occurs only in Turkey Creek, construction work during dam removal, view of dam before dam removal, sediment control activities, and shoreline restoration upstream in the previous lake footprint.

GOODWINS MILL DAM 2013

Goodwins Mill dam was an abandoned mill dam located on Big Canoe Creek in St. Clair County, Alabama. In addition to blocking migration of aquatic fauna, flow patterns around the dam during floods were causing major bank erosion, which threatened a nearby house. The TNC worked with the USFWS to remove the dam, restore connectivity and natural flows, and repair the eroding bank. Fish species diversity doubled in the upstream reach after Goodwins Mill dam was removed. This reach of river is near the range of the threatened Trispot Darter (*Etheostoma trisella*), Canoe Creek Clubshell (*Pleurobema athearni*), and Triangular Kidneyshell (*Ptychobranchus greenii*).

SUCARNOOCHEE RIVER DAM AT LIVINGSTON 2016

The City of Livingston, Alabama, at one time supplied drinking water to the public through a surface water impoundment source on the Sucarnoochee River. Increasing levels of pollution in the Sucarnoochee River, and parallel increases in treatment costs, forced the city to switch to a groundwater source for public supply. The surface water source dam on the Sucarnoochee was abandoned and left in place on the river. Safety concerns plus the fact that it was a significant fish barrier prompted the USFWS to cooperate with the city to remove the unwanted dam and water transfer infrastructure in 2016 (fig. 25).

HOWELL AND TURNER DAM 2019

The Howell and Turner dam near Heflin was a part of Alabama history. A center of commerce for over a half century, the grist mill and cotton gin powered by the Tallapoosa River was a centerpiece of rural life in the early 1900s of east Alabama. When power generation ceased in the late 1990s, the dam became obsolete, and its negative impacts quickly came into focus. There were the obvious fish migration issues, but of perhaps greater significance were water quality issues caused by legacy pollution from an animal processing facility discharging into the river upstream of the dam.

After more than four years of planning, it took less than five days for the equipment operators to chip away and remove a barrier that had stood for nearly 100 years (fig. 26). Before the dam was completely removed from the river, four species of fish could be seen straining against the flow in salmon-like runs over the rubble and past the century-old migration barrier.

Figure 25.—Removal of a dam on the Sucarnoochee River at Livingston, Sumter County, Alabama. The dam was used for a surface water supply for the city (left, pre-removal; right, post-removal).

Figure 26.—Howell and Turner dam removal on the Tallapoosa River, Cleburne County, Alabama. Clockwise from top left: dam pre-removal, dam during removal, the River Redhorse, and dam post-removal. The River Redhorse is a species of moderate conservation concern (ADCNR, 2025) whose Tallapoosa River distribution is poorly known.

IMPROVED WATER QUALITY

In addition to reestablishing connectivity as a means of restoring the water resource, the goal of improved water quality is also paramount to enhanced ecosystem health. Maintaining acceptable water-quality conditions in Alabama streams, rivers, lakes, and estuaries falls under the regulatory responsibility of the ADEM while working closely with the USEPA. Working as the state trustee for water under the federal CWA, ADEM regulates water quality using several programs and tools (https://adem.alabama.gov/water). The ADEM water quality program is most closely aligned with restoration and recovery objectives of the ESA because work under this program includes those activities that directly affect aquatic organisms and their habitats such as surface water quality assessments, water quality standards, a biennial §305(b) report to Congress, the §303(d) list of impaired waters, and the total maximum daily load (TMDL) program.

The amount of water quality assessment activity conducted by ADEM in SHUs and SRRUs is impressive both in the number of samples collected and in the number of parameters measured. From 1990 through 2021, 2,927 stations were sampled, 19,151 samples were collected, and 654,490 individual water-quality parameters were measured (fig. 27). Through close coordination with ARSN, ADEM began focusing some of their statewide sampling and analytical work in SHUs beginning around 2006. From 2006 to 2021, the number of parameters measured in

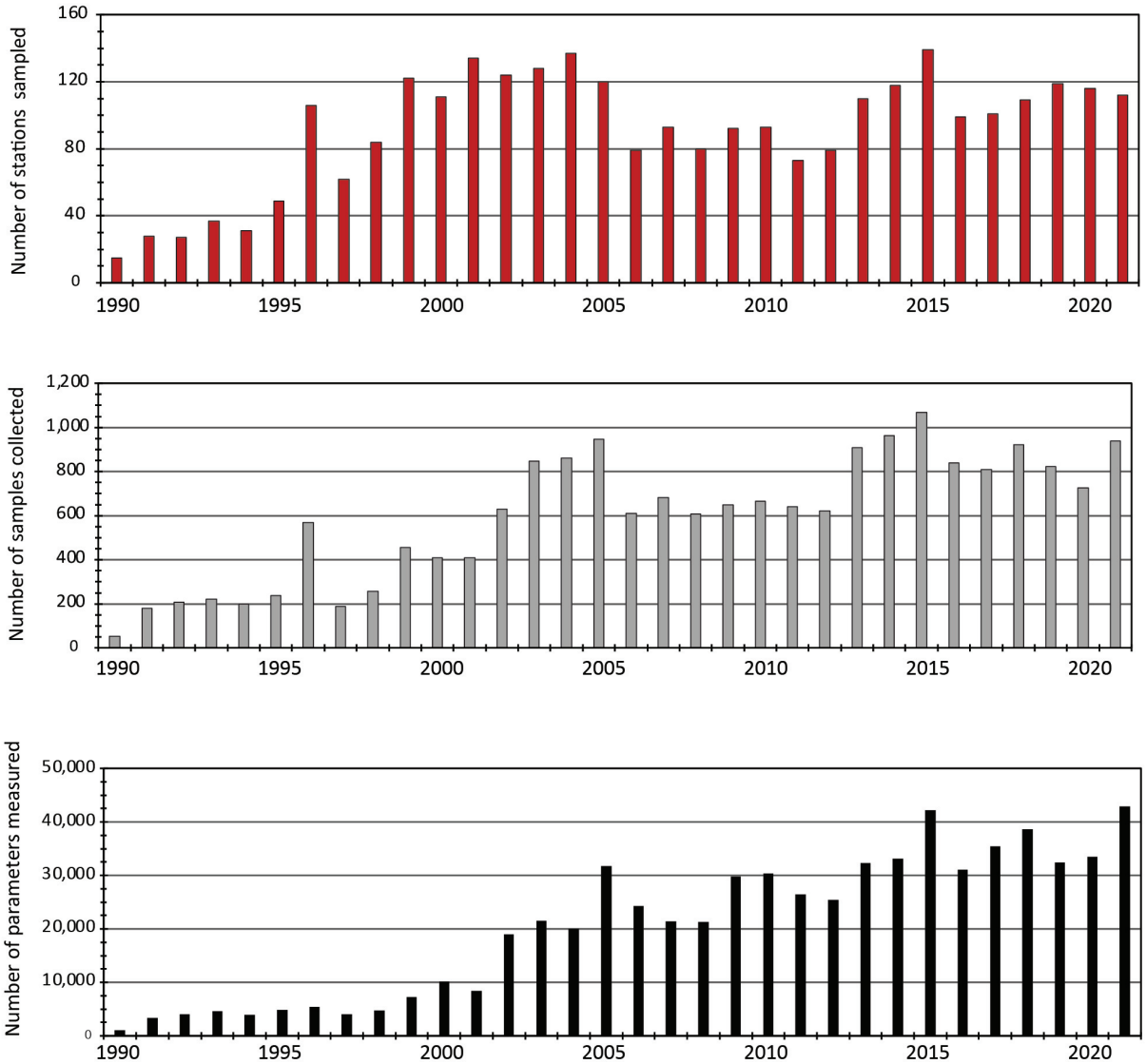

Figure 27.—Water-quality sampling statistics for collections made by the Alabama Department of Environmental Management (ADEM) in Strategic Habitat Units and Strategic River Reach Units from 1990 to 2021. Graphed information is unpublished data provided by ADEM in 2023.

SHUs was 500,544, about 76 percent of the total parameters measured since 1990. This illustrates that there is significant ecological, environmental, and regulatory value in a prioritized set of watersheds that several agencies can cooperatively work in to improve water resource conditions and, in the process, restore and recover species. Thanks to the ARSN approach, listed species are recognized as a valid reason to manage and restore water quality in a watershed.

THE CAHABA RIVER STORY

The Cahaba River drains an area of approximately 1,825 mi^2 (4,726 km^2) in central Alabama, is a major free-flowing tributary to the Alabama River, and supports one of the most diverse fish, mussel, and crayfish faunas for its size in the Southeast (Pierson and others, 1989; Mettee and others 1996; Boschung and Mayden, 2004; Williams and others, 2008; Schuster and others, 2022). The

river was at one time significantly degraded from nonpoint source polluted runoff from urban, mining, and agricultural sources and discharge of treated, and many times untreated, wastewaters from surrounding communities. Significant eutrophication events occurred annually, which had damaging impacts on water quality and the aquatic fauna. Several federally listed aquatic species currently occur in the Cahaba River, making this watershed a high priority for imperiled species recovery activities (table 6). Regulatory actions made under the CWA and ESA since these times have resulted in significant improvements to water quality and the conservation status of listed species in the Cahaba River.

One regulatory action taken by the USEPA, ADEM, and USFWS was instrumental in moving the Cahaba TMDL process forward in Alabama. Both the Cahaba Shiner and the Goldline Darter are found in shallow shoals in the middle reaches of the Cahaba River. Nutrient pollution from wastewater treatment plants around Jefferson and Shelby Counties was causing severe eutrophication downstream in the prime habitats of these two species. Massive algal mats were physically smothering the preferred habitats in the shallow shoals and causing associated water quality problems, particularly with extreme variability of dissolved oxygen. Under the CWA all existing uses, known as “prior use” (and fish and wildlife are considered an existing or prior use), must be protected under the law. Because the fish species inhabited and used water in the Cahaba River prior to November 28, 1975 (“prior use” starting date for water quality), the “prior use” rule was used as scientific justification for moving forward with a nutrient TMDL plan for the Cahaba River. The CWA TMDL program in Alabama began in earnest when a consent decree issued in 1998 paved the way for ADEM to establish TMDLs based on the 1996 §303(d) list of 115 water-quality impaired waterbodies in the state.

Essentially, the listed fish species were linked to habitat degradation resulting from water quality issues controllable under the CWA. The resulting Cahaba River nutrient TMDL plan (ADEM, 2006) took many years to

Table 6.—Mussel, snail, and fish species on the federal endangered species list, with conservation status, presently or historically occurring in the Cahaba River.

Scientific name	Common Name	Status*
Species with present occurrence in the Cahaba River:		
Paranotropis cahabae	Cahaba Shiner	E
Percina aurolineata	Goldline Darter	E
Hamiota altilis	Finelined Pocketbook	T
Hamiota perovalis	Orangenacre Mucket	T
Pleurobema decisum	Southern Clubshell	E
Pleurobema perovatum	Ovate Clubshell	E
Ptychobranchus foremanianus	Rayed Kidneyshell	E
Leptoxis ampla	Round Rocksnail	T
Lepyrium showalteri	Flat Pebblesnail	E
Lioplax cyclostomaformis	Cylindrical Lioplax	E
Species with historical occurrence in the Cahaba River but not known to be currently present:		
Acipenser desotoi	Gulf Sturgeon	T
Scahpirhynchus suttkusi	Alabama Sturgeon	E
Cyprinella caerulea	Blue Shiner	T
Epioblasma penita	Southern Combshell	E
Medionidus accutissimus	Alabama Moccasinshell	T
Medionidus parvulus	Coosa Moccasinshell	E
Potamilus inflatus	Inflated Heelsplitter	T

*E–endangered, T–threatened

implement, but eventually, very substantial progress has been accomplished in reducing nutrients, thereby significantly reducing the algal pollution threat. Through the combination of reducing pollution loads through TMDL plans and restoring stream flows and migration routes by removing dams and barriers (e.g., the Marvel Slab dam), the Cahaba aquatic fauna, especially the Cahaba Shiner and Goldline Darter, have exhibited significant signs of recovery and expanded their distributions in this central region of the Cahaba.

Several organizations have worked resolutely since about 1975 in the Cahaba watershed to improve water quality and therefore improve the status of listed species. Some of the key organizations are ADEM, USFWS, USEPA, GSA, ADCNR-AABC, Cawaco, The Cahaba Clean Water Partnership (now disbanded), The Cahaba River Coalition (formerly The Cahaba River Society and Cahaba Riverkeeper), Samford University, University of Alabama-Birmingham, Birmingham Southern College, City of Birmingham, Jefferson County Environmental Services, and City of Hoover.

ADAPTATIONS OF THE ALABAMA RIVERS AND STREAMS NETWORK APPROACH

The ability to adapt to changing ecological conditions and societal needs is critical to ensuring long-term sustainability for the ARSN approach. Multiple methods for assessing recovery and analyzing restoration efforts have undergone revision since ARSN's inception, and many other methods are in the process of additional data collection to determine the best modifications needed to meet project specific goals and address the human dimension components of restoration.

STREAM CONNECTIVITY

The greatest threats to aquatic species are habitat loss through anthropogenic stream fragmentation and the associated resulting ecological impacts that cause populations to decline. Stream fragmentation is defined as an interruption to a river's natural flow and is often associated with dams on large rivers. However, some of the greatest causes of stream fragmentation are small road culverts, which, when not functioning properly, are considered in-stream barriers that act like a small dam. Culverts are any structure, other than a bridge, where water flows under a roadway or other surface. Culverts commonly become barriers when natural processes erode the stream channel at the outlet (downstream) side of a culvert, creating a perched surface (elevation) that aquatic species cannot move past. Perched culverts (fig. 28) may function as a manufactured waterfall and, depending on the aquatic species, can become a barrier with a drop in stream level of only a few inches. When aquatic organism passage is lost due to perched culverts, aquatic species can become isolated from upstream habitats and headwaters, which many times are primary spawning habitats. This can lead to reduced population size, loss of gene flow, and undesirable ecosystem conditions.

Not only are culverts a threat to aquatic life, but they also affect ecosystems through altering of natural flow regimes and degradation of water quality. Culverts that are undersized, installed incorrectly, or failing can impact hydraulic stability, resulting in a cascading degradation of stream channels and causing significant downstream channel erosion. For example, an undersized culvert can build back pressure in a stream, much like a pressure washer, and once that energy is released at the outlet, it can blast away at the stream channel, increasing sediment loads. Sediment in streams is a natural occurrence and is necessary for healthy functioning of aquatic ecosystems; however, increased amounts of sediment can exceed a river system's threshold for sediment transport capability. According to the USEPA (2017), sediment is one of the most significant nonpoint source pollutants of rivers and streams across the U.S., along with pathogens and nutrients, and is one of the top reasons streams are placed on the USEPA's §303(d) list for impaired waters. Bacteria, algae, and other contaminants will bind to sediment and move through a stream system, causing further degradation of water quality.

Figure 28.—An example of a perched culvert that blocks aquatic species movement.

Suspended sediment can linger in the system or be deposited in susceptible reaches of a river if the flow cannot flush sediment through the system, thereby smothering primary aquatic habitat. Excessive sediment can also exacerbate alterations to the landscape by increasing the erosion potential of fluvial processes. A river channel naturally migrates laterally within its floodplain through erosion and deposition of meanders (bends). Elevated sediment loads can increase the speed at which these processes occur and lead to bank failure through undercutting and subsequent bank collapse. This may not seem like much of a concern, but it has the potential to cause significant loss of farm acreage and crop yields. Any stream bank failures, whether natural or exacerbated, only increase the sediment load of a river and its erosive potential during flood events. If excessive sediment loads reach another undersized or failing culvert downstream, the back pressure can reduce flow to a point where sediment will settle out and clog the stream channel, thereby increasing the risk of flooding.

Flash flood emergencies and damage may be intensified by failing or undersized culverts, and the frequency and magnitude of flash floods are predicted to increase as precipitation events become more intense (e.g., Hurricane Helene and complete devastation in the upper Tennessee Basin in western North Carolina in September 2024). The U.S. Department of Transportation, Federal Highway Administration estimates Alabama had almost 202,000 miles of roadways as of October 2009. Superimposing county, state, and federal roadways on Alabama's 132,000 miles of rivers and streams results in well over 200,000 stream-road crossings (fig. 29). A better estimate cannot be given, as it will be a gross underestimate due to continuous urban development. However, the takeaway is that with the impressive numbers of stream-road crossings comes several potential risks to daily life, as each crossing can be susceptible to flooding, flash flooding, or blow-out—meaning the entire road collapses and breaks away. While these events can be inconvenient to urban dwellers that may have to renegotiate routes and deal with increased traffic, these events can be extremely dangerous for rural communities. If a culvert fails in a rural area, it could cut off an entire community from access to emergency services, such as fire, police, and first responders, or prevent access to essential needs, such as grocery stores, hospitals, and work locations. The number of stream-road crossings in the mapped SHU footprint is estimated at around 147,776, with only 6.5 percent (9,578) of these crossings evaluated for sediment risk or perched culverts as of 2024 (table 7).

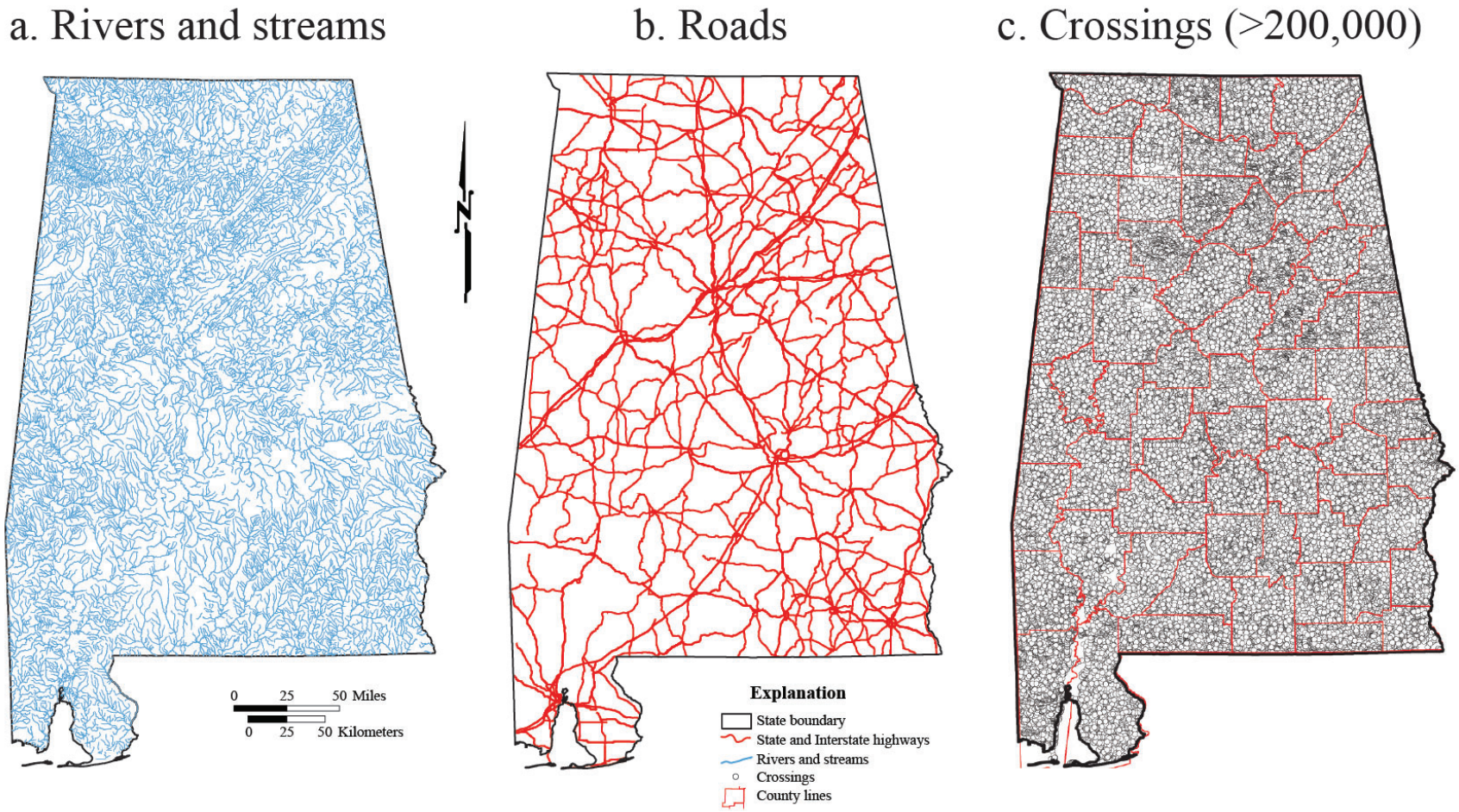

Figure 29.—Maps showing (a) rivers and streams; (b) state, federal, and interstate highways; and (c) stream-road crossings in Alabama.

Table 7.—Number of stream-road crossings and number of crossing surveys in Strategic Habitat Units and Strategic River Reach Units in Alabama, Mississippi, Tennessee, Georgia, and Florida, 2012 to 2023.

SHU/SRRU no. and name [1]	State					Total crossings	Crossing surveyed	Percent surveyed
	AL	MS	TN	GA	FL			
1. Bear Creek	1,057	260				1,317	464	*35.23*
2. TN River (d/s [2] Wilson Dam)	12					12		
3. Cypress Creek	585		208			793		
4. Shoal Creek (0603)	50		1,167			1,217		
5. Elk River	379		7,043			7,422	424	*5.71*
6. Limestone Creek (0603)	901		53			954	933	*97.80*
7. TN River (d/s Guntersville Dam)	18					18		
8. Flint River	1,577		309			1,886		
9. Paint Rock River	632		80			712		
10. TN River (d/s Nickajack Dam)			10			10		
11. Lower Tombigbee River	29					29		
12. Sucarnoochee River	550	845				1,395	153	*10.97*
13. Trussels Creek	87					87	12	*13.79*
14. Sipsey River	1,155					1,155	132	*11.43*
15. Lubbub Creek	496					496	93	*18.75*
16. Coalfire Creek	148					148	19	*12.84*
17. Luxapalila Creek	1,444	556				2,000	38	*1.90*
18. Buttahatchee River	1,053	337				1,390	392	*28.20*
19. East Fork Tombigbee River		441				441		
20. Bull Mountain Creek	163	445				608	1	*0.16*
21. North River	360					360	135	*37.50*
22. Upper Sipsey Fork	142					142	13	*9.15*
23. Locust Fork	2,734					2,734	2,424	*88.66*
24. Lower Alabama River	36					36		
25. Big Flat Creek	195					195	140	*71.79*
26. Bogue Chitto Creek	546					546		
27. Cahaba River	4,049					4,049	3	*0.07*
28. Coosa River (d/s Jordan Dam)	8					8		
29. Hatchet Creek	451					451		
30. Yellowleaf Creek	480					480		
31. Coosa R. (d/s Logan Martin dam)	3					3		
32. Kelly Creek	547					547	1	*0.18*

Table 7.—Number of stream-road crossings and number of crossing surveys in Strategic Habitat Units and Strategic River Reach Units in Alabama, Mississippi, Tennessee, Georgia, and Florida, 2012 to 2023—continued.

SHU/SRRU no. and name [1]	State					Total crossings	Crossing surveyed	Percent surveyed
	AL	MS	TN	GA	FL			
33. Lower Choccolocco Creek	12					12	10	*83.33*
34. Cheaha Creek	216					216	8	*3.70*
35. Shoal Creek	217					217	38	*17.51*
36. Big Canoe Creek	568					568	500	*88.03*
37. Weiss Lake bypass (Old Coosa R.)	21					21		
38. Terrapin Creek	624			16		640		
39. Oostanaula River			478	6,417		6,895		
40. Uphapee Creek	684					684	671	*98.10*
41. Upper Tallapoosa River	621			671		1,292	2	*0.15*
42. Conecuh-Escambia River	17				13	30		
43. Murder Creek	752					752	667	*88.70*
44. Amos Mills Creek	18					18	17	*94.44*
45. Five Runs Creek	189					189	9	*4.76*
46. Lower Pea River	22					22		
47. Upper Pea River	749					749	64	*8.54*
48. Lower Choctawhatchee River	26				14	40		
49. W. Fork of Choctawhatchee River	377					377		
50. Upper Chipola River	690				538	1,228		
51. Uchee Creek	528					528	353	*66.86*
52. Flat Creek	334				30	364		
53. Limestone Creek	8				30	38		
54. Wrights Creek	99				348	447		
55. Bruce Creek					128	128		
56. Holmes Creek	39				900	939		
57. Econfina Creek					98	98		
58. Mobile-Tensaw River Delta	52					52	2	*3.85*
59. Lower Chipola River					19	19		
NON-SHU Crossings	66,626	5,538	8,194	9,987	9,227	99,572	1860	*1.87*
TOTALS	93,376	8,422	17,542	17,091	11,345	147,776	9,578	*6.48*

[1] Wynn and others (2018)

[2] d/s–downstream

From 2016 to 2025, methods used to evaluate stream-road crossings have changed to include assessment of both structure and stream characteristics that could pose threats to aquatic organism survival. This modification allows for additional data collection, which could help identify flood-prone areas and inform more efficient emergency management efforts.

SEDIMENT RISK INDEX

In the summer of 2016 (fig. 30), ARSN began using a newer method for evaluating stream-road crossings, which utilized a modified version of the Sediment Risk Index (SRI). The SRI method was developed out of work by the U.S. Fish and Wildlife Service (2005) and Witmer and others (2009) to assess if a crossing structure increased or altered sediment input into a stream system. The SRI method was designed primarily for use in coordination with forestry and timber harvesting in northwest Florida by the Three Rivers Resource Conservation and Development Council to evaluate the effectiveness of best management practices in the region.

Adaptations to the SRI method (USFWS and GSA, 2021) identify attributes that provide documentation for possible issues related to the stream-road crossing and possible issues for future restoration projects. These include observations such as degree of riparian (tree) cover, degree of livestock access, and(or) fish barrier presence. The latter is probably the most significant additional attribute measured as it is generally a result of a perched culvert, in which case a measurement of the outlet drop (waterfall) is taken. The ARSN-SRI uses data collected from the modified SRI method in species recovery plans and(or) watershed management plans to create a prioritized listing of stream-road crossings to better focus resources on high-priority remediation sites (O'Neil and others, 2015). An initial analysis of 5,443 fully completed surveys, as of October 2023, revealed 12.8 percent of crossings as moderate to high risk for sediment input (fig. 31a). This has led to the conclusion that, unlike unpaved roads, stabilized paved roads, which make up 91.4 percent of crossing surveys completed, have significantly less influence on sediment input. Construction of new paved

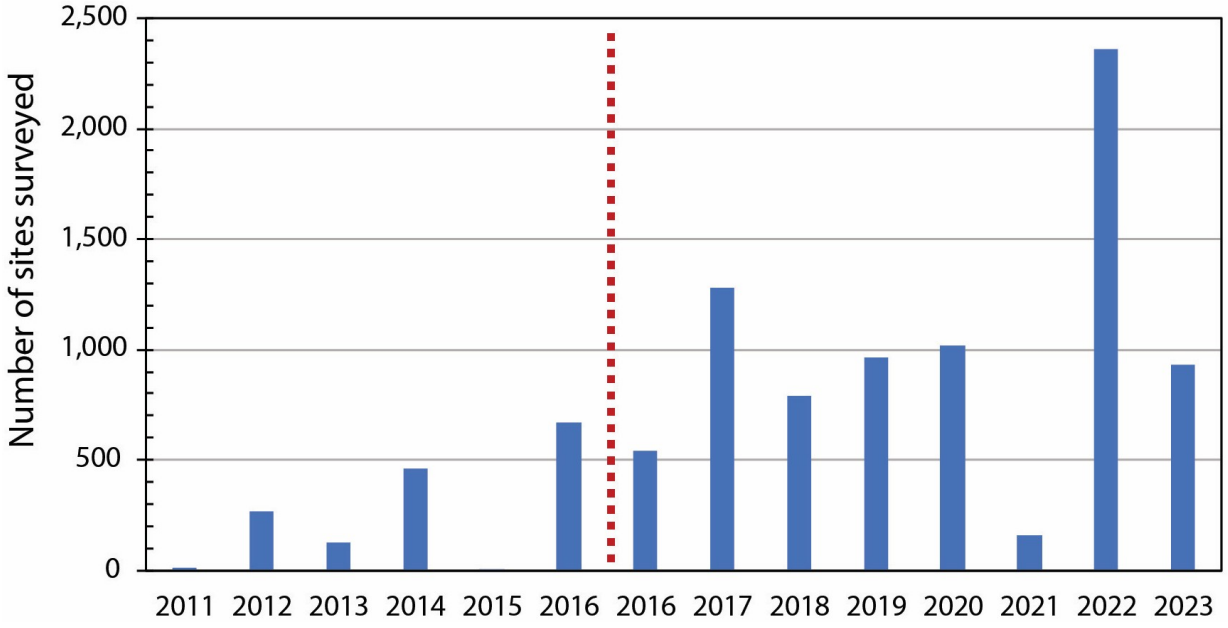

Figure 30.—Number of stream-road crossing surveys completed prior to and after modified stream survey method was instituted in 2016. Red dotted line indicates the time of transition.

roads can, however, result in significant sediment input and stream degradation if appropriate sediment control measures are not integrated into the construction phase of the project. A simple analysis of the same 5,443 surveys focusing on the outlet drop (fig. 31b) resulted in 31.82 percent of crossings having a perched culvert barrier.

ALABAMA RIVERS AND STREAMS NETWORK INCLUDING CONNECTIVITY

The ARSN-SRI method provides good baseline data; however, it does not capture the larger risk of stream flow issues related to the crossing structure. Therefore, a different approach was needed, which led in 2022 to partnering with a regional organization

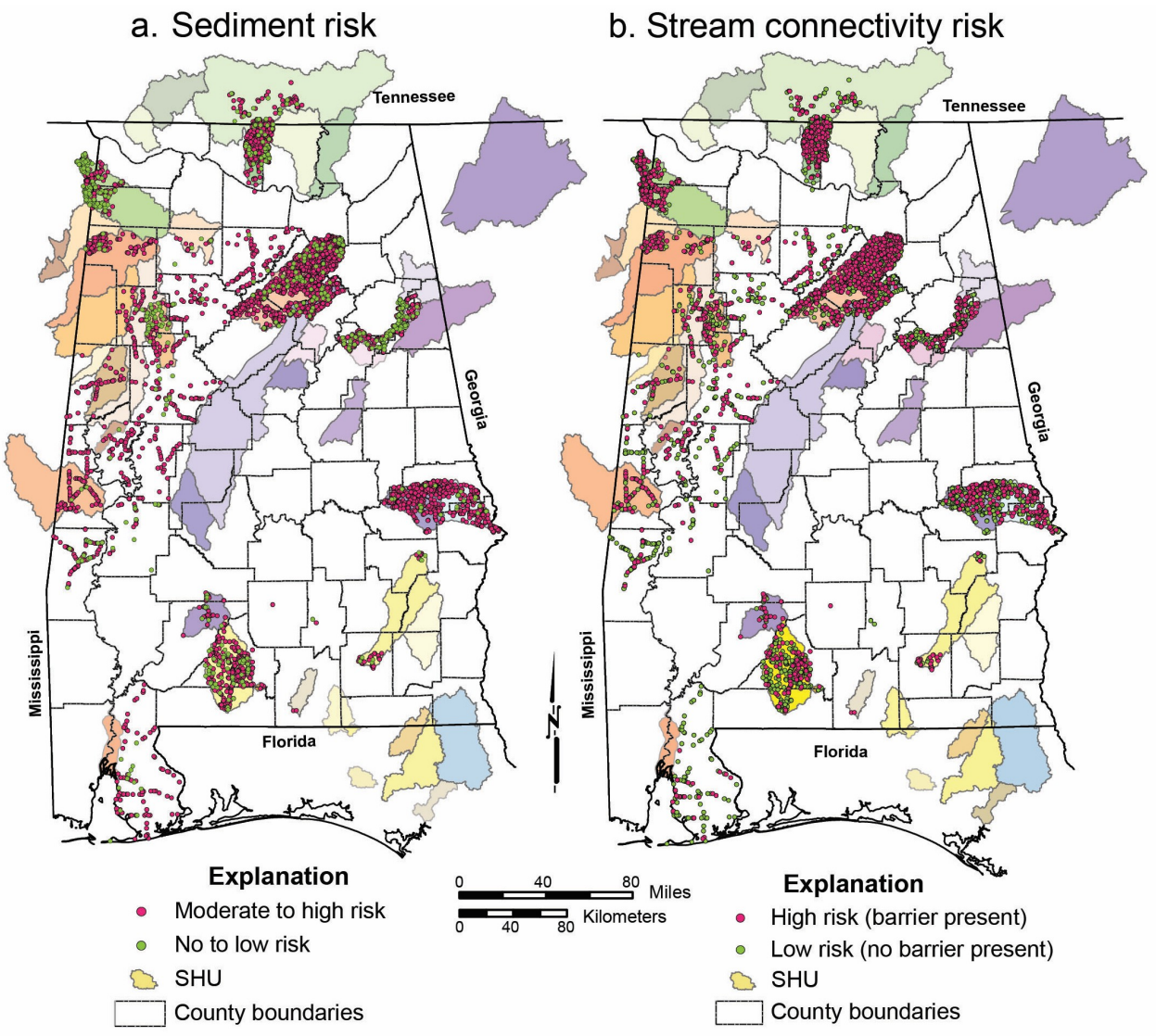

Figure 31.—Maps showing comparisons between sediment risk analysis and stream connectivity risk analysis for stream-road crossing sites evaluated in Alabama. (a) Sediment risk interpreted as no to low risk, or moderate to high risk, of sedimentation harming stream ecosystems, and (b) stream connectivity risk to migration and movement of aquatic species, identified as low risk (no barrier present) or high risk (barrier present).

focused on stream connectivity, the Southeast Aquatic Resources Partnership (SARP). The SARP stream crossing evaluation method is more labor intensive with a primary focus on stream flow through the structure and its influence on aquatic organism passage (SARP, 2023).

In the autumn of 2021, a group within ARSN formed the Alabama Rivers and Streams Network including Connectivity (ARSNiC) group (fig. 32). This group, led by the GSA, includes the USFWS, University of Alabama, Auburn University, and Troy University, with support from Cawaco and SARP. The group was established as part of SARP's Aquatic Connectivity Team program with an official kick-off in May 2022. The initial collaboration involved a trickle-down analysis of the extensive road crossing dataset collected during ARSN surveys prior to 2021 (fig. 33). While the trickle-down analysis design proved to be beneficial, it was realized that redundancy could become problematic in the future, and ARSNiC began to discuss ways to redesign the stream-road crossing field method that would only require a single site visit.

While ARSNiC understood the value of having detailed data derived from the SARP level analysis, it also realized that maintaining a rapid survey field protocol was essential to its mission to inventory, assess, and prioritize stream-crossing structures in Alabama. To meet both needs, a new Stream Crossing Assessment (SCA) method was devised, a hybrid method of the ARSN-SRI evaluation and SARP's aquatic organism passage evaluation. Over the course of 2023, ARSNiC redesigned the ARSN-SRI method to begin capturing variables that would indicate restricted species passage. The resulting method (appendix E) maintains the desirable rapid field approach and captures greater details in dimensional measurements, such as structure height, channel constriction ratio, and flow and substrate comparisons through the structure. During the winter of 2023-24, beta testing the new SCA method began while a database was being developed to house and disseminate the data. This new method will provide information regarding areas with greater flood potential, which will help inform more efficient emergency management efforts.

INTERPRETING BIOLOGICAL RESPONSES

Biological assessments are an integral part of the ARRM procedures of ARSN and by nature are always subject to revision to better capture biological responses to natural and anthropogenic processes. Biological assessments serve dual purposes, to locate stream reaches where biological conditions have

Figure 32.—Alabama River and Streams Network including Connectivity logo.

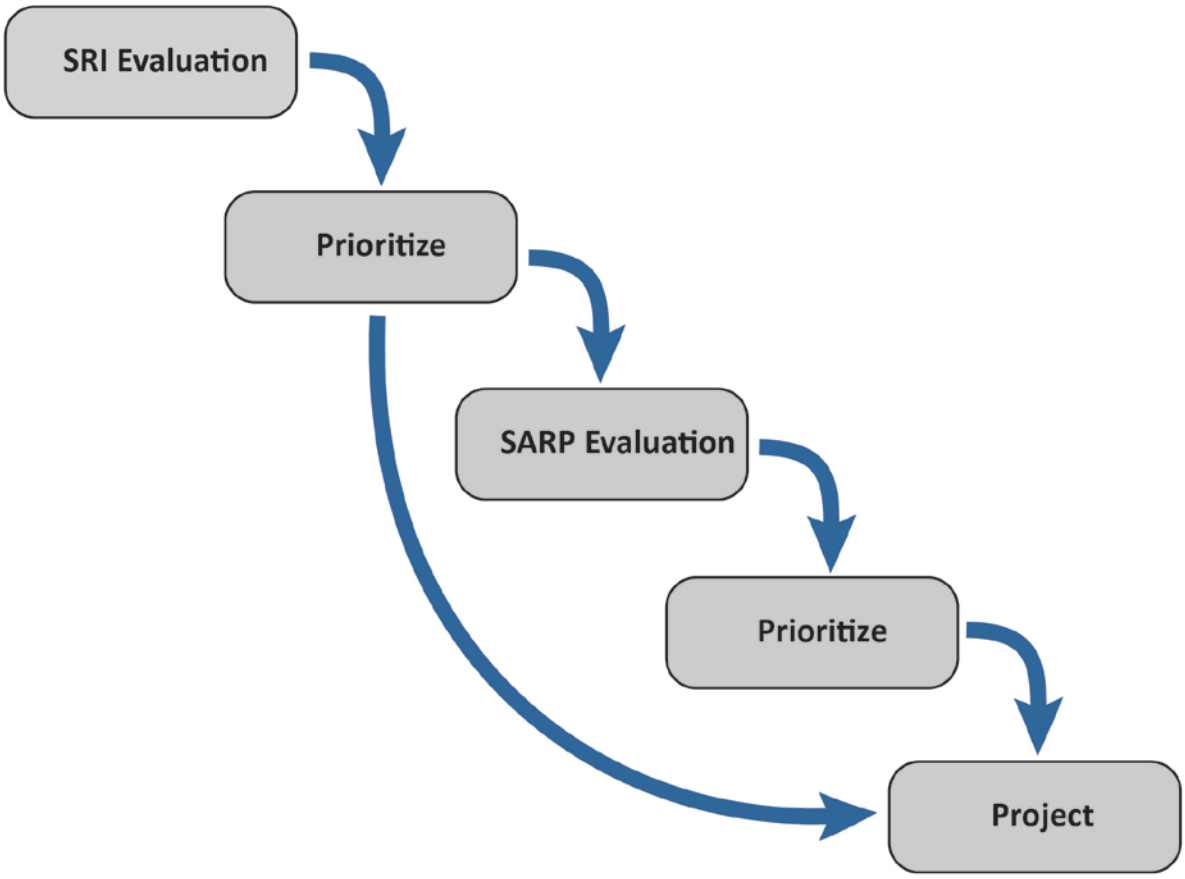

Figure 33.—Flow chart showing trickle-down process for the sediment risk index (SRI) prior to 2021.

deteriorated and to monitor biological conditions after improvements have been made to habitat, water quality, and stream crossings. The process of biological assessment is a systems approach for evaluating water resources that focuses on the actual condition of the resource, assessing chemical and physical water quality, biotic interactions, hydrology, energy and trophic interactions, and habitat structure (fig. 16).

METHODOLOGIES

The objective of the CWA is to restore and maintain the physical, chemical, and biological integrity of the Nation's waters. Meeting this objective requires a uniform set of assessment methodologies and standardized concepts. These methodologies must be specific, well-defined, and allow for waters of different natural quality and different desired uses. The ADEM has developed standard operating procedure (SOP) manuals for conducting biological assessments using benthic macroinvertebrates and fishes (ADEM, 2022), as well as for habitat assessment and a host of other water-quality related methodologies:

- Benthic macroinvertebrates (ADEM, 2010, 2012, 2013, 2014a, 2025)
- Fishes (ADEM, 2014b, 2022)
- Habitat (ADEM, 2021a, 2021b, 2024)

The ADEM benthic macroinvertebrate SOP manual is based on a modification of the rapid, multi-habitat assessment procedure established by the USEPA (Plafkin and others, 1989; Barbour and others, 1999). Biological surveys are a direct measure of the condition of aquatic life and an effective way to measure the impact of multiple stressors on waterbodies. One survey method ADEM employs is macroinvertebrate sampling within a specific waterbody type. Macroinvertebrate surveys

are conducted during specified sampling periods within waterbody types which increase the number of samples that can be collected yearly while maintaining sampling consistency and comparability of results among streams in the same ecoregion. Ecoregional stratification coupled with standardized sampling methods and comparison of sampled stations to reference conditions are key factors when comparing biological sampling results to water quality standards.

The fish bioassessment procedure is based on work also presented in Plafkin and others (1989) and Barbour and others (1999) and a series of IBI development reports for Alabama waters (O'Neil and others, 2006; O'Neil and Shepard, 2007, 2010, 2011a, 2011b, 2011c, 2012). Most biological assessment work by ADEM uses the benthic macroinvertebrate multi-habitat method, while other ARSN cooperators in Alabama generally base their work on the fish IBI.

Over 1,000 fish IBI samples have been collected since 1995 in Alabama within SHUs and ichthyoregions sampled when developing the IBI (fig. 34). The first comprehensive IBI biological condition survey done in Alabama was completed in the Locust Fork watershed from 1997 to 1998 (Shepard and others, 2004). This study facilitated a discussion of faunal changes in the watershed and featured a map showing biological condition in tributaries and the main channel. The IBI proved to be useful for comparing biological condition to land use, land cover, and pollution sources along a longitudinal gradient in the main channel of Locust Fork (fig. 35). Additional IBI surveys in the Locust Fork about a decade later were useful for depicting how biological conditions may have changed through time either improving, degrading, or remaining the same (fig. 36) (Shepard and others, 2019).

Methodologies for sampling other aquatic taxa groups (mollusks, crayfishes) vary depending on the species, sampling goal, and habitat type. Additional research is ongoing linking the response of these groups to water quality changes and anthropogenic influences.

BIOLOGICAL CONDITION GRADIENT

The classic biological assessment procedures for benthic macroinvertebrates and fishes have recently been reformulated into a tiered system of aquatic life use designation along a gradient (known as the Biological Condition Gradient, or BCG) that better positions biological condition results into a national set of standards (USEPA, 2016).

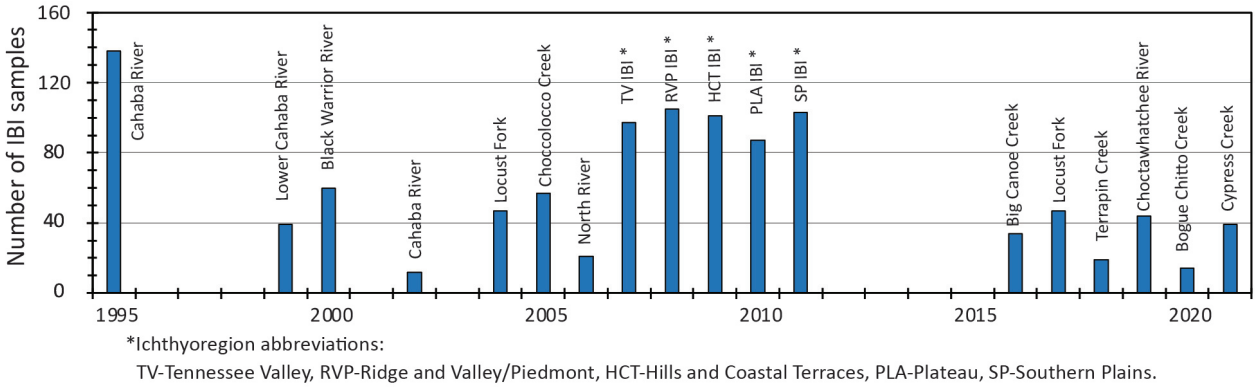

Figure 34.—Number of fish samples collected from Strategic Habitat Units and ichthyoregions of Alabama for determination of the Index of Biotic Integrity from 1995 to 2021.

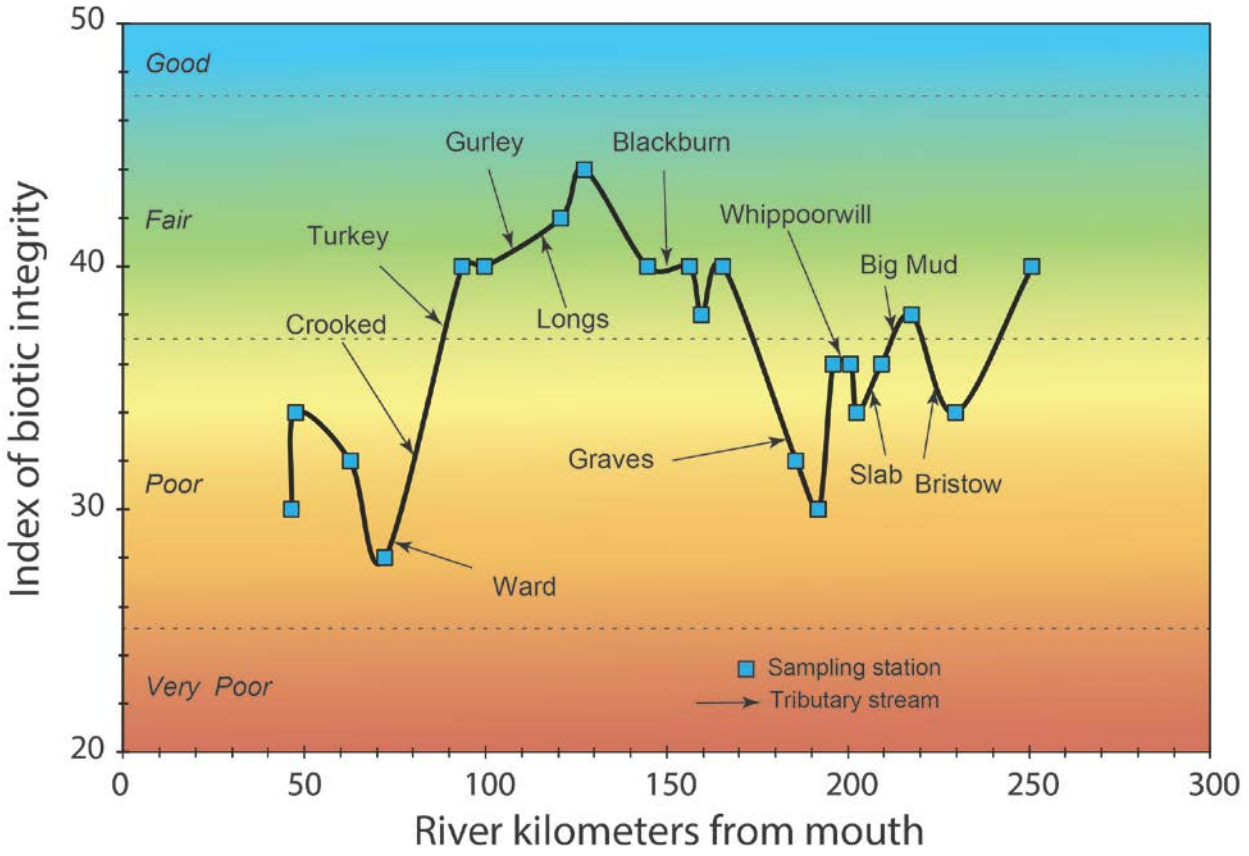

Figure 35.—Variability of the Index of Biotic Integrity in the flowing reaches of Locust Fork main channel, 1997-98 (Shepard and others, 2004).

The BCG is a conceptual scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems (fig. 37). It was developed around common patterns of biological response to stressors as observed empirically by aquatic biologists using benthic macroinvertebrate community evaluation methods and fish methods like the IBI. Scientists from throughout the country representing many states, agencies, universities, and the private sector have been involved in BCG development (USEPA, 2016). The BCG framework describes how 10 characteristics (attributes) (table 8) of aquatic ecosystems change in response to increasing levels of stressors, from an "as naturally occurs" condition (e.g., undisturbed/minimally disturbed condition) to severely altered conditions.

The ADEM, working with USEPA scientists, has been instrumental in integrating the BCG model into Alabama bioassessment work. Two workshops were held, one January 28-30, 2014, and the other April 21-23, 2015, to begin the work to calibrate the BCG to local ecoregional conditions and integrate the BCG into biological assessment work in Alabama (Jessup and Gerritsen, 2014; Stamp and Jessup, 2016). The Alabama benthic macroinvertebrate BCG model is currently used by ADEM in its monitoring strategy. The Alabama fish BCG has been developed but is not used to any significant degree at this time. Eventually moving to application of the fish BCG concept in SHUs and SRRUs will have added assessment benefits for describing watershed conditions and focusing restoration and recovery efforts for imperiled species. The USEPA (2016) outlined several uses of the

BCG model that also correspond with goals for imperiled species recovery:

- Set scientifically defensible, ecologically based aquatic life goals based on existing conditions and potential for improvement.
- Determine baseline conditions and measure impacts of multiple stressors or system altering conditions (e.g., climate change) on aquatic life.
- Further the use of biological monitoring data for the assessment of water quality standards and tracking changes in biological condition.
- Identify high quality waters for protection, such as Outstanding Alabama Waters, and relate them to the distribution of imperiled species.
- Communicate to stakeholders the likely impact of decisions on protection and management of aquatic resources.

ASSESSING HABITAT HEALTH

Habitat evaluations are an integral part of the work to describe biological conditions because good biological conditions are quite often predicated on the presence of stable and diverse habitat. Habitat evaluations are most often site-specific and must be flexible in design to capture changing conditions and technological advancements.

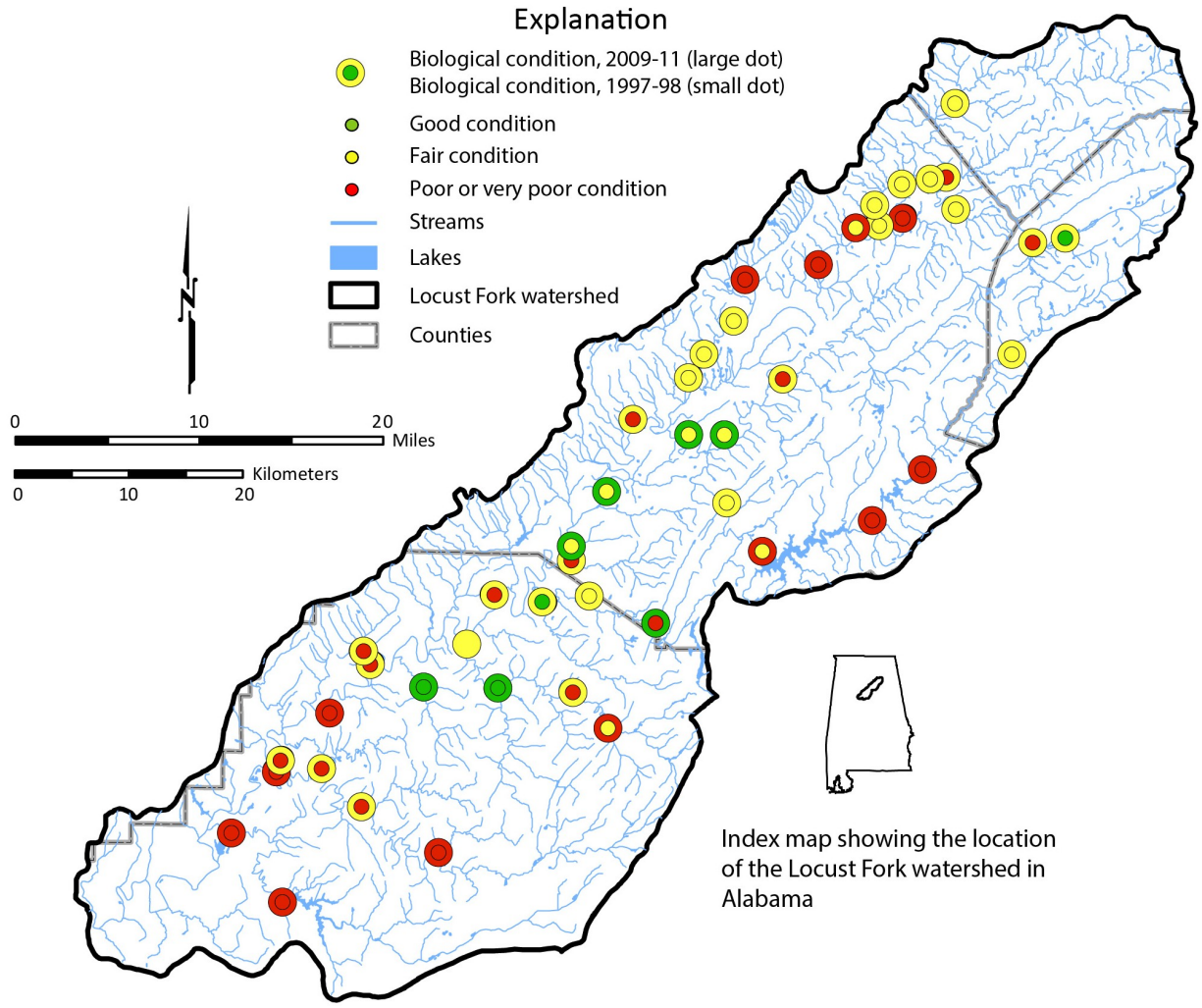

Figure 36.—Comparison of the Index of Biotic Integrity at 47 sampling stations in the Locust Fork system, 1997-98 and 2009-11 (modified from Shepard and others, 2019).

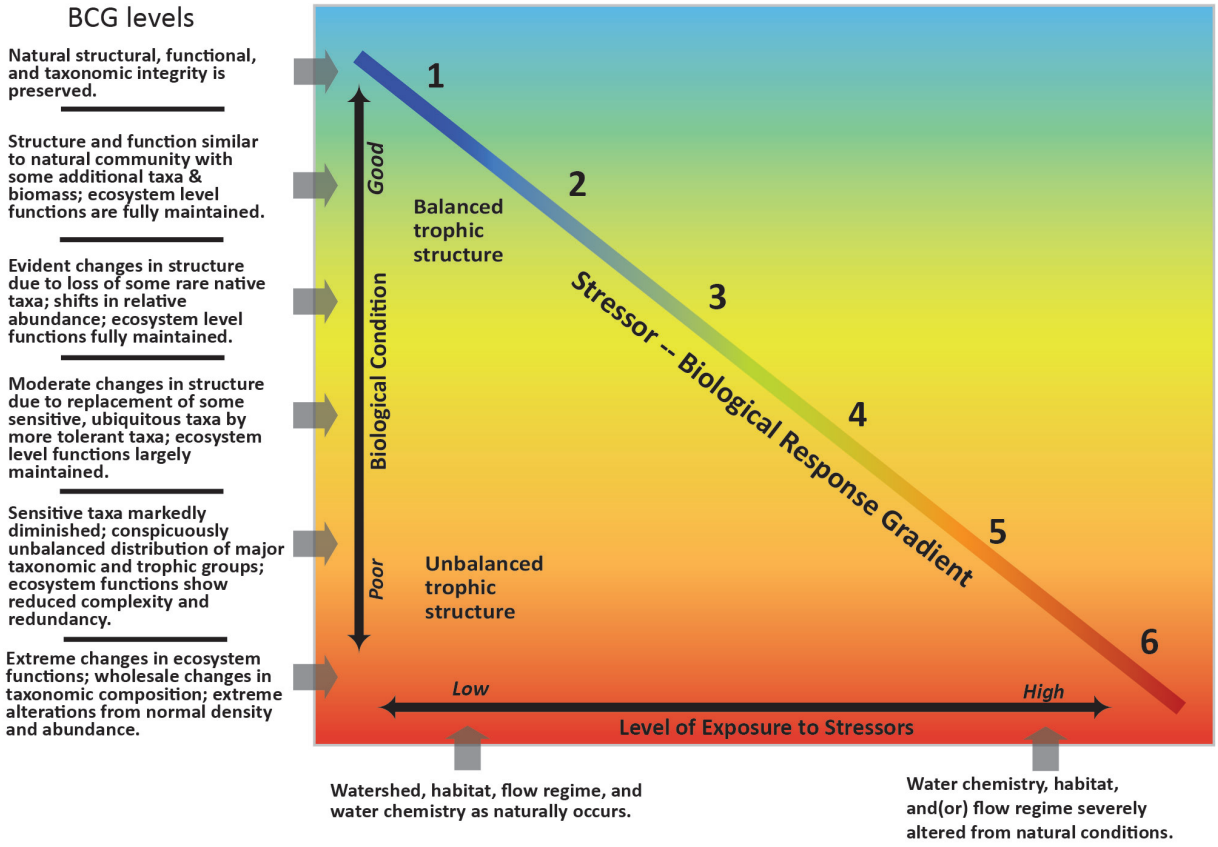

Figure 37.—Conceptual model of the Biological Condition Gradient (modified from USEPA, 2016).

Table 8.—Ecological attributes used to describe and score for the biological condition gradient conceptual model (USEPA, 2016).

Attribute	Description
I	Historically documented, sensitive, long-lived, or regionally endemic taxa
II	Highly Sensitive Taxa
III	Intermediate Sensitive Taxa (or Sensitive and Common Taxa)
IV	Taxa of Intermediate Tolerance
V	Tolerant Taxa
VI	Non-native or Intentionally Introduced Species
VII	Organism Condition
VIII	Ecosystem Function
IX	Spatial and Temporal Extent of Detrimental Effects
X	Ecosystem Connectivity

Habitat is an inclusive term that incorporates several features and processes in streams including the physical components such as rock and rubble, logs, mud, and channel and substrate condition; the chemical and physical components of water quality such as pH, dissolved chemical constituents, temperature, and dissolved gases; and flow components such as flood and drought frequencies, velocity regimes, and discharge. For a quantitative assessment, the habitat concept is generally narrowed to include the physical components of habitat and substrate structure, the degree of channel alteration, and the condition of banks and the adjacent riparian corridor. These components directly affect the structure and function of the aquatic biological community, and they can be visually assessed for quality and relative degree of impairment. In addition to discrete data collected at select points in time, the habitat concept may also encompass continuous physical, chemical, and video data taken by floating the stream with advanced digital monitoring instruments. Both discrete site-specific and continuous data methodologies have limitations but provide valuable information needed to accurately assess suitable habitat conditions for aquatic species survival and persistence.

METHODOLOGIES

The visual site-specific riffle-run and glide-pool rapid assessment procedures used in studies to quantify habitat conditions were originally reported in Plafkin and others (1989) and modified by Barbour and others (1999) and ADEM (appendix E). Stream habitat assessments entail evaluating the structure of the surrounding physical habitat that influences water resource quality and thus the condition of the resident biological community (Barbour and others, 1999). Generally, three habitat characteristics contribute to the maintenance and health of aquatic biological communities: the availability and quality of the habitat-substrate components and instream cover, morphology of the instream channel, and structure of the bank and riparian vegetation zone (Plafkin and others, 1989). Barbour and others (1999) developed two sets of habitat metrics, one for evaluating upland stream habitat dominated by riffle-run microhabitats and hard substrates and the other for evaluating lowland and coastal plain streams that are dominated by glide-pool and run-pool habitats with unconsolidated sandy substrates. An example of how the rapid habitat assessment data can be used to comparatively evaluate habitat conditions is shown in figure 38 for the North River watershed in the Black Warrior River system.

The bank erodibility and hazard index (BEHI) is a fluvial geomorphology procedure developed by Rosgen and others (2006) at Wildland Hydrology that is used to evaluate the susceptibility of streambanks to erosion based on a variety of streambank and erodibility variables. The BEHI incorporates an assortment of indicators to rank the severity and probability of streambank erosion (fig. 39). This protocol is effective in assessing potential streambank erosion, is used as a standard assessment tool for restoration of stream banks closer to natural conditions, and can be used in conjunction with other water quality and habitat assessments to better understand factors that may be impacting imperiled species.

A useful manifestation of a modified BEHI methodology, the Bank Erosion Susceptibility Index (BESI), was introduced by Trutta Environmental Solutions, Inc. (Trutta), with their High-Definition Stream Survey (HDSS) technology. River habitat conditions are assessed with forward-facing georeferenced video technology and side-scan sonar while traversing a stream to include left and right banks, habitat type (riffle, run, pool), water depth, presence of large woody debris, man-made structures, and water quality (Connell and Parham, 2014). The BESI determinations are made in the office while reviewing the continuous field video data. One advantage of this methodology is that a high resolution, continuous habitat record is created compared to the traditional single point records. Work completed in the Bear Creek SHU by Trutta (Connell and Parham, 2014) (fig. 40) illustrates the continuous output of their technology. Future development of the BESI

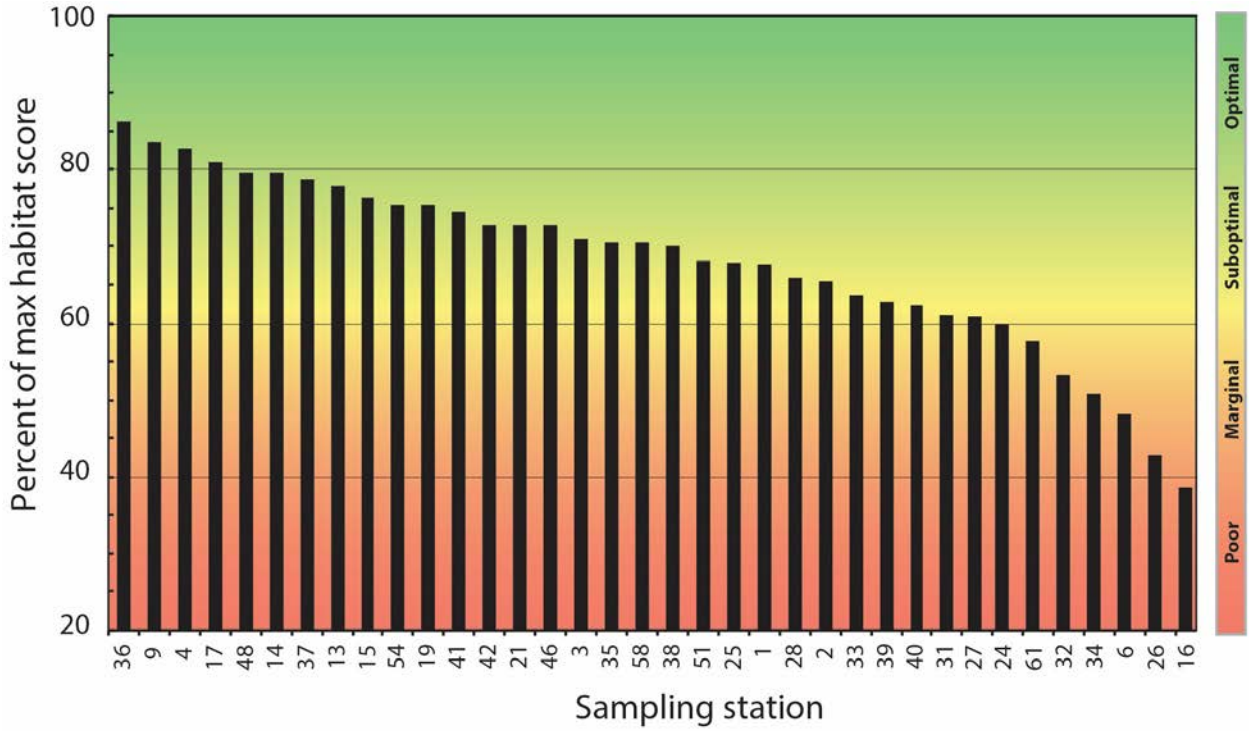

Figure 38.—Example of rapid habitat assessment of streams based on data collected in the North River watershed, Black Warrior River system (modified from O'Neil and others, 2011).

by Trutta may include integrating AI technology into evaluating the massive digital datasets, shortening the amount of time from stream survey to final product.

The Wolman (1954) pebble count method (Leopold and others, 1964; Leopold, 1970; Kondolf, 1997) is applied in studies of channel geomorphology as a means of habitat analysis in relation to stream biology, as a monitoring tool to evaluate stream restoration activities and stream channel stability, and as an assessment tool to evaluate BMP effectiveness for silvicultural and agricultural activities. Pebble counts describe the proportion of bed material less than a given standard size class with particle sizes tallied in geometric class progression of the Wentworth scale (Wentworth, 1922). Pebble counts are used to determine if the composition of the coarse bed surface differs between reference and study streams, which can reflect differences in sediment supply, and to monitor substrate composition and habitat conditions quantitatively through time. Characterizing the bed materials using pebble counts can help determine if habitat is suitable to support resident species, while measuring the composition of bed particles through time will help determine the long-term trends of habitat stability. Knowing if habitat is remaining relatively consistent and stable through time, improving from a previous degraded state, or degrading through import of fine bed materials (particularly in pool and riffle complexes) is important information for imperiled species restoration and recovery activities. Pebble counts were used in a study of Locust Fork to characterize riffle habitat condition and to establish a long-term baseline at several sites from which to track changes (Shepard and others, 2019) (fig. 41).

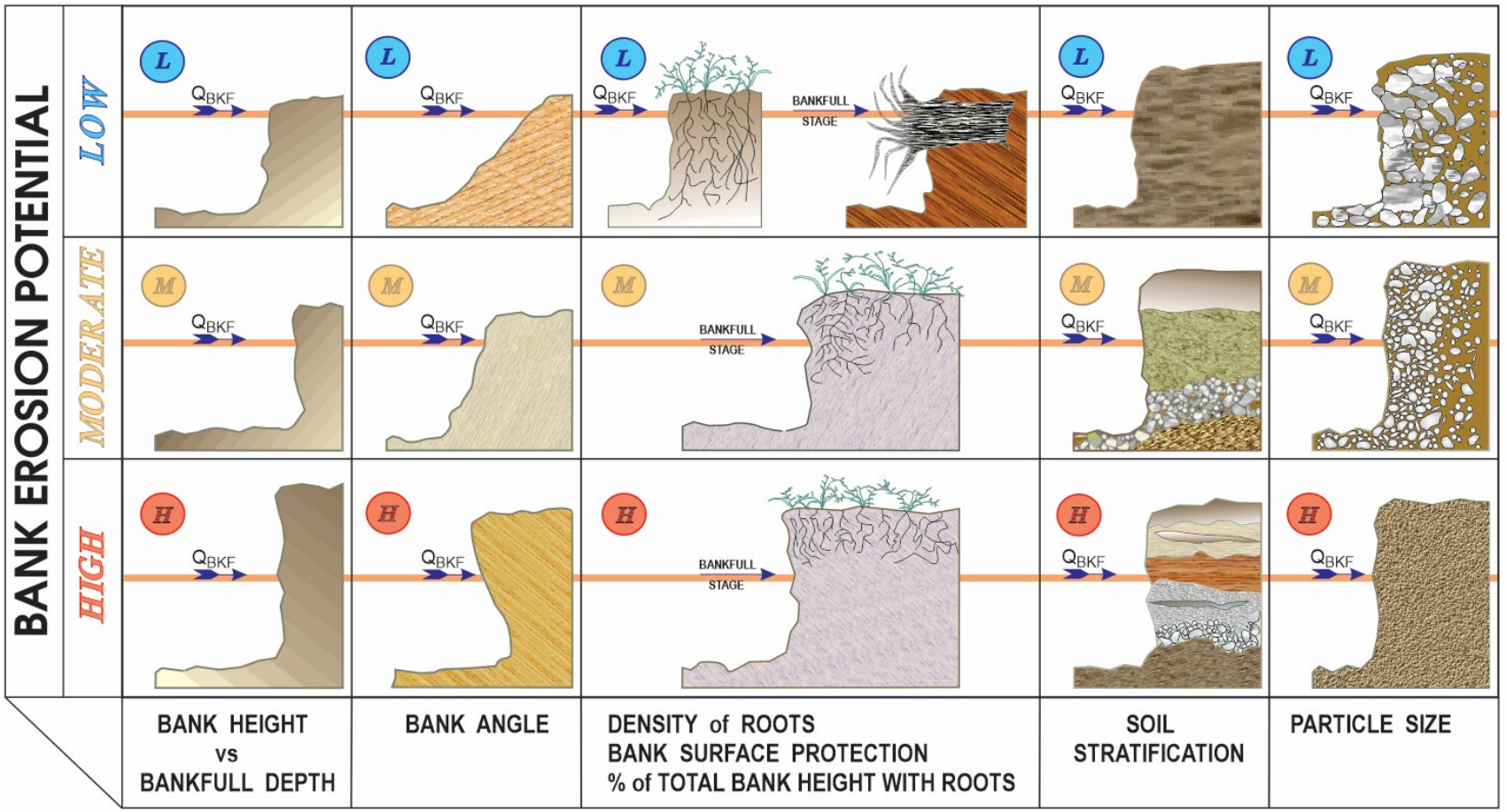

Figure 39.—Metrics of the Bank Erosion Hazard Index with illustrations depicting conditions of bank erosion potential (used with permission of Wildland Hydrology, Rosgen, 1996).

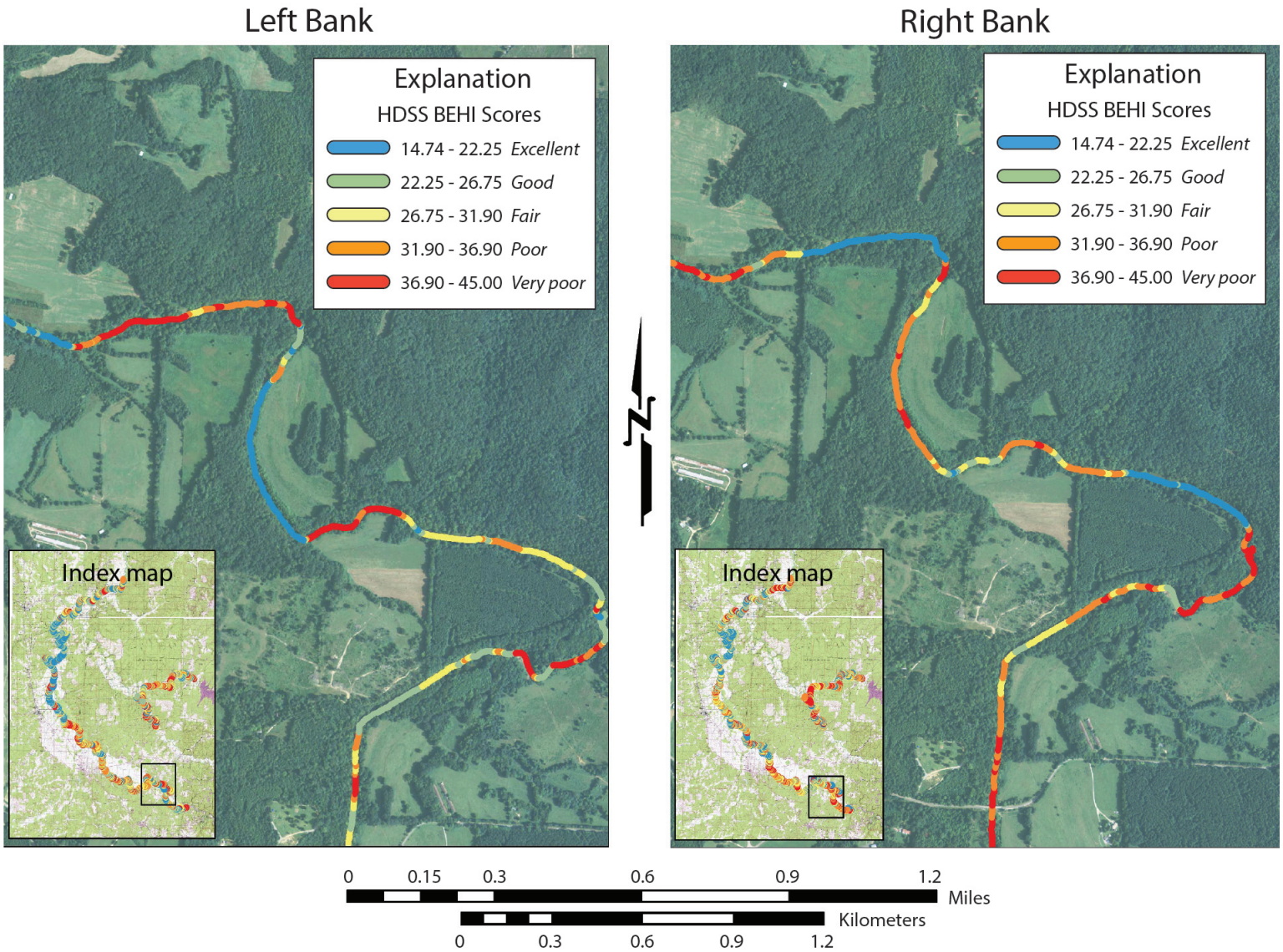

Figure 40.—Example of the Bank Erosion Susceptibility Index analysis for left and right banks along a reach of Bear Creek, Franklin County, Alabama (data provided by and used with permission of Trutta Environmental Solutions, modified from original material).

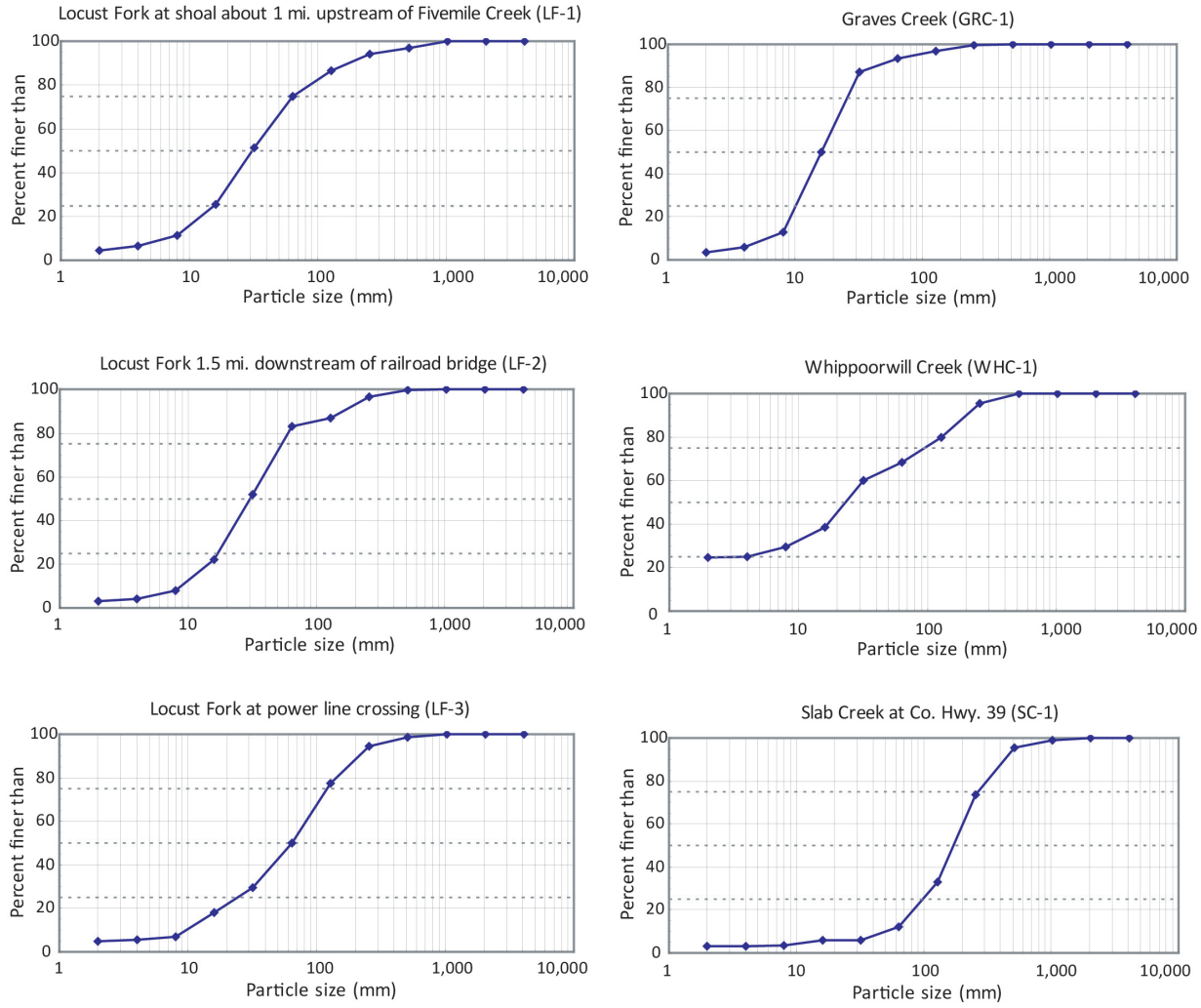

Figure 41.—Example of particle size distribution plots for selected stations in the Locust Fork Strategic Habitat Unit, 2009-11, using the Wolman pebble count method (from Shepard and others, 2019).

LONG-TERM HABITAT MONITORING

While discrete measurements taken as part of assessments for water quality, biology, and habitat are useful for capturing conditions at select moments in time, long-term continuous monitoring is needed to effectively assess seasonal or yearly changes as well as anthropogenic influences and the combined effect on species resilience and survival. Due to increased awareness of the reliance of certain imperiled species on groundwater-surface water interactions, ARSN members have prioritized use of multiparameter environmental sondes to record continuous surface water-quality conditions. Parameters such as temperature and dissolved oxygen may determine local habitat suitability and drive species distributions, while parameters such as turbidity may indicate the effectiveness of stream restoration efforts.

HUMAN DISTURBANCE GRADIENT

Holistic data collection is vital to quantifying stressors to aquatic resources. Stressors to imperiled species and aquatic resources are diverse in type and magnitude and variably affect ecosystem processes. Quantifying these stressors is necessary to understand how restoration and recovery

activities can be most efficiently applied to species conservation. The BCG generalized stressor gradient was created as a tool to characterize environmental stresses that are likely related to biological responses within aquatic communities. Stressors are defined as physical, chemical, or biological factors that cause an adverse response in aquatic biota (USEPA, 2000), with the degree of response determined by the magnitude, frequency, and duration of exposure to stressors.

The diverse array of human activities can make the task of defining and quantifying human disturbance difficult, but recent advances in GIS technology have refined our ability to quantify landscape-scale human disturbance. Landscape features that stream ecologists have qualitatively known for years to be sources of ecosystem stress—such as type of land cover, type and intensity of land use, number of stream-road intersections, number of point-source discharges, population density, and agricultural animal density—can now be quantified into digital datasets using GIS analysis.

Disturbance can be quantified at several scales ranging from human disturbance metrics that describe landscape-level features (Brown and Vivas, 2003; Fore, 2004) to the rapid habitat assessment metrics that describe reach-level features (Rankin, 1989; Barbour and others, 1999). Both landscape- and reach-level measures are important for quantifying disturbance and relating it to biological condition indices.

The Analytical Tools Interface for Landscape Assessments (ATtILA) program has been developed by the USEPA to readily calculate many common landscape metrics using GIS technology. The human disturbance gradient (HDG) has eight landscape metrics that combine to produce a dimensionless index for evaluating the degree of human disturbance in a watershed (Brown and Vivas, 2003): human density, phosphorus load, percent urban land use, percent barren land use, percent pastureland use, percent crop land use, road density, and number of road-stream crossings.

An example of how the HDG can be used to understand the distribution of stressors affecting imperiled species is presented in figure 42. This graphic is a profile of HDG conditions in upper Coosa River watersheds where the Trispot Darter (*Etheostoma trisella*) occurs or may occur. The HDG scores for the 92 level 12 hydrologic unit code (HUC-12) watersheds draining Cambrian-age geologic units in the range of *E. trisella* in the upper Coosa River system varied from 66 to 960 with 42.4 percent (n=39) of these watersheds having the least or a low level of human disturbance, 33.7 percent (n=31) having a moderate level of disturbance, and 23.9 percent (n=22) of these watersheds having a high or very high level of human disturbance. For the subset of 28 HUC-12 watersheds where *E. trisella* was historically or is currently found, 42.9 percent (n=12) were least disturbed or had a low level of human disturbance, 35.7 percent (n=10) had a moderate level of human disturbance, and 21.4 percent (n=6) had a high or very high level of disturbance. Visualizations of landscape disturbance alongside the distribution of imperiled species has significant merit for locating conservation opportunities and focusing resources for restoration and recovery purposes.

ECONOMIC IMPACT OF THE ALABAMA RIVERS AND STREAMS NETWORK

As outlined by the numerous adaptations of the ARSN approach, the founding framework has successfully addressed the intersection of ecological restoration with a growing human population and prioritized projects that minimize threats to both aquatic species survival and human health. In turn, these efforts have shown that the value of interdisciplinary work extends far beyond the number of species recovered and the number of streams restored. Often, benefits are realized on a more local level and most notably in the form of cost savings for those dependent on natural resources such as a public water supply.

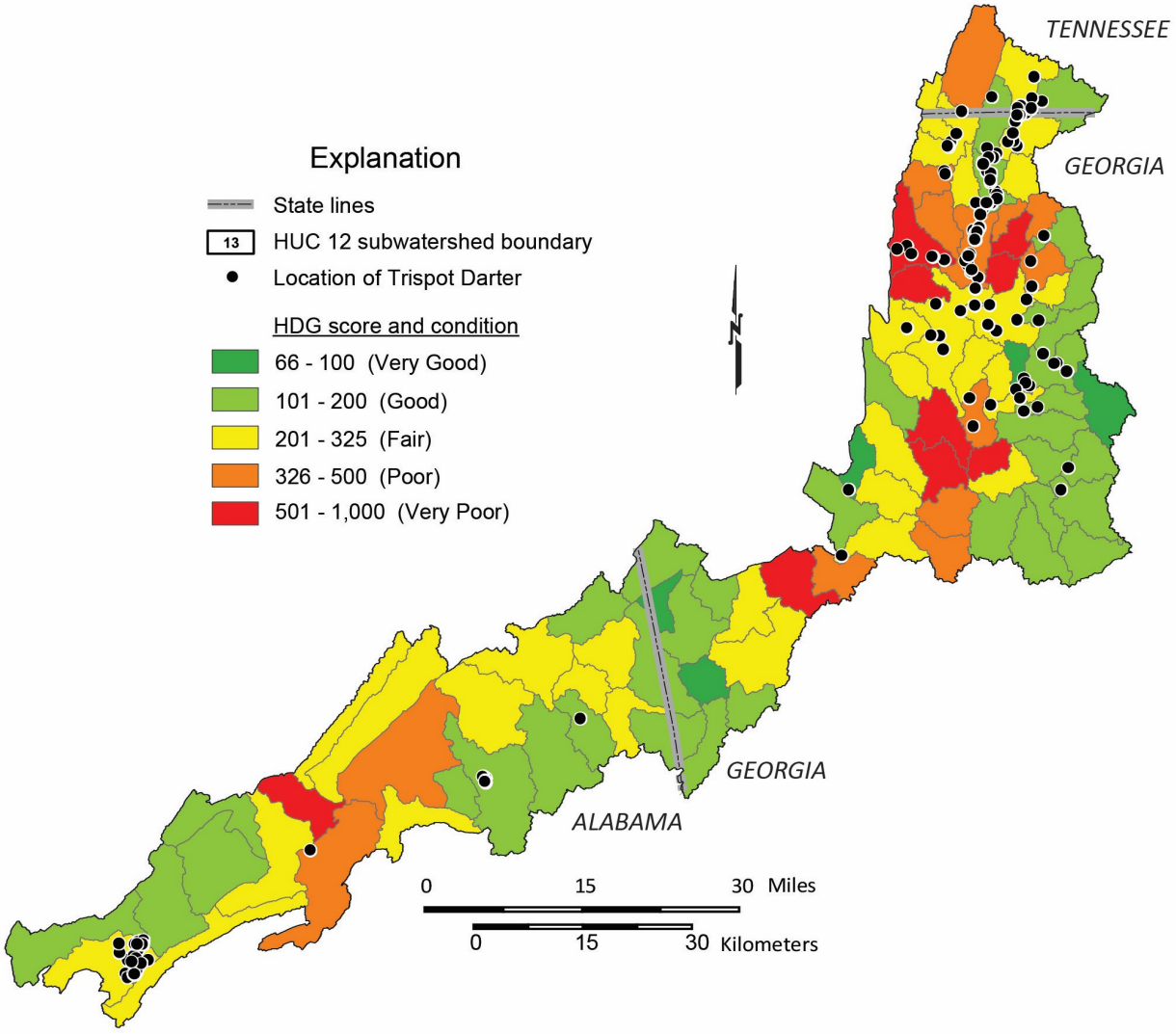

Figure 42.—Example of a human disturbance gradient map based on HUC-12 subwatersheds encompassing Cambrian-aged geology in the upper Coosa River system where the threatened Trispot Darter occurs (modified from O'Neil and others, 2022).

NORTH RIVER STRATEGIC HABITAT UNIT CASE STUDY

The effectiveness of watershed wide conservation actions and subsequent financial benefits to local water users was demonstrated by the North River SHU watershed assessment. The North River is a 1,111 km^2 (429 mi^2) watershed in Tuscaloosa and Fayette Counties, Alabama, and supports two water supply impoundments, Bays Lake and Lake Tuscaloosa. Lake Tuscaloosa is a significant reservoir that was designed to supply up to 757,082 cubic meters (m^3) per day (200 million gallons per day) for water use, and Bays Lake is a small water supply reservoir supplying the town of Berry in Fayette County. A 71 km (44 mi) reach of the North River was listed as impaired by nutrients, siltation, and habitat alteration in the §303(d) lists from 1998 through 2008, as well as having mercury impairment from atmospheric deposition. The upper North River is also listed as critical habitat for several federally endangered and threatened mussel species.

A pilot investigation was conducted in the North River SHU to evaluate the effectiveness

of simple roadside settling basins at retaining sediment by using check dams (O'Neil and others, 2015). The Clear Creek subwatershed in the upper reaches of North River feeds the Bays Lake 32.8-hectare (81-acre) impoundment. The town of Berry constructed a new water treatment plant for this water source and a new lagoon treatment system for the town's domestic wastewater. Bays Lake provides water to around 1,500 customers in the eastern half of Fayette County. Normal water production is 1,893 m^3 per day (500,000 gallons per day), and the plant can produce up to 3,785 m^3 per day (1,000,000 gallons per day) of treated water. Bays Lake is significant because it marks the upstream limit of critical mussel habitat in the North River, and it influences the stream flow and water quality of Clear Creek downstream of the dam.

Starting in the fall of 2011, small riprap check dams were constructed at 13 unpaved road sites in the Clear Creek watershed. The height of check dams was maintained at levels that would allow storm water to be temporarily impounded and kept off the unpaved road surface yet still allow sediments to settle. From November 2011 through December 2013, the basins collectively captured an estimated 70,000 kilograms (70 tons) of sediment, with the average volume of sediment captured per month varying from 0.053 to 0.322 m^3 (0.069 to 0.421 cubic yards). Although the total volume retained by the basins is relatively small, the resulting reduction of turbidity in Bays Lake was significant (fig. 43). The slopes of the turbidity-precipitation relationships pre- and post-BMP are statistically no different for any value of precipitation, but the average

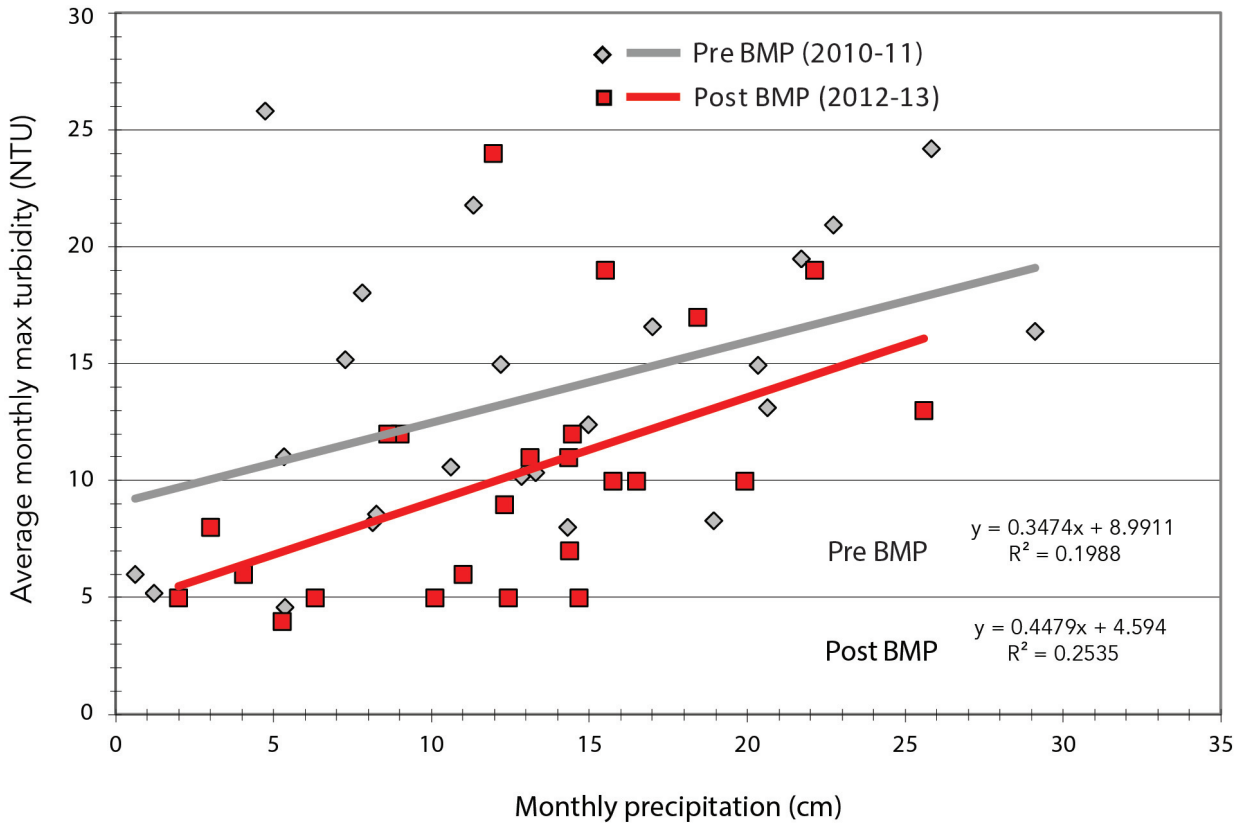

Figure 43.—Comparison of source water turbidity data from two years of pre-best management practice (BMP) installation (2010-11) with two years of post-BMP installation (2012-13) at the water treatment plant at Berry, Fayette County, Alabama.

monthly turbidity of the incoming water to the treatment plant was about 4 Nephelometric turbidity units (NTU) lower post-BMP compared to pre-BMP. Over a four-year period, two years prior to construction of the basins and two years after their implementation, the Berry water treatment plant observed a 25 percent reduction in average maximum monthly turbidity, resulting in a 46 percent reduction in cost of chemicals used in treatment. This cost savings was directly attributed to the presence of the small check dams on unpaved roads upstream of Bays Lake that reduced the volume of bed sediment entering the lake.

Managing the future quality of the water resources in the North River watershed by limiting sedimentation is of obvious significance from an economic standpoint of water supply treatment and from the standpoint of restoring natural stream conditions to support imperiled aquatic species. This study demonstrated that mutually beneficial goals can be accomplished by reducing sediment input, managing chemical water quality conditions through better implementation of BMPs, enforcing water quality regulations, working to restore stream features, and implementing a basin-wide watershed management plan. If the water resource is restored and protected, then imperiled aquatic species will benefit tremendously.

The cost savings transferred to water users through reducing sediment loads in water supply sources is just one example of the economic benefits provided by restoration initiatives. The inherent value of ecosystem services provided by nature is often overlooked in the traditional accounting of the dollar value of goods and services. Ecosystem services are those direct and indirect benefits derived from nature that contribute to human well-being and the well-being of the ecological systems and functions that provide these services. Agricultural systems, rangelands, forests, wetlands, oceans, lakes—essentially all ecosystems on earth—provide food, water, medicines, construction materials, renewable energy, air purification, pollution processing, and many more services to support human populations. These services have been valued at more than $150 trillion annually, about twice the world's gross domestic product, and the operations of four major value chains (food, energy, infrastructure, and fashion) drive more than 90 percent of the man-made pressure on biodiversity (Kurth and others, 2021). These services (table 9) can be classified into one of four types: provisioning, cultural, regulating, and supporting (Abt Associates, 2016; National Wildlife Federation, 2024).

The North River SHU also provided an opportunity for the ARSN approach to monetize the role of ecosystem services (Abt Associates, 2016) (table 10). This study estimated that the North River watershed provides at least $6.58 billion in total present value of ecosystem services over the baseline period of 2010 to 2050, or $203.6 million annually (table 11). Improving the landscape through surface mine reclamation yields an additional $71.2 million in terrestrial ecosystem services from 2010 to 2050. The estimated total present value of benefits by achieving water quality targets ranged between $42.6 to $119.6 million. Figure 44 is a breakdown of values for each ecosystem service category, showing water supply as providing the greatest economic value among all the monetized ecosystem services.

PROJECTED COSTS OF CONSERVATION TO SOCIETY

Increasing awareness of the ecological and economic values of species and the importance of maintaining functional aquatic systems is paramount to ensuring that conservation initiatives can continue, managing the known and preparing for the unknown. Conservation initiatives are not cheap, and when deviations from normal environmental patterns in the form of droughts, floods, heat waves, or other extreme events are exacerbated by climate change, the costs increase. However, restoration efforts should be scaled accordingly to avoid even greater costs to society.

Table 9.—General classification of ecosystem services and goods provided by natural assets (modified from Abt Associates, 2016).

Provisioning	Cultural	Regulating	Supporting
• Energy and raw materials • Food • Water supply • Medicinal resources • Ornamental plant resources • Oil and natural gas	• Recreation and tourism • Science and education • Natural beauty • Spiritual and historic • Artistic and cultural	• Climate stability • Air quality • Flood control • Soil retention • Biological control • Pollination • Waste treatment • Water regulation	• Habitat and nursery • Genomic pool • Photosynthesis • Nutrient cycling • Soil Creation • Water cycle

Table 10.—Ecosystem services provided by the North River watershed (modified from Abt Associates, 2016).

Service	Aquatic resources	Terrestrial resources	Assessed services
Provisioning	• Drinking water supply • Agricultural water supply • Industrial water supply	• Timber products • Food production • Raw materials (coal, methane)	• All services are assessed in monetary terms
Cultural	• Water-based recreation o Fishing o Boating o Kayaking o Other recreation • Aesthetic (water color/clarity) o Property values o Scenic vistas • Nonuse o Aquatic biodiversity • Education and outreach	• Terrestrial recreation o Hunting o Birdwatching o Wildlife viewing o Hiking o Other (camping) • Aesthetic (landscape effects) o Property values o Scenic vistas • Nonuse o Wildlife and plant biodiversity o Regional character • Education and outreach	• Services assessed in monetary terms o Fishing o Swimming o Boating o Hunting o Wildlife viewing o Change in total nonmarket value of services provided by water resources
Supporting	• Habitat and Nursery • Genomic resources	• Habitat and Nursery • Genomic resources	• Not assessed in monetary terms
Regulating	• Hydrology o Stream bank stabilization o Stream channel protection o Groundwater recharge • Water quality o Filtration/nutrient removal o Stream temperature moderation	• Air o Air pollutant removal o Carbon storage and sequestration o Air temperature volatility reduced • Soil o Erosion control • Sediment retention	• Services assessed in monetary terms o Air pollutant removal o Carbon storage o Carbon sequestration

Table 11.—Estimated economic value of ecosystem services provided by the North River watershed under the baseline scenario of 2010 to 2050 (values shown in millions in 2015 dollars) (from Abt Associates, 2016).

Ecosystem service	Annualized value [1]	Total Present Value (2010-2050) [2]
Provisioning services	$134.7	$3,304.3
Recreational value	39.1	1,487.4
Regulating services	29.8	1,791.3
Education and outreach	Positive qualitative benefit	
Endangered and threatened species protection	Positive qualitative benefit	

[1] Annualized value is estimated using a 3% discount rate.
[2] Total present value is estimated using a 3% discount rate.

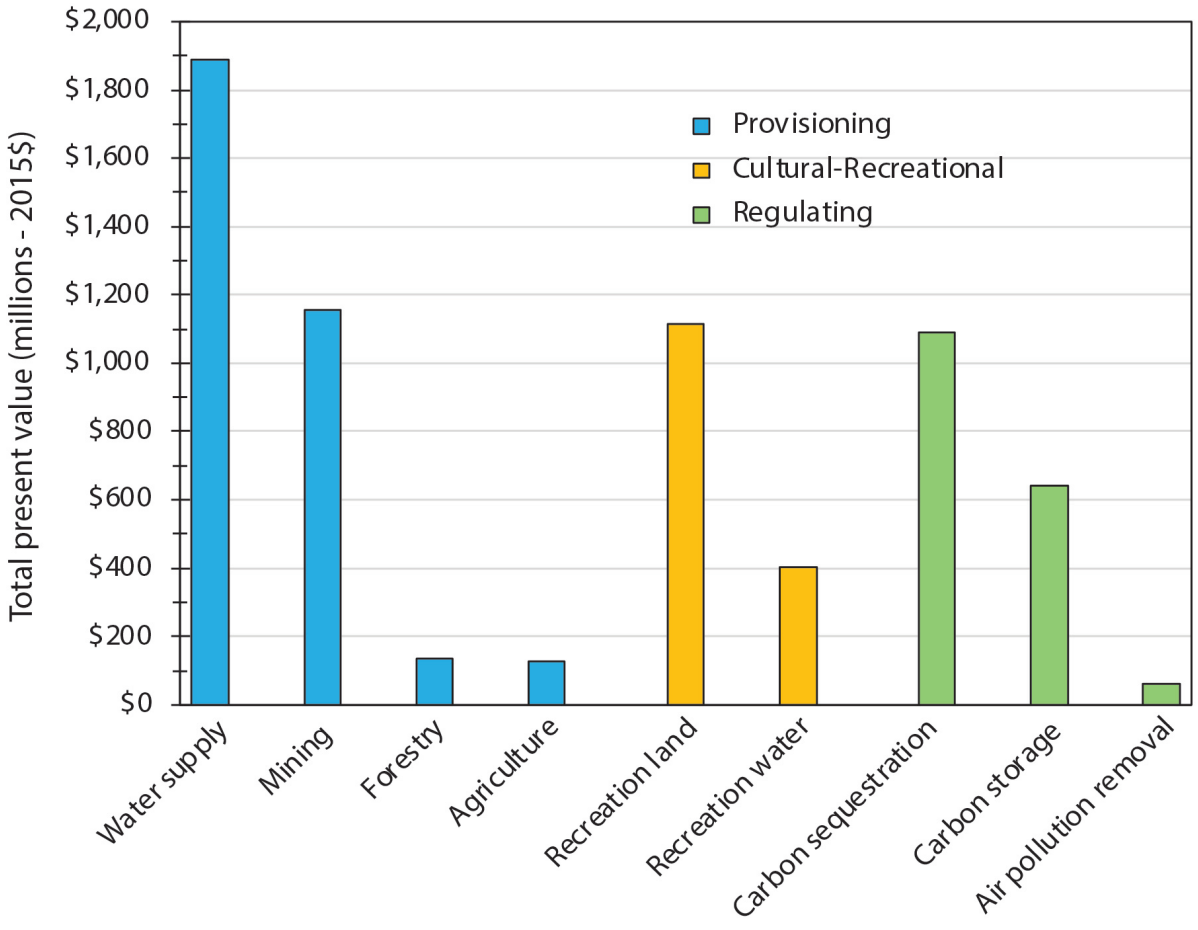

Figure 44.—Total present value of ecosystem services provided by the North River watershed, Black Warrior River system, under the baseline scenario from 2010 to 2050 (modified from Abt Associates, 2016).

Researchers at the University of Oxford Environmental Change Institute recently evaluated scenarios for climate-nature shocks and gathered evidence on the very critical nature of these shocks for the global financial system. They reported that shocks to the global economy related to biodiversity loss and ecosystem damage could cost upwards of $5 trillion. The erosion of natural capital, linked with biodiversity loss and environmental degradation, generated significant long-term risks to society, the economy, and finance from the increased risk of pandemics, floods, and droughts. Nature's services are not all about birds and butterflies; human society is fundamentally eroding the natural capital upon which societies and economies are built. Global food systems were shown to be at particularly significant risk because of soil erosion, land-use change, and loss of insect pollinators (Ranger and others, 2023).

Integrating nature into economic planning, policies, and investments is expensive. The Bloomberg News research service (BloombergNEF) in an article on April 5, 2023, reported that financing to protect and restore earth's more fragile natural resources amounts to $166 billion per year, less than 1/6 of the annual investment spent on energy transition, and that this amount will need to increase to $1 trillion by 2030 just to sustainably manage ecosystem integrity (Oktavia, 2023). T. Rowe Price has valued the estimated global annual investment required for protecting nature's services over the next decade at $10 trillion and is actively exploring how to integrate biodiversity into its investment strategies and portfolios (Kunorubwe, 2023). These estimates to protect biodiversity stand in comparison to the anticipated economic cost of biodiversity loss by the end of the decade which could amount up to $2.7 trillion annually.

The BloombergNEF "Biodiversity Finance Factbook" (Bromley, 2024) identified six tasks that governments, companies, and financial institutions should do to address these anticipated economic and biodiversity losses:

- Back initiatives to collect and share biodiversity data and harmonize metrics and frameworks;
- Integrate biodiversity into planning, operations, and reporting;
- Reform environmentally harmful subsidies and boost biodiversity support;
- Develop replicable business models and use concessional funding to address the shortage of bankable biodiversity projects;
- Improve the environmental integrity of offsets and other mechanisms; and
- Promote industry and local community buy-in.

By its very nature, the ARSN approach provides the proper framework to organize and execute proactive attempts to mitigate and alleviate these anticipated losses. The call to action is urgent.

CONCLUSIONS

The ARSN model is a multidisciplinary, collaborative, iterative, and adaptive approach to conservation with a long and complex history, a growing number of engaged partners, a lengthy list of achievements, and a proven ability to change as ecological conditions and societal needs require. At its very core, ARSN is a partnership-based and comprehensive process to implement "cooperative conservation" with the goals of improving water resources and habitat quality, educating the public about the benefits of good natural resource stewardship, and recovering aquatic species to sustainable levels. In keeping with the goal of removal or reduction of identified threats sufficient to eliminate federal protections under the ESA, the ARSN approach focuses on the "water resource" for habitat restoration activities and engages a broad array of stakeholders and landowners working cooperatively to restore and recover habitat and environmental conditions, thereby restoring and recovering species as the by-product of good water and natural resources stewardship.

The conservation of biodiversity is hard and complicated work and requires a focused team approach. The conservation of southeastern aquatic biodiversity is even harder work for a few simple reasons. First, the aquatic biodiversity in southeastern rivers and streams is very high in many watersheds, and

the available financial resources to tackle the issues are very limited. Second, aquatic species are confined to ribbons of habitat transecting multiple private lands, and there are few landscape-scale publicly protected watersheds where significant quantities of imperiled species are found. Third, most lands in the Southeast are privately owned, necessitating a different conservation paradigm compared to the large publicly owned lands in the West. Multiple privately owned land parcels overlapping with multiple water resource management and conservation agencies and organizations warrant a cooperative approach as the tactic most likely to be successful.

The ARSN approach is founded on the belief that habitat protection and improvement in Alabama can best be accomplished through working with private landowners around three general activities: restoration, enhancement, and prevention of degradation. Habitat restoration activities include repairing eroding stream banks to reduce the amount of sediment entering a channel and removing degrading and unneeded dams to restore natural flows. Restoring stream flows to a more natural hydrologic pattern of spring floods and summer low flows is a significant restoration opportunity because aquatic life histories are intimately linked to the natural drought and flood cycles of streams through the seasons. Habitat enhancement activities could include replacing degraded stream crossing structures and bridges with structures compatible with stream hydrology that allow aquatic fauna to move and migrate freely. Habitat enhancement activities could also include working with forest product companies to make sure forest roads are more sustainable, forestry BMPs are followed, logging activities do not create stream barriers while conducting operations, and functional streamside management zones are maintained. Activities to prevent further degradation of aquatic habitat would be working with farmers to implement BMPs to reduce sediment and fertilizer runoff from fields to streams and working with departments of environmental quality to assess and manage water quality by reducing discharged nutrients, further limiting toxic substances, and limiting polluted water runoff from urban areas.

The ARSN strategy for conserving imperiled aquatic species is demonstrating that the bottom-up cooperative conservation path does work. However, this method requires, first and foremost, that conservation participants approach the issues in good faith, be willing to negotiate and compromise for win-win outcomes, and establish personal relationships among all parties involved, working to avoid heavy-handed tactics. Approaching the aquatic conservation issue alone in an agency or organization silo may result in a less than desirable outcome for the species of concern because the conservation solution will typically require a range of technical skills, people and organizational management skills, and political skills. Rarely are all these talents, legislative directives, or political mandates found in any one agency, organization, or landowner.

Thanks to its solid foundation and cooperative framework, the ARSN approach can be used as a model for more than aquatic species conservation. Terrestrial species conservation, water management planning, and other initiatives addressing the nexus of conservation science and a concerned society can benefit from the proven strategy that has benefited both imperiled species conservation and Alabama's citizens since ARSN's inception.

With the ongoing erosion of quality habitat and emerging environmental challenges, the aquatic biodiversity crisis in the U.S. will no doubt continue its troubling, undesirable trajectory into the biological bottleneck. A better understanding and application of nature's economics, implemented through conservation approaches such as the ones practiced by ARSN, is one solution. Updating state water policies to include biodiversity protection at some level is another approach with significant merit for very positive improvements, not only to aquatic biodiversity but to water resources as well. Protecting instream flow, managing water withdrawals, and integrating biodiversity goals with water

quality goals would be a win-win solution to many water resource ailments. All these approaches require integrating foundational knowledge about biodiversity and water resources with the political will to make conservation a priority. Every successful water resource conservation project, no matter how small, benefits aquatic biodiversity. Progress will take time. The current biodiversity predicament in the U.S. has been 250 years in the making. In turn, even more time may be required to work through the biodiversity bottleneck to hopefully reach a sustainable outcome in the future.

Revisiting the biodiversity quotes mentioned in the introduction and putting them into context of aquatic species conservation in the Southeast, the themes of biological connectedness, resource sustainability, and the human role in assuring our natural systems remain functional gain even greater relevance moving forward. The ARSN model of cooperative conservation offers a reasonable and prudent approach to recover and sustain aquatic biodiversity and can be used to address these and other pressing needs at the intersection of science and society.

FOR MORE INFORMATION

ARSN offers a variety of outlets for sharing and receiving information.

REPORTS

Information and data generated through research and restoration activities of ARSN partners is the foundation for effective imperiled species recovery. Selected reports, literature, and information covering many different topics related to biodiversity and species recovery in SHUs and SRRUs are presented in appendix F.

INTERACTIVE STRATEGIC HABITAT UNIT MAPPER

The SHU website and database system (https://alabama-rivers-and-streams-network-fws.hub.arcgis.com/pages/dashboard) is a product of ARSN that serves as a repository for both tabular and geospatial data related to specially designated watersheds, river segments, and road crossings within Alabama and neighboring states. Multiple datasets can be displayed on the mapper including the National Hydrological Dataset (NHD), road crossing assessments, Bank Erosion Hazard Index (BEHI), Fish Index of Biotic Integrity, and USFWS designated critical habitat for federally listed species. This mapper is used by both the public and special interest groups to understand their watershed and where research and restoration efforts should focus.

ALABAMA RIVERS AND STREAMS NETWORK WEBSITE AND SOCIAL MEDIA PLATFORMS

The Alabama Rivers and Streams Network hosts a website (alh2o.org) to disseminate information on the network, events, news, and aquatic biodiversity in Alabama and surrounding states. The ARSN website has information on much of the work being done in SHUs and SRRUs and provides information on news stories, calendar of events, meeting notes, and contact information for ARSN members. The website also provides information for each strategic habitat unit and a link to the Interactive SHU Mapper. Additionally, ARSN maintains a social media presence on Facebook, Instagram, and YouTube to allow for more instantaneous and interactive photo and video sharing.

ALABAMA RIVERS AND STREAMS NETWORK ANNUAL MEETING

An annual meeting is typically held early in the calendar year for the purpose of sharing current projects and prioritizing SHUs and watersheds for future work. Planning and meeting operations are led by four regional working groups based on geographic areas for the USFWS Partners for Fish and Wildlife Program: North, South, East, and West. These working groups conduct meetings as needed in their corresponding regions and create action plans that are presented at the annual meeting.

ALABAMA RIVERS AND STREAMS NETWORK EMAIL LISTSERV

The ARSN email Listserv functions as a dynamic database of contact information for all ARSN members and allows for transmission of information regarding training opportunities,

job announcements, partner recognition, project success stories, and project needs.

EDUCATIONAL OPPORTUNITIES

Members of ARSN conduct multiple educational events throughout the year in response to partner needs for training or outreach requests. Examples include:

- Field and laboratory identification workshops for aquatic organisms (fishes, benthic macroinvertebrates, crayfishes, mollusks);
- Field sampling techniques for fishes and benthic macroinvertebrates;
- Habitat assessment training workshops;
- Natural resource related workshops for business and industry;
- Water policy workshops; and
- K-12 outreach events.

In summary, the Alabama Rivers and Streams Network is a group of nonprofit organizations, private companies, federal, state, and local agencies, and concerned citizens that recognize the importance of clean water and the need to work together to maintain healthy water supplies. The goal of the ARSN is to investigate water quality, habitat conditions, and biological quality in rivers and streams and to communicate findings to the public. Each Strategic Habitat Unit has a unique group of stakeholders that need to be brought to the table in order for restoration efforts to be successful.

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APPENDIX A —
FEDERALLY LISTED ENDANGERED AND THREATENED AQUATIC SPECIES IN ALABAMA

(from U.S. Fish and Wildlife Service, 2023a)

Abbreviations used in Status column of listing
are as used in the Endangered Species Act (1972):
E–endangered, T–threatened, PE–provisional endangered,
NEP–nonessential experimental population

Appendix A — Continued

Family	Scientific name	Common Name	Status	Year Listed
Crustaceans				
	Cambarus cracens	Slenderclaw Crayfish	E	2021
	Palaemonias alabamae	Alabama Cave Shrimp	E	1988
Mussels				
	Alasmidonta triangulata	Southern Elktoe	PE	
	Cumberlandia monodonta	Spectaclecase	E	2012
	Cyprogenia stegaria	Fanshell	E	1990
	Dromus dromus	Dromedary Pearlymussel	E, NEP	1976, 2001
	Elliptio chipolaensis	Chipola Slabshell	T	1998
	Elliptoideus sloatianus	Purple Bankclimber	T	1998
	Epioblasma brevidens	Cumberlandian Combshell	E	1997
	Epioblasma capsaeformis	Oyster Mussel	E	1997
	Epioblasma obliquata	Purple Cat's Paw	E, NEP	1990, 2001
	Epioblasma penita	Southern Combshell	E	1987
	Epioblasma triquetra	Snuffbox Mussel	E	2012
	Fusconaia burkei	Tapered Pigtoe	T	2012
	Fusconaia cor	Shiny Pigtoe	E	1976
	Fusconaia cuneolus	Finerayed Pigtoe	E	1976
	Fusconaia escambia	Narrow Pigtoe	T	2012
	Fusconaia subrotunda	Longsolid	T	2023
	Hamiota altilis	Finelined Pocketbook	T	1993
	Hamiota australis	Southern Sandshell	E	2012
	Hamiota perovalis	Orangenacre Mucket	T	1993
	Hamiota subangulata	Shinyrayed Pocketbook	E	1998
	Hemistena lata	Cracking Pearlymussel	E	1989
	Lampsilis abrupta	Pink Mucket	E	1976
	Lampsilis virescens	Alabama Lampmussel	E	1976
	Lemiox rimosus	Birdwing Pearlymussel	E, NEP	1976, 2001
	Margaritifera marrianae	Alabama Pearlshell	E	2012
	Medionidus acutissimus	Alabama Moccasinshell	T	1993
	Medionidus conradicus	Cumberland Moccasinshell	PE	
	Medionidus parvulus	Coosa Moccasinshell	E	1993
	Medionidus penicillatus	Gulf Moccasinshell	E	1998
	Obovaria choctawensis	Choctaw Bean	E	2012
	Obovaria subrotunda	Round Hickorynut	T	2023
	Obovaria unicolor	Alabama Hickorynut	PE	
	Plethobasus cicatricosus	White Wartyback	E	1976
	Plethobasus cyphyus	Sheepnose Mussel	E	2012
	Pleurobema athearni	Canoe Creek Clubshell	E	2022

Appendix A — Continued

Family	Scientific name	Common Name	Status	Year Listed
Mussels–cont'd				
	Pleurobema clava	Clubshell	E, NEP	1993, 2001
	Pleurobema decisum	Southern Clubshell	E	1993
	Pleurobema rubellum	Warrior Pigtoe	E	1993
	Pleurobema georgianum	Southern Pigtoe	E	1993
	Pleurobema hanleyianum	Georgia Pigtoe	E	2010
	Pleurobema oviforme	Tennessee Clubshell	PE	
	Pleurobema perovatum	Ovate Clubshell	E	1993
	Pleurobema plenum	Rough Pigtoe	E	1976
	Pleurobema pyriforme	Oval Pigtoe	E	1998
	Pleurobema strodeanum	Fuzzy Pigtoe	T	2012
	Pleurobema taitianum	Heavy Pigtoe	E	1987
	Pleuronaia barnesiana	Tennessee Pigtoe	PE	
	Pleuronaia dolabelloides	Slabside Pearlymussel	E	2013
	Potamilus inflatus	Inflated Heelsplitter	T	1990
	Ptychobranchus foremanianus	Rayed Kidneyshell	E	1993
	Ptychobranchus greenii	Triangular Kidneyshell	E	1993
	Ptychobranchus jonesi	Southern Kidneyshell	E	2012
	Reginaia rotulata	Round Ebonyshell	E	2012
	Theliderma cylindrica	Rabbitsfoot	T	2013
	Theliderma intermedia	Cumberland Monkeyface	E, NEP	1976,2001
	Toxolasma cylindrellus	Pale Lilliput	E	1976
	Venustaconcha trabalis	Cumberland Bean	E	1976
Extinct Mussel Species				
	Alasmidonta mccordi	Coosa Elktoe		
	Epioblasma arcaeformis	Sugarspoon		
	Epioblasma biemarginata	Angled Riffleshell		
	Epioblasma cincinnatiensis	Ohio Riffleshell		
	Epioblasma flexuosa	Leafshell		
	Epioblasma florentina	Yellow Blossom		
	Epioblasma haysiana	Acornshell		
	Epioblasma lenior-	Narrow Catspaw		
	Epioblasma lewisii-	Forkshell		
	Epioblasma metastriata-	Upland Combshell		
	Epioblasma othcaloogensis-	Southern Acornshell		
	Epioblasma personata	Round Combshell		
	Epioblasma propinqua	Tennessee Riffleshell		
	Epioblasma stewardsonii	Cumberland Leafshell		

Appendix A — Continued

Family	Scientific name	Common Name	Status	Year Listed
Extinct Mussel Species – cont'd				
	Epioblasma torulosa	Tubercled Blossom		
	Epioblasma turgidula	Turgid Blossom		
	Lampsilis binominata	Lined Pocketbook		
	Obovaria haddletoni	Haddleton Lampmussel		
	Pleurobema curtum	Black Clubshell		
	Pleurobema fibuloides	Kusha Pigtoe		
	Pleurobema marshalli	Flat Pigtoe		
	Pleurobema stabile	Coosa Pigtoe		
	Pleurobema verum-	True Pigtoe		
	Reginaia apalachicola	Apalachicola Ebonyshell		
	Theliderma stapes	Stirrupshell		
Snails				
	Athearnia anthonyi	Anthony's Riversnail	E	1994
	Campeloma decampi	Slender Campeloma	E	2000
	Elimia crenatella	Lacy Elimia	T	1998
	Leptoxis ampla	Round Rocksnail	T	1998
	Leptoxis compacta	Oblong Rocksnail	PE	
	Leptoxis coosaensis	Painted Rocksnail	T	1998
	Leptoxis foremani	Interrupted Rocksnail	E	2010
	Leptoxis plicata	Plicate Rocksnail	E	1998
	Lepyrium showalteri	Flat Pebblesnail	E	1998
	Lioplax cyclostomatiformis	Cylindrical Lioplax	E	1998
	Marstonia pachyta	Armored Snail	E	2000
	Pleurocera foremanii	Rough Hornsnail	E	2010
	Tulotoma magnifica	Tulotoma Snail	T	1991
Extinct Snail Species				
	Amphigyra alabamensis	Shoal Spire		
	Clappia umbilicate	Umbilicate Pebblesnail		
	Elimia catenoides	Lirate Elimia		
	Elimia clausa	Closed Elimia		
	Elimia fusiformis	Fusiform Elimia		
	Elimia gibbera	Shouldered Elimia		
	Elimia hartmaniana	High-spired Elimia		
	Elimia impressa	Constricted Elimia		
	Elimia jonesi	Hearty Elimia		
	Elimia laeta	Ribbed Elimia		
	Elimia macglameriana	Wrinkled Elimia		

Appendix A — Continued

Family	Scientific name	Common Name	Status	Year Listed
Extinct Snail Species – cont'd				
	Elimia pilsbryi	Rough-lined Elimia		
	Elimia pupaeformis	Pupa Elimia		
	Elimia pupoidea	Bot Elimia		
	Elimia pygmaea	Pygmy Elimia		
	Gyrotoma excise	Excised Slitshell		
	Gyrotoma lewisii	Striate Slitshell		
	Gyrotoma pagoda	Pagoda Slitshell		
	Gyrotoma pumila	Ribbed Slitshell		
	Gyrotoma pyramidata	Pyramid Slitshell		
	Gyrotoma walker	Round Slitshell		
	Leptoxis clipeata	Agate Rocksnail		
	Leptoxis formosa	Maiden Rocksnail		
	Leptoxis ligata	Rotund Rocksnail		
	Leptoxis lirata	Lirate Rocksnail		
	Leptoxis minor	Knob Mudalia		
	Leptoxis occultata	Bigmouth Rocksnail		
	Leptoxis showalterii	Coosa Rocksnail		
	Leptoxis torrefacta	Squat Rocksnail		
	Leptoxis vittate	Striped Rocksnail		
	Marstonia olivacea	Olive Marstonia		
	Neoplanorbis carinatus	Carinate Flat-top Snail		
	Neoplanorbis tantillus	Little Flat-top Snail		
	Neoplanorbis umbilicatus	Umbilicate Flat-top Snail		
	Pomatiopsis hinkleyi	Alabama Walker		
Fishes				
	Acipenser desotoi	Gulf Sturgeon	T	1991
	Cottus paulus	Pygmy Sculpin	T	1989
	Cyprinella caerulea	Blue Shiner	T	1992
	Elassoma alabamae	Spring Pygmy Sunfish	T	2013
	Erimonax monachus	Spotfin Chub	T, NEP	1977, 2005
	Etheostoma boschungi	Slackwater Darter	T	1977
	Etheostoma chermocki	Vermilion Darter	E	2001
	Etheostoma nuchale	Watercress Darter	E	1970
	Etheostoma phytophilum	Rush Darter	E	2011
	Etheostoma trisella	Trispot Darter	T	2019
	Miniellus albizonatus	Palezone Shiner	E	1993
	Nothonotus wapiti	Boulder Darter	E	1988

Appendix A — Continued

Family	Scientific name	Common Name	Status	Year Listed
Fishes – cont'd				
	Paranotropis cahabae	Cahaba Shiner	E	1990
	Percina aurolineata	Goldline Darter	T	1992
	Scaphirhynchus suttkusi	Alabama Sturgeon	E	2000
	Speoplatyrhinus poulsoni	Alabama Cavefish	E	1977
Extinct Fish Species				
	Fundulus albolineatus	Whiteline Topminnow		
	Moxostoma lacerum	Harelip Sucker		
Reptiles and Amphibians				
	Necturus alabamensis	Black Warrior Waterdog	E	2018
	Sternotherus depressus	Flattened Musk Turtle	T	1987

APPENDIX B —
THE ALABAMA STURGEON STORY

by

Patrick E. O'Neil

In any good story, there should be a protagonist that is the focus of interest, be that loathing, devotion, or perhaps something in between. In the case of the Alabama Rivers and Streams Network (ARSN) story, that early protagonist is the Alabama Sturgeon (*Scaphirhyncus suttkusi*) (fig. B-1). The Alabama Sturgeon is a small shovelnose sturgeon known from the waters of the Alabama and Tombigbee Rivers in Alabama and Mississippi. All the extant species of shovelnose sturgeon are primitive fishes feeding on the bottom with their tubular, vacuum-like protrusible mouths consuming invertebrates living in mud and gravel shoals of large rivers. There are three described species of *Scaphirhyncus* in North America. The Shovelnose Sturgeon (*S. platorynchus*) described by Rafinesque (1820), the Pallid Sturgeon (*S. albus*) described by Forbes and Richardson (1905), and the Alabama Sturgeon (*S. suttkusi*) described by Williams and Clemmer (1991). Until its formal description, the Alabama Sturgeon was considered the same species as the Shovelnose Sturgeon. Williams and Clemmer (1991) based their conclusion of a unique species differing from the Shovelnose Sturgeon by differences in eye morphology, color, and external spine characters on the snout.

Figure B-1. The Alabama Sturgeon, *Scaphirhynchus suttkusi* (photo taken at Marion Fish Hatchery in 2007).

Sturgeon in the Mobile River basin were captured in the late 19th century by the hundreds of thousands (likely including Alabama and Gulf Sturgeon) by commercial fishermen (Hershey and others, 2024), but by the early 20th century, their presence was ghostly, with very sporadic reports of sightings and even fewer captures. A quote from the Federal Register, where the endangered status for the Alabama Sturgeon was proposed, contained a summary for just one year of commercial catch in 1898 (64 FR 14678):

> *There are records of sturgeon captures from the Black Warrior, Tombigbee, Alabama, Coosa, Tallapoosa, Mobile, Tensaw, and Cahaba rivers (Burke and Ramsey 1985, 1995). The Alabama sturgeon was once common in Alabama, and perhaps also in Mississippi. The total 1898 commercial catch of ''shovelnose'' sturgeons (i.e., Alabama sturgeon) from Alabama was reported as 19,000 kg (42,900 lb) in a statistical report to Congress (U.S. Commission of Fish and*

Fisheries 1898). Of this total, 18,000 kg (39,500 lb) came from the Alabama River and 1,000 kg (2,300 lb) from the Black Warrior River. Given that an average Alabama sturgeon weighs about 1 kg (2 lb), the 1898 commercial catch consisted of approximately 20,000 fish. These records indicate a substantial historic population of Alabama sturgeon.

Today, the species is neither commercially nor recreationally viable, and its numbers are so low that it was protected as an endangered species by the U.S. Fish and Wildlife Service (USFWS) in 2000 under the Endangered Species Act (ESA). At the time of its description, the Alabama Sturgeon was very rarely encountered and considered endangered in Alabama by ichthyologists. Only about 40 specimens of the Alabama Sturgeon captured from the upper Tombigbee, Alabama, Cahaba, and lower Coosa Rivers were known to exist in museums at the time of the description.

To say the effort to list the Alabama Sturgeon as an endangered species under the ESA was controversial is perhaps the ichthyological understatement of the century. The pathway to listing required branching off the main path to include multiple efforts to ensure the protection of the declining population as well as efforts to begin the recovery of the species. There was the regulatory pathway that included the actions and documents required by the ESA to fulfill the regulatory requirements of listing, then there was the science/social pathway that included all comments, investigations, surveys, and legal challenges to the listing. A brief chronology of the regulatory and recovery actions pathway is outlined below:

- ***1982***, December 30. Review of vertebrate wildlife for listing as endangered or threatened species. Identification of the Shovelnose (Alabama) Sturgeon for listing consideration (47 FR 58454 58460).
- ***1991,*** Description of the Alabama Sturgeon. Williams, J.D., and Clemmer, G.H., 1991, *Scaphirhynchus suttkusi*, a new sturgeon (Pisces:Acipenseridae) from the Mobile Basin of Alabama and Mississippi: Bulletin of the Alabama Museum of Natural History, no. 10, p. 17-31.
- ***1993***, June 15. Proposed endangered status and designation of critical habitat for the Alabama Sturgeon (*Scaphirhynchus suttkusi*) (58 FR 33148 33154).
- ***1993***, November 19. Emergency petition to list the Alabama Sturgeon as endangered under the ESA, submitted by Friends of the Alabama Sturgeon, The Biodiversity Legal Foundation, Edward Mudd, and Ray Vaughn.
- ***1997***, September 19. Review of plant and animal taxa that are candidates of proposed listing as endangered or threatened, annual notice of findings on recycled petitions, and annual description of progress on listing actions. Alabama Sturgeon considered C5-candidate species, priority 5 (62 FR 49398 49411).
- ***1998***, July 16. Petition to list the Alabama Sturgeon as endangered and declare critical habitat by The Biodiversity Legal Foundation, Wild Alabama, Edward Mudd, and Ray Vaughn.
- ***1999***, October 25. Review of plant and animal taxa that are candidates of proposed listing as endangered or threatened, annual notice of findings on recycled petitions, and annual description of progress on listing actions. Alabama Sturgeon listed provisionally as Endangered, priority 5 (64 FR 57535 57547).
- ***2000,*** May 5. Official listing of the Alabama Sturgeon as endangered (65 FR 26438).
- ***2001***, October 30. Review of plant and animal taxa that are candidates or proposed for listing as endangered or threatened, annual notice of findings on recycled petitions, and annual description of progress on listing actions. Removal of Alabama Sturgeon from candidate list (66 FR 54808 54832).

- ***2007***, April 3. The last capture of an Alabama sturgeon by biologists with the Alabama Department of Conservation and Natural Resources.
- ***2009***, April 23. Last observation of the Alabama Sturgeon by biologists with the Alabama Department of Conservation and Natural Resources.
- ***2009***, June 2. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Alabama Sturgeon (*Scaphirhynchus suttkusi*). In total 326 miles of river was designated as critical habitat including portions of the Alabama and Cahaba Rivers in Autauga, Baldwin, Bibb, Clarke, Dallas, Lowndes, Monroe, Perry, and Wilcox Counties in Alabama (74 FR 26488 26509). Alabama River–from its confluence with the Tombigbee River 245 miles upstream to R.F. Henry Lock and Dam; Cahaba River–from its confluence with the Alabama River 81 miles upstream to US Hwy. 82 crossing in Bibb County.
- ***2009***, July 6. Endangered and Threatened Wildlife and Plants; 5-Year Status Reviews of 23 Southeastern Species. Announcement of 5-year status review of the Alabama Sturgeon by the Daphne Field Office of the USFWS (74 FR 31972 31973).
- ***2012***, April 12. Notice of Availability of a Technical/Agency Draft Recovery Plan for the Alabama Sturgeon 77 FR 21993-21994.
- ***2013***, August 6. Notice of availability of a recovery plan for the Alabama Sturgeon (78 FR 47722 47723). Downlisting of the Alabama sturgeon may be considered when the following criteria are met: (1) A population consisting of approximately 500 sexually mature Alabama sturgeon is shown to be surviving and naturally reproducing in the Alabama/Cahaba Rivers; (2) population studies show that the Alabama sturgeon population is naturally recruiting (consisting of multiple age classes), sustainable over a period of 20 years (2–3 generations), and no longer requires hatchery augmentation; and (3) an agreement is in place that ensures adequate flows are being delivered down the Alabama River for successful development of sturgeon larvae and passage of the fish both upstream and downstream at dams on the Alabama River.
- ***2018***, 5-year status reviews for 35 southeastern species.
- ***2019***, 28 Draft Recovery Plan Revisions for 53 Species in the Southeast, Mountain-Prairie, and Pacific Southwest Regions of the United States; Notice of Availability.

This flurry of listing activity naturally led to significant legal challenges to the listing by utilities, river associations, paper industries, barge companies, and others (collectively known under the banner of Alabama-Tombigbee Rivers Coalition, or the “Coalition”) who saw the action as a significant deterrent to their business operations with the potential to close Mobile basin rivers to all commerce. This confrontation was intense and attacked the listing along several fronts including science (was the listing valid scientifically?), regulatory (did the USFWS follow the rules of listing?), and socially through the media.

The scientific challenge (Howell, 1993) was a critique of the taxonomic methodology of meristic counts and measurements of certain key morphological features of the Alabama Sturgeon; a lack of specific life history information about habitat, spawning habitat, reproduction and growth, and the author’s conjectural assignment of these data from the Shovelnose Sturgeon to the Alabama Sturgeon with no scientific justification; statistical errors presented in the description; attribution of morphological uniqueness to normal biological clinal variation for wide-ranging species; the failure of USFWS to use the best scientific and commercial data available in their listing decision; USFWS making conjectural statements about impacts to Alabama Sturgeon without scientific data to support such statements; the USFWS erroneously assuming that impoundments in the Mobile River basin are responsible for sturgeon decline; and the erroneous use by USFWS of biological needs data from sturgeon species in Russia to the Alabama

Sturgeon. A review of the taxonomic and population status of the Alabama Sturgeon was prepared by the Alabama Sturgeon Scientific Review Panel (=Coalition) and raised other points concerning the description, listing, and logic of the process (Alabama Sturgeon Scientific Review Panel, 1993). Overall, these two reports were an aggressive critique of the description and the resulting proposal and process to list the sturgeon under the ESA.

In a refute of the above critique, Mayden and Kuhajda (1996) published a reevaluation of the morphological distinctiveness of the Alabama Sturgeon using improved statistical tests and examination of new data derived from Shovelnose Sturgeon taken from a larger geographic area. Eight new morphological characters that did not appear to have clinal variation were distinctive for the Alabama Sturgeon. The USFWS (1998) prepared a status report incorporating the Mayden and Kuhajda (1996) review, new genetic analyses, and refined catch data along with new capture data to conclude that the Alabama Sturgeon was indeed a unique species as defined under the ESA and that it continued to survive at the time of the report (1998).

These early battles over the science behind the Alabama Sturgeon and the process to list the sturgeon under the ESA led to a very polarized environment, threatening the possibility of constructive conservation actions for the species. Fortunately, representatives from some of the parties came together to form the Mobile River Basin Aquatic Ecosystem Coalition in June 1996.

Having concluded that the Alabama Sturgeon was at risk of further decline and possible extinction, the USFWS acknowledged that conservation efforts underway at the time benefitted this species and may increase its chances of survival. The Alabama Department of Conservation and Natural Resources (ADCNR) protected the Alabama Sturgeon from commercial, recreational, and scientific take and implemented a conservation plan for the sturgeon that addressed the immediate threat to the species—its depressed population numbers. This plan was funded through an appropriation through Congress and endorsed by the USFWS, the U.S. Army Corps of Engineers, and private groups including the Alabama-Tombigbee Rivers Coalition and the Mobile River Basin Aquatic Ecosystem Coalition. The immediate focus of the plan was to prevent extinction through a captive breeding program and eventual release of propagated fish. Longer range objectives of the plan included determining life history information essential to effectively manage and restore habitat for the species.

Recovery of the Alabama Sturgeon is problematic in that it appears to exist only in very low numbers. Since its listing as endangered in 2000, and notwithstanding many hours of sampling in the intervening years, only one Alabama Sturgeon has been officially captured (in 2007), and one individual has been sighted from a sampling boat (in 2009). The captive propagation program of ADCNR is still active should any Alabama Sturgeon be captured in future sampling efforts or investigations. A significant recovery activity was recently initiated with the U.S. Army Corps of Engineers and The Alabama Chapter of The Nature Conservancy, which launched a joint feasibility study in 2021 to evaluate federal interest in establishing fish passage at Claiborne and Millers Ferry locks and dams through restoring connectivity in the Alabama and Cahaba Rivers. The disruption of native aquatic fauna and their migration patterns by these locks and dams has resulted in a decline in populations of native aquatic species including a wide array of fishes, mussels, snails, crayfishes, and turtles. A successful fish bypass project would assist in Alabama Sturgeon restoration by reconnecting over 230 miles of the Alabama and Cahaba Rivers with the Mobile-Tensaw River Delta and eventually with the Gulf of America (U.S. Army Corps of Engineers, 2023). A natural bypass channel at both dams was selected as the most viable alternative economically and one that would provide the most ecological “lift” to the aquatic system. It is projected that thirteen federally listed aquatic species would benefit from the natural bypass alternative.

APPENDIX C —
ALABAMA RIVERS AND STREAMS NETWORK (ARSN)
LIST OF PARTNERS, 2006-2025

Federal Agency
Natural Resources Conservation Service
Tennessee Valley Authority
U.S. Army Corps of Engineers
U.S. Department of Transportation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey

State Agency
Alabama Department of Conservation and Natural Resources
Alabama Department of Environmental Management
Alabama Department of Workforce-Abandoned Mine Land Program
Alabama Forestry Commission
Choctawhatchee, Pea and Yellow Rivers Watershed Management Authority
Geological Survey of Alabama
Georgia Department of Natural Resources

Local Government
Blount County Commission
City of Elba, Alabama
City of Gadsden, Alabama
City of Livingston, Alabama
City of Red Bay, Alabama
City of Springville, Alabama
City of Tuscaloosa, Alabama
Fayette County Commission
Jefferson County Greenways
St. Clair County Commission

Business-Forestry
Alabama Forestry Association
Alabama Forestry Foundation
Manulife (formerly Hancock Timber)
Resource Management Service, LLC
The Westervelt Company
Weyerhaeuser

Business-Utility
Alabama Power Co.
PowerSouth Energy Cooperative

Business-Consulting
Trutta Environmental Solutions
Volkert

Business-Manufacturing
Toyota-Mazda
Vulcan Materials

Conservation
Alabama Natural Heritage Program
Alabama Water Watch
Alabama Wildlife Federation
Big Canoe Creek Nature Preserve
Cawaco RC&D
Conservation Fisheries, Inc.
Freshwater Land Trust
National Fish and Wildlife Foundation
Southeast Aquatic Resource Partnership
Tennessee Aquarium Conservation Institute
Tennessee River Basin Network
The Atlantic Coastal Conservancy
The Nature Conservancy
Turkey Creek Preserve
Wildlife Mississippi

Academic
Alabama A&M University
Alabama Cooperative Extension Service
Alabama Museum of Natural History
Alabama Water Institute
Auburn Cooperative Extension Service
Auburn University
Florida Museum of Natural History
Jacksonville State University
Mississippi Museum of Natural History
Samford University
The Auburn Water Center
Troy University
Tuskegee University
University of Alabama
University of Alabama-Huntsville
University of North Alabama
University of West Alabama

Environmental
Black Warrior Riverkeeper
Cahaba River Society
Cahaba Riverkeeper
Coosa Riverkeeper
World Wildlife Fund

APPENDIX D —
ENDANGERED SPECIES ACT PETITION, LISTING, AND SECTION 7 CONSULTATION PROCESSES

by

Patrick E. O'Neil and Jeffrey R. Powell

PETITION PROCESS

Petitions are formal requests from the public to list a species as endangered or threatened under the Endangered Species Act of 1973 (ESA). The ESA requires that the U.S. Fish and Wildlife Service (USFWS) make and publish specific findings on the petition within 90 days of receiving a petition (to the extent practicable) as to whether or not there is "substantial information" indicating that the petitioned listing *may be* warranted. Aquatic species listed under the ESA and occurring in Alabama and streams flowing into Alabama can be found in appendix A of this report.

If the preliminary finding indicates that a species listing is warranted, a status review is conducted. Within one year of receipt of the petition (12-month finding), the USFWS must make a further finding that the listing either is or *is not* warranted. A positive 12-month finding can be incorporated into a proposed listing; however, if a prompt proposal is precluded by higher priority listing activities, the USFWS may defer the proposal. The species then becomes a candidate for listing and is added to the candidates list. These "warranted but precluded" proposals require subsequent one-year findings on each succeeding anniversary of the petition until either a proposal is undertaken or a "not warranted" finding is made. For further information about the petition process and how petitions are evaluated, refer to "Public Advisory: Information to Consider When Submitting a Petition under the Endangered Species Act" on the USFWS website at https://www.fws.gov/sites/default/files/documents/ESA-Public-Petition-Guidance.pdf.

SPECIES RECENTLY PRECLUDED FROM LISTING

When the USFWS is petitioned to list a species, a process is triggered to determine if the species is warranted for listing. Rarely is there enough information about the geographic range and perceived threats to the species for the listing process to move forward. Therefore, the petition can provide a means for conducting field surveys to delineate the range of a species, identify new populations, evaluate potential threats, and investigate critical life history needs and genomic/taxonomic relationships with other species. From 2013 to 2023, 23 aquatic species have been determined to be ineligible for listing due to information that was discovered during this assessment period.

2015
Warrior Darter
Ample Elimia
Caper Elimia
Cobble Elimia
Compact Elimia
Mud Elimia
Shortspire Hornsnail

2016
Bluestripe Shiner
Broadstripe Shiner

2017
One-Toed Amphiuma
Warrior Pigtoe
Sucarnoochee River Crayfish

2018
Conasauga Blue Burrower
Coosawattee Crayfish
Etowah Crayfish
Brother Spike
Inflated Spike
Cylinder Elimia
Prune Elimia
Walnut Elimia
Setose Cream and Brown Mottled Microcaddisfly
Alabama Cave Crayfish
Skirted Hornsnail

SPECIES RECENTLY DOWNLISTED AND DELISTED

If the threats to the species have been removed and the goals of the recovery plan have been satisfied, then a species may be considered for downlisting or delisting. Due in part to the proactive nature of ARSN and the implementation of ongoing recovery efforts and collaborative partnering opportunities of the ARSN, six species have been removed completely from the ESA

(delisted) and one has improved enough to be downlisted. The following summarizes recent rulings in Alabama.

Species	Status	Decision Year
Snail Darter	delisted	2023
Southern Acornshell	delisted	2023
Green-blossom Pearly Mussel	delisted	2023
Flat Pigtoe	delisted	2023
Stirrupshell	delisted	2023
Upland Combshell	delisted	2023
Tulotoma	downlisted	2011

SECTION 7 CONSULTATIONS

The purpose of the ESA is to provide a means to conserve the ecosystems upon which endangered and threatened species depend and to provide a program for the conservation of such species. The ESA directs all federal agencies to participate in conserving these species through Sections 7(a)1 and 7(a)2. Section 7(a)(1) of the ESA charges federal agencies (including the USFWS when implementing its authorities outside of the ESA) to carry out programs within their authorities to advance the recovery of endangered and threatened species. This obligation is species specific and is triggered when a species is listed under the ESA. Agencies have considerable discretion about what measures to take to meet the conservation obligation, but the duty to comply with Section 7(a)(1) is nondiscretionary. Section 7(a)(1) programs that move species toward recovery may assist other Federal agencies with their obligations under Section 7(a)(2), which ensures their action(s) do not jeopardize the continued existence of listed species. Robust Section 7(a)(1) programs, therefore, have the potential to streamline or, in highly successful cases, eliminate the need for consultation under Section 7(a)(2). For all of these reasons, Section 7(a)(1)'s proactive approach to species and habitat conservation holds a great deal of unrealized potential to achieve the ESA's goals of species protection and recovery.

Section 7(a)(2) requires Federal agencies to ensure their activities are not likely to jeopardize the continued existence of federally listed species or destroy or adversely modify designated critical habitat (USFWS, 2023b). It requires Federal agencies to consult with the USFWS to ensure that actions they fund, authorize, permit, or otherwise carry out will not jeopardize the continued existence of any listed species or adversely modify designated critical habitats. Critical habitats are the designated areas within the geographic area that contain the physical and biological features that are essential to the conservation of endangered and threatened species and that may need special management or protection. Critical habitat designations affect only Federal agency actions, federally funded actions, or permitted activities that require a federal permit. Federal agencies must consult with the USFWS, or the action agency issuing the Federal permit, when a project or action they authorize, fund, or carry out may affect a listed species or designated critical habitat. The consultation process can vary depending on the complexity of the project or action. The USFWS works with federal agencies to develop the documentation needed to initiate and complete consultation.

CONSULTATION PROCESS

Step 1 - Informal Consultation

The consultation process usually begins as informal consultation between a federal action agency and the USFWS. The action agency must initiate consultation when any action

they authorize, fund, or carry out (such as through a permit) may affect a listed endangered or threatened species or designated critical habitat.

Step 2 - Review

In the early stages of project planning, the action agency or associated entities can request technical assistance from the appropriate USFWS field office. Discussions between the two agencies may include what types of listed species and habitat may be present in the proposed action area and what effect the proposed action may have on those species and habitat. Agencies may use the USFWS digital project planning tool, Information for Planning and Consultation, to get a list of species and critical habitats that may be present in the action area.

Step 3 - Determination

If the action agency determines, through a biological assessment or other review, that any minimization measures provided are not enough to avoid “take,” then the appropriate decision would be a “may affect, likely to adversely affect” for the listed species or critical habitat, at which point, the action agency would submit to the USFWS a request for formal consultation. “Take” is defined as to harm, harass, pursue, hunt, shoot, wound, trap, kill, capture, collect, or to attempt to engage in any such conduct.

Step 4 - Formal Consultation

During the formal consultation process, the USFWS and the action agency share information about the proposed project and the species or critical habitat likely to be affected, as well as any volunteer minimization measures being presented. Formal consultation may last up to 90 days, after which the USFWS will prepare a biological opinion within an additional 45 days. Therefore, the maximum length of time to complete a formal consultation is 135 days. The intent of a biological opinion is to analyze if the proposed action is likely to jeopardize the continued existence of the species or destroy or adversely modify designated critical habitat, analyze the effects of the proposed action to the listed species or designated critical habitat, and minimize “take” to listed species.

Step 5 - Conclusion of Biological Opinion

The conclusion of the biological opinion will state whether the federal agency has ensured that its action is not likely to jeopardize the continued existence of a listed species and/or result in the destruction or adverse modification of critical habitat. A biological opinion includes reasonable and prudent measures, as needed, to minimize any "take" of listed species and usually includes conservation recommendations to further the recovery of listed species. The USFWS has 45 days after completion of formal consultation to write the biological opinion.

SPECIES STATUS ASSESSMENTS

Ideally, the Species Status Assessment (SSA) is conducted during or prior to the candidate species assessment or 12-month finding stage but can be initiated at any time. The SSA is designed to “follow the species” in the sense that the information on the biological status is available for conservation use immediately and can be updated with new information. Thus, the SSA provides a single source for species’ biological information needed for all ESA decisions (e.g., listing, consultations, grant allocations, permitting, habitat conservation plans, and recovery planning). The biological analysis and the resulting stand-alone science-focused assessment allow for State and partner engagement in the science used as a basis for ESA decisions. Early identification of what most influences the species’ condition affords timely opportunities to work with partners to implement conservation efforts in advance of potential ESA decisions.

An SSA begins with a compilation of the best available information on the species (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and/or species levels based on how environmental factors are understood to act on the species and its habitat.

Next, an SSA describes the current condition of the species' habitat and demographics and the probable explanations for past and ongoing changes in abundance and distribution within the species' ecological settings (i.e., areas representative of geographic, genetic, or life history variation across the range of the species). Lastly, an SSA forecasts the species' response to probable future scenarios of environmental conditions and conservation efforts. Overall, an SSA uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3Rs" as defined in the USFWS SSA Framework of 2016) as a lens to evaluate the current and future condition of the species. As a result, the SSA characterizes a species' ability to sustain populations in the wild over time based on the best scientific understanding of current and future abundance and distribution within the species' ecological settings (USFWS, 2016b).

APPENDIX E —
ALABAMA RIVERS AND STREAMS NETWORK
STREAM-ROAD CROSSING ASSESSMENT FIELD FORM AND
ALABAMA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
PHYSICAL HABITAT CHARACTERIZATION AND HABITAT ASSESSMENT FORM

BASELINE INFORMATION			
SHU Name:		**SHU #:**	**Visible Threats (check all that apply)**
Crossing ID: (FIPS# - Crossing #) ___ ___ ___ ___ ___ - ___ ___ ___ ___			Livestock Access □
Date:	**Time** (24hr): Start	End	Eroding Banks □
Road Name:		New Crossing? □	Fish Barriers □
Stream Name:			Road Material in Stream □
Surveyor(s):			ATV Access □
State:	**County:**		No Riparian Cover □
Latitude (DD):	**Flow Condition**		No Visible Threats □
Longitude (DD):	No Flow High Moderate Normal Low No Data		Others:
Road Type: Public Private	**Surface Type:** Paved Unpaved		
Full Survey Performed? Yes No **If No, why not?**			**Restoration Project Possibility (circle one):**
Comments:			Yes No Maybe

STREAM CROSSING ASSESSMENT

Waterway	5	3	1	Score
1. Upstream Channel Morphology	Least Impacted	Moderately Impacted	Most Impacted	
2. Downstream Channel Morphology	Least Impacted	Moderately Impacted	Most Impacted	
3. Downstream Channel/Bank Alteration	Natural	Minor or Partial	High	

Crossing Structure	**Crossing Type**: Culvert Bridge Ford	**Number of Culverts:**	**TOTAL:**

Culvert Type (circle all that apply): Round Culvert/Pipe Pipe Arch/Elliptical Culvert Arch Culvert Open Bottom Arch Culvert Box Culvert Open Bottom Box Winged Other:

Structure Materials (circle all that apply): Corrugated Metal PVC Synthetic Reinforced Concrete Wood Other Metal Native Soil Clay Rock Other:

Bankfull Width(ft):	**Bat Signs Present:** □	**Undermining:** Upstream □ Downstream □

Water Velocity Matches Stream: Yes No-Faster No-Slower Dry Dry-Stream also dry Unknown

Water Depth Matches Stream: Yes No-Shallower No-Deeper Unknown

Structure Substrate Coverage: None 25% 50% 75% 100% Unknown

Dimensions ***Note: Measure to the nearest tenth of a foot.*** **Constriction:** No/None Minor Moderate Severe

Inlet Drop to Stream Bottom:	**Outlet Drop to Water Surface:**	**Outlet Drop to Stream Bottom:**

Outlet Grade (pick one): At Stream Grade Free Fall Cascade Free Fall onto Cascade Clogged/Collapsed/Submerged Unknown

Length (primary)(ft): **Height (primary)(ft):** **Width (primary)(ft):** ***Note: If more than one culvert, measure all widths.***

Width 2: **Width 3:** **Width 4:** **Width 5:** **Width 6:** **Width 7:** **Width 8:** **Width 9:** **Width 10:** **Sum:**

Crossing Structure Conditions	5	3	1	Score
4. Upstream Culvert Skew Angle (worst):	< 5º	5º to 30º	> 30º	
5. Crossing Fill Condition (dominant)	Good / Vegetated	Fair / Riprap	Poor / Bare soil	
6. Crossing Inlet/Outlet Condition:	No Impairment	Sediment Islands and/or Scouring	Blocked	

Comments:	**TOTAL:**

ROAD APPROACHES I	***Note: Right = right road approach when facing downstream.***

Dimensions (right): Length (mi): Width (ft): Road Prism Fill (in): Slope (%):

Potential Eroded Volume (right): Length x Width x Road Prism Fill x 16.3 = c.y.

Dimensions (left): Length (mi): Width (ft): Road Prism Fill (in): Slope (%):

Potential Eroded Volume (left): Length x Width x Road Prism Fill x 16.3 = c.y.

Right (%)	1._____	4._____	**Left (%)**	1._____	4._____
Avg.	2._____	5._____	**Avg.**	2._____	5._____
_____	3._____	6._____	_____	3._____	6._____

Surface Conditions	5	3	1	Score
7. Potential eroded volume (mean)	< 18 c. y.	18-35 c.y.	> 35 c.y.	
8. Surface Erosivity	Low	Medium	High	
9. Road approach slope (mean %)	< 1.7 %	1.7 to 3.5 %	> 3.5%	
10. Surface Erodibility Factor	Low	Medium	High	

Comments: **TOTAL:**

Photos

Extra Pictures Description:

Photo Order Taken		
	1	Upstream Channel from Crossing
	2	Downstream Channel from Crossing
	3	Right Road Approach from Crossing
	4	Left Road Approach from Crossing
	5	Crossing Structure from Upstream
	6	Crossing Structure from Downstream
	7	Extra Picture #1
	8	Extra Picture #2

ROAD APPROACHES II ***Note: Right = right road approach when facing downstream.***

DOWNSTREAM

Left Outlet (pick one):	Vegetated	Riprap/Fibrous mat.	Bedrock	+1	**Right Outlet (pick one):**	Vegetated	Riprap/Fibrous mat.	Bedrock	+1
	Bare soil	Concrete	Walled	+0		Bare soil	Concrete	Walled	+0
Left Ditch (pick one):	Vegetated	Riprap/Fibrous mat.	Stream	+1	**Right Ditch (pick one):**	Vegetated	Riprap/Fibrous mat.	Stream	+1
	Bare soil	Concrete	Damaged/Synthetic	+0		Bare soil	Concrete	Damaged/Synthetic	+0

UPSTREAM

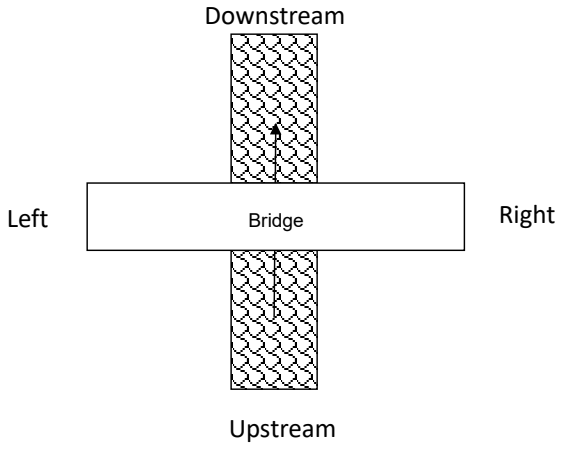
Left Outlet (pick one):	Vegetated	Riprap/Fibrous mat.	Bedrock	+1	**Right Outlet (pick one):**	Vegetated	Riprap/Fibrous mat.	Bedrock	+1
	Bare soil	Concrete	Walled	+0		Bare soil	Concrete	Walled	+0
Left Ditch (pick one):	Vegetated	Riprap/Fibrous mat.	Stream	+1	**Right Ditch (pick one):**	Vegetated	Riprap/Fibrous mat.	Stream	+1
	Bare soil	Concrete	Damaged/Synthetic	+0		Bare soil	Concrete	Damaged/Synthetic	+0

OUTLET SUM:		**DITCH SUM:**	
If SUM = 4,2, or 0, then add	+1	If SUM = 4,2, or 0, then add	+1
If SUM = 1, then add	+2	If SUM = 1, then add	+2
If SUM = 3, then add	+0	If SUM = 3, then add	+0
11. Outlet TOTAL		**12. Ditch TOTAL**	

Sediment Risk Index (SRI) **TOTAL SRI SCORE:**

SRI Score Range:	**46 - 60**	**37 - 45**	**12 - 36**
SCA Narrative Risk Rank:	**Low risk**	**Moderate risk**	**High risk**

NOTES



Use English Units Only

Signature

ADEM SCORING RULES FOR RIFFLE/RUN AND
GLIDE/POOL HABITAT SURVEY FORMS

(ADEM 2021a, 2021b, 2024)

This survey is suitable for most wadeable streams in ecoregions 45, 65j, 67, 68, and 71.

Use these field sheets if riffles are not present due to disturbances (sedimentation, sludge deposits or channel alterations), but the slope is moderate to high and in moderate to high gradient streams that naturally do not have riffles (steep mountain streams or moderate gradient bedrock streams). The only time a low gradient field sheet should be used in these ecoregions is if the stream is in a low gradient area (sometimes occurs near the mouth of large streams).

Riffle/Run Habitat Survey Rules

1. Instream Cover

This metric estimates the quantity and types of natural structures available to bugs and fish. Natural habitats include cobble or gravel riffles, bedrock crevices, submerged trees/large woody debris, decaying leaf litter, undercut banks, root mats, macrophytes, large rocks, etc. Variable and abundant habitat increases the potential for recovery from disturbance. To assign a condition category, look at how much of the stream reach is covered by natural, stable, productive habitat. The numeric score within the condition category is assigned based on the variety and quality of habitat. Variations in habitat that provide niches for different faunal types are considered different habitat types (e.g., rootmats in flowing water and pools). Bedrock with natural aquatic plants is included as stable habitat by estimating percent bedrock, and then estimating percent covered by vegetation. Filamentous and other nuisance algae should not be included in this estimate. Habitat that is not of sufficient quantity to support faunal populations (<5%), is not colonized (newly fallen leaves), is not productive (seamless bedrock), or is likely to wash out should not be included. Artificial structures, such as riprap, tires, etc., are also not included, since the goal is to evaluate natural habitat.

Optimal—>50% of reach has natural, stable habitat for colonization by bugs and/or fish. Four or more habitats present. Stream exhibits a well-developed riffle-run complex. Deadfall, leaf litter, snags, etc. show evidence of decay. If <4 habitats present, drop to Sub-optimal.

20 – 7 habitats present and/or stable substrate dominated by cobble and small boulders.
19 – 6 or more habitats present and stable substrate dominated by cobble and/or boulders.
18 – 5 habitats present and stable substrate dominated by boulders or cobble.
17 – 4 habitats common and cobble riffle or runs are available, but not plentiful.
16 – 4 habitats common and cobble riffle and runs are absent.

Sub-optimal—Natural, stable habitat covers 30-50% of reach. Three or more productive habitats present. If near 50% and more than 3 habitats available, score as Optimal.

15 – 7 habitats present and/or stable substrate dominated by cobble and small boulders.
14 – 6 or more habitats present and stable substrate dominated by cobble and/or boulders.
13 – 5 habitats present and stable substrate dominated by boulders or cobble.
12 – 4 habitats common and cobble riffle or runs are available.
11 – 4 habitats common and cobble riffle and runs are absent.

Marginal—Natural, stable habitat covers 10-30% of reach. If coverage nears 30% and 3 or more habitats present, score as Sub-optimal.

10 – 6 habitats present and/or stable substrate dominated by cobble and small boulders.

9 – 5 or more habitats present and stable substrate dominated by cobble and/or boulders.

8 – 4 habitats present and stable substrate dominated by boulders or cobble.

7 – 3 habitats common and cobble riffle or runs are available, but not plentiful.

6 – 3 habitats common and cobble riffle and runs are absent.

Poor—<10% mix of boulder, cobble, or other natural, stable habitat, regardless of the number of habitats present; lack of habitat obvious.

5 – 2 habitat types present, additional habitat types rare; substrate dominated by gravel and sand, short runs, and some riffle.

4 – Only 2 habitats present; OR, substrate dominated by gravel and sand, with some riffle.

3 – 1 habitat type common, additional types rare; substrate dominated by gravel and sand, with long runs, no riffles.

2 – 1 habitat type, substrate dominated by gravel and sand or bedrock with short runs, no riffles.

1 – 1 habitat type present, but rare; substrate dominated by rock and sand, no runs or riffles.

0 – No natural, stable, productive habitats within the reach; substrate dominated by sand with no riffles or runs.

2. Riffle Substrate Characterization

This metric evaluates the type, complexity, and condition of riffle substrates. To assign a condition category, first look at the quantity of riffle habitat available and the quality of riffle-run sequences in the reach. When sampling macroinvertebrates with a riffle kick, take note of the type and layers of substrate available for colonization. The numeric score (rank) within the condition category is assigned, based on the quality and availability of stable substrate for colonization by organisms in the stream.

Optimal—>75% of riffle habitat with flow, substrate, and water depth optimal for reaeration. Well-developed riffle-run sequences. Multiple layers of stable substrate for colonization. Mixture of riffle substrate, with an abundance of cobble. Natural aquatic plants (e.g., Podostemum, moss) would be considered a layer for colonization.

20 – Cobble substrate dominant in riffle. Multiple layers for colonization.

19 – Small boulder and cobble dominant in riffle. Multiple layers for colonization.

18 – Boulders dominant in riffle. Multiple layers for colonization.

17 – Cobble and gravel dominant in riffle. Multiple layers for colonization.

16 – Mix of boulder, cobble, and gravel in riffles. Multiple layers for colonization.

Sub-optimal—50-75% of riffle habitat with flow, substrate and water depth optimal for reaeration. Riffle-run sequences adequate to provide productive habitat. Abundance of cobble, but mix of boulders and gravel common. Multiple layers of stable substrate not available for colonization.

15 – Cobble dominant in riffle. Multiple layers for colonization not available.

14 – Small boulder and cobble dominant in riffle. Multiple layers for colonization not available.

13 – Boulder, cobble and gravel substrates in riffles. Multiple layers not available for colonization.

12 – Cobble and gravel substrates dominant in riffles. Multiple layers not available for colonization.

11 – Other productive substrate dominant (e.g., *Podostemum*, moss). Multiple layers not available for colonization.

Marginal—25-50% of riffle habitat with flow, substrate, and water depth optimal for reaeration. Riffle-run sequences present in reach, but run area may be lacking and/or pools have replaced run areas. Multiple layers of cobble or small boulder not available as niche space for colonization. Habitat limited to gravel or large boulders or bedrock surface substrates. Some cobble present.

10 – Large gravel substrate dominant in riffles. Cobble AND aquatic plants present.
9 – Gravel substrate is dominant in riffles. Cobble OR aquatic plants present.
8 – Large boulder substrate is dominant in riffle. Cobble AND aquatic plants present.
7 – Bedrock substrate is dominant in riffle. Cobble AND aquatic plants present.
6 – Bedrock substrate is dominant in riffle. Cobble OR aquatic plants present.

Poor—< 25% of riffle habitat with flow, substrate and water depth optimal for reaeration. Natural riffle or runs absent, or almost nonexistent. Large boulders or bedrock may be dominant. Cobble minimal or absent. Scouring may be present.

5 – Large boulder is dominant in riffle. Cobble present.
4 – Large boulder is dominant in riffle. Cobble absent or very rare.
3 – Fissured bedrock is dominant substrate in riffles. Cobble OR aquatic plants present, but rare.
2 – Fissured bedrock is dominant substrate in riffles. Cobble AND aquatic plants absent.
1 – Unfissured bedrock OR other unproductive substrate is dominant. Cobble OR aquatic plants may be present, but rare.
0 – Natural riffles absent.

3. Embeddedness

This metric appraises the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into silt, sand, or mud. As rocks become embedded, niches available to bugs and fish is decreased. Embeddedness is a result of large-scale sediment movement and deposition. Evaluate embeddedness in the upstream portion riffle and cobble substrate areas of high gradient streams. If riffles are absent due to sedimentation, score a “0”. When sampling macroinvertebrates with a riffle kick, take note of the type and layers of substrate available, fine sediment trapped around the rocky substrate, and the degree to which a sediment plume is created through disturbance. In moderate to high-gradient streams that naturally do not have cobble riffles, the parameter would score lower due to lack of niche space, even if embeddedness is not high. To select the condition category, estimate how much of rocks is surrounded by fine sediment. Select the score by examining the amount of niche space provided by layered cobble (ideal). Sediment-free space between and under rocks provides habitat for bugs and small fish. If the stream type is not cobble-riffle, other examples of riffle or run niches affected by embeddedness include the bottom area of round boulders where it curves into the substrate or the spaces between gravel in a bedrock fissure. In moderate gradient bedrock streams without gravel (bedrock shelves), examine loose rocks or slabs in areas of fast flow. These are less productive and should be scored lower in the selected category.

Optimal—Gravel, cobble, and boulders are 0-25% surrounded by fine sediment. If embeddedness is close to 25%, use quality of niche space to differentiate between optimal and suboptimal condition categories. Optimal would be layered cobble. To determine rank within category, consider available niche space.

20 – Niche spaces are free of sediment. Multiple layers of cobble provide niche space for colonization.

19 – Niche spaces are free of sediment, but natural substrate does not provide multiple layers or isn't cobble.

18 – Minimal sediment (≤10%), niches are not compromised. Multiple layers of cobble for colonization.

17 – Minimal sediment (≤10%), niches are not compromised. Multiple layers of cobble absent.

16 – Sediment more pronounced, affecting up to 25% of niche space. Multiple layers of cobble available for colonization.

Sub-optimal—Gravel, cobble, and boulders are 25-50% surrounded by fine sediment. If embeddedness is close to 25%, use quality of niche space to differentiate between Optimal and Sub-optimal categories. Optimal would be layered cobble. As number approaches 50%, use quality of niche space to differentiate between Sub-optimal and Marginal. Sub-optimal would be layered cobble.

15 – Approximately 25% of niche space is affected. Substrate is not layered cobble.

14 – Approximately 30-35% of niche space affected. Substrate is layered cobble.

13 – Approximately 40-45% of niche space affected. Substrate is layered cobble.

12 – Approximately 30-45% of niche space affected. Substrate is not layered cobble

11 – Approximately 50% niche space is affected. Substrate is layered cobble.

Marginal—Gravel, cobble, and boulders are 50-75% surrounded by fine sediment. As amount approaches 50%, use quality of niche space to differentiate between Sub-optimal and Marginal categories. Sub-optimal would be layered cobble.

10 – Approximately 50% of niche space affected. Substrate is not layered cobble.

9 – Approximately 55-65% of niche space affected. Substrate is layered cobble.

8 – Approximately 55-65% of niche space affected. Substrate is not layered cobble.

7 – Approximately 70-75% of niche space affected. Substrate is layered cobble.

6 – Approximately 70-75% of niche space affected. Substrate is not layered cobble.

Poor—Gravel, cobble, and boulders are more than 75% surrounded by fine sediment.

5 – Approximately 80-85% of niche space affected. Substrate is layered cobble.

4 – Approximately 80-85% of niche space affected. Substrate is not layered cobble.

3 – Approximately 90-95% of niche space affected. Substrate is layered cobble

2 – Approximately 90-95% of niche space affected. Substrate is not layered cobble.

1 – Niche space is completely filled in by sediment. Substrate is layered cobble.

0 – Niche space is completely filled in by sediment. Substrate is NOT layered cobble.

4. Velocity-Depth Regimes

This metric assesses patterns of velocity and depth that are included for high-gradient streams as an important feature of habitat diversity. The best streams in most high-gradient regions will have all four patterns present: slow-deep, slow-shallow, fast-deep, and fast-shallow. Differentiation between regimes will vary depending on stream size. The general guidelines for wadeable streams (~1 meter deep) are > 0.5 meters (est. knee-deep) is deep, and 0.3 meters/second or more is fast. The occurrence of these four patterns relates to the stream's ability to provide and maintain a stable aquatic environment. Condition category is based on how many of the four regimes are present. Ranking is based on which ones are prevalent.

Optimal—All four velocity/depth regimes are present.

20 – All four velocity/depth regimes are equally available.
19 – Fast-shallow is the dominant regime.
18 – Slow-shallow is the dominant regime.
17 – Fast-deep is the dominant regime.
16 – Slow-deep is the dominant regime.

Sub-optimal—Only 3 of the 4 velocity/depth regimes are present. If fast-shallow is missing, score lower.

15 – Slow-deep is the only missing regime.
14 – Fast-shallow is dominant.
13 – Slow-shallow is dominant.
12 – Fast-deep is dominant.
11 – Slow-deep is dominant.

Marginal—Only 2 of the 4 regimes are present. Both regimes are adequate to support aquatic population adapted to that habitat. If fast-shallow or slow-shallow are missing, score lower.

10 – Fast-shallow and slow-shallow are present.
9 – Fast-shallow and fast-deep are present.
8 – Fast-shallow and slow-deep are present.
7 – Slow-shallow and fast-deep are present.
6 – Fast-deep and slow-deep are present.

Poor—One of the 4 regimes dominates the reach (if another is present, it is too small or infrequent to sustain an aquatic population adapted to that habitat).

5 – Fast-shallow is dominant. A second regime may be present but is too infrequent to sustain a population.
4 – Slow-shallow is dominant. A second regime may be present but is too infrequent to sustain a population.
3 – Fast-deep is dominant. A second regime may be present but is too infrequent to sustain a population.
2 – Slow-deep is dominant. A second regime may be present but is too infrequent to sustain a population.
1 – Slow-deep is the only regime present.
0 – None of the velocity depth regimes is present (no water, or separated pools).

5. Man-made Channel Alteration

This metric concerns measurable, large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been widened, straightened, deepened, and/or diverted into concrete channels for flood control or irrigation. Such streams have fewer habitats than naturally meandering streams. Channel alteration may include artificial embankments, riprap, or other forms of artificial bank stabilization structures; reaches with very straight pattern for significant distances; dams and bridges. Consider man-made structures present upstream or downstream of the reach if they affect flow patterns. Scouring is often associated with channel alteration. Beaver activity is natural condition and is not accounted for in this parameter. It should be noted on the field form, however.

Optimal—Stream follows a normal, meandering pattern; alteration other than restoration is absent or minimal; shoring structures absent; no artificial structures present; structures upstream or downstream not affecting reach.

20 – No evidence of channelization, no artificial structures in reach or its impact area. No evidence of past or present gravel dredging or rock removal or off-road vehicle activity. Stream has normal meander pattern.

19 – No evidence of channelization, no artificial structures in reach or its impact area. Minimal evidence of past rock removal. No evidence of gravel/sand dredging or off-road vehicle activity. Meander pattern and habitat unaffected.

18 – No evidence of channelization; no artificial structures in reach. Evidence of past gravel/sand dredging is minimal. No evidence of off-road vehicle activity. Stream flow pattern and habitat not affected.

17 – Evidence of past channel alteration is <5% of reach. Stream flow pattern not affected. Modification is stable, well-vegetated with natural vegetation, low erosion potential. No artificial structures in reach or its impact area. No evidence of off-road vehicle activity.

16 – Evidence of past off-road vehicle activity. Riffle and run areas intact, contours not affected. Artificial structures may be present outside reach, but not affecting flow patterns, habitat, or contours in reach.

Sub-optimal—<40% of reach channelized and disrupted; channel stabilized; altered flow not affecting biology; artificial structures in or outside of reach not affecting flow.

15 – Historic channelization stabilized (may also include pre-Civil War rock walls). Modification is stable, well-vegetated with natural vegetation, and no erosion potential.

14 – Bridge, culverts, shoring, or artificial structures may be present but do not affect natural flow patterns. (Includes structures upstream or downstream, as well as within reach.)

13 – Recent off-road vehicle activity in stream. Riffle or run areas slightly disturbed. Natural stabilization and re-colonization expected.

12 – Evidence of recent rock removal or gravel/sand dredging has had slight impact on reach. Natural stabilization and re-colonization is expected.

11 – New channelization in up to 40% of stream reach. Modification is stable, well-vegetated with natural vegetation, no erosion potential. (If not stable, score 10.)

Marginal—40-80% of reach channelized and disrupted; some channelization may not have stabilized; artificial structures within or outside reach may slightly affect flow.

10 – Less than 40% of reach altered, but has not stabilized.

9 – 40-80% of reach has been channelized, but is stable with natural vegetation.

8 – Bridge, culverts, shoring, or artificial structures have slight effect on natural flow patterns in reach. (Includes structures upstream or downstream, as well as within reach.)

7 – 40-80% of reach affected by dredging, rock removal, off-road vehicle activity, or other instream activity.

6 – 40-80% of reach has been altered and has not stabilized.

Poor—>80% of reach channelized or disrupted; instream habitat greatly altered or removed entirely OR artificial structures within reach or upstream or downstream structures have greatly affected flow.

5 – Over 80% of the stream reach has been channelized but is stable with natural vegetation.

4 – Over 80% of the stream reach is channelized and has been stabilized with artificial shoring (riprap, cement, etc.).

3 – Over 80% of the stream reach is channelized and has not stabilized.

2 – Impoundment, bridge, or other artificial structure has high level of impact on normal flow and/or channel pattern. Include upstream or downstream structures that have seriously affected the reach.

1 – At least part of stream bottom substrate is in concrete or other artificial channel (including culverts).

0 – 100% of stream bottom substrate is in concrete or other artificial channel (including culverts).

6. Sediment Deposition

This metric estimates the relative amount of sediment that has accumulated and the changes that have occurred to the stream bottom as a result of the deposition of gravel, sand, and silt. Deposition occurs from large-scale movement of sediment caused by erosion. Sediment deposition may cause the formation of islands, point bars, or shoals. It may also result in the filling of pools. Usually deposition is evident in areas that are obstructed by natural or man-made debris and in areas where stream flow decreases, such as bends. High levels of sediment deposition create an unstable and continually changing environment that becomes unsuitable for many organisms. Select condition category by estimating the percent of stream bottom that is affected by sediment deposition. Only areas of new, unvegetated deposition on point bars and islands should be considered when scoring. Rank within each category is determined by the areas most affected by sediment deposition. Sediment in pools or slow areas will score higher than sediment on point bars and islands.

Optimal—Sediment deposition affects less than 5% of stream bottom in quiet areas. New deposition on islands and point bars is absent or minimal.

20 – No islands or point bars. No sediment in pools or slow areas.

19 – No new deposition on stable islands or point bars. No sediment in pools or slow areas.

18 – No new deposition on islands or point bars. Small amount of sediment in pools or slow areas.

17 – Slight amount of new deposition on islands or point bars. No sediment in pools or slow areas.

16 – Slight amount of new deposition on islands or point bars. Small amount of sediment in pools or slow areas. Almost 5% of bottom area affected.

Sub-optimal—Sediment deposition affects 5-30% of stream bottom. Slight deposition in pools or slow areas. Some new deposition on islands and point bars.

15 – Sediment deposition affects 5-15% of the bottom substrate. Most of the deposition is in pools or bends, with little new accumulation on islands or point bars.

14 – Sediment deposition affects 5-15% of the bottom substrate. Deposition occurs in both pool areas and as new accumulation on bars and islands.

13 – Sediment deposition affects 20-25% of the bottom substrate. Most of the deposition is in pools or bends, with little new accumulation on islands or point bars.

12 – Sediment deposition affects 20-25% of the bottom substrate. Deposition occurs in both pool areas and as new accumulation on bars and islands.

11 – Sediment deposition affects 30% of the bottom substrate. The majority of deposition is in pools or bends with little new build-up of islands or point bars. Score as Marginal if build-up of islands and point bars approaches 30%.

Marginal—Sediment deposition affects 30-50% of stream bottom. Deposits at obstructions, constrictions, and bends. Moderate deposition of pools.

10 – Sediment deposition affects 30% of stream bottom. Deposits on bars and islands and pools and bends.
9 – Sediment deposition affects 35-45% of stream bottom. Most of deposition is in pools rather than build-up of bars and islands.
8 – Sediment deposition affects 35-45% of stream bottom. Moderate deposition of pools, as well as new deposition on bars and islands.
7 – Sediment deposition affects almost half of the stream bottom. Most of deposition is in pools rather than new deposition on bars and islands.
6 – Sediment deposition affects almost half of the stream bottom. New sediment accumulation on bars and islands, as well as in pools.

Poor—Heavy deposits of fine material. Increased bar development. >50% of the stream bottom changing frequently. Pools almost absent due to substantial sediment deposition.

5 – Approximately 50% sediment deposition.
4 – Approximately 60% sediment deposition.
3 – Approximately 70% sediment deposition.
2 – Approximately 80% sediment deposition.
1 – Approximately 90% sediment deposition; pools absent due to deposition.
0 – 100% sediment deposition; pools absent due to deposition; bottom silt moves with almost any flow above normal.

7. Frequency of Riffles

The riffle/run ratio is a way to measure the sequence of riffles, and thus the heterogeneity, of a stream. These areas provide diversity of habitat, control flow, and refugia for organisms during storm events. Therefore, an increased frequency of occurrence greatly enhances the diversity of the stream community. Any swift-moving re-oxygenation zones count, including bedrock riffles, large boulders, and bends. The ratios are calculated by dividing the distance between the riffles by the stream width. To score this parameter, a longer segment may need to be incorporated into the evaluation if there are not at least 3 re-oxygenation areas within the sample reach. It may be necessary to pace off or measure distances. In larger streams where bends are the only re-oxygenation areas, maps may be used to determine frequency. Frequency will determine the condition category. Quality of habitat provided will determine the rank within the category.

Optimal—Occurrence of re-oxygenation zones relatively frequent. Distance between riffles divided by average width of the stream is 7 or less.

20 – Re-oxygenation areas are high quality cobble riffles.
19 – Re-oxygenation areas are high quality gravel riffles.
18 – Re-oxygenation areas are not high quality cobble/gravel riffles, but provide productive habitat (may include cobble runs or lower quality cobble riffles).
17 – Re-oxygenation areas are primarily bedrock, large boulders, or other relatively unproductive habitat.
16 – Re-oxygenation areas are plunge pools, or at bends with cobble runs.

Sub-optimal—Occurrence of re-oxygenation zones infrequent. Distance between riffles divided by average width of the stream is from 8 to 15.

15 – Re-oxygenation areas are high quality cobble riffles.

14 – Re-oxygenation areas are high quality gravel riffles.

13 – Re-oxygenation areas are not high quality cobble/gravel riffles, but provide productive habitat (may include cobble runs or lower quality cobble riffles).

12 – Re-oxygenation areas are primarily bedrock, large boulders, or other relatively unproductive habitat.

11 – Re-oxygenation areas are at bends with boulder or gravel runs.

Marginal—Occasional re-oxygenation zones. Distance between riffles divided by average width of the stream is 16 to 25.

10 – Re-oxygenation areas are high quality cobble riffles.

9 – Re-oxygenation areas are high quality gravel riffles.

8 – Re-oxygenation areas are not high quality cobble/gravel riffles, but provide productive habitat (may include cobble runs or lower quality cobble riffles).

7 – Re-oxygenation areas are primarily bedrock, large boulders, or other relatively unproductive habitat.

6 – Re-oxygenation areas are bends.

Poor—Generally all flat water or flat bedrock. Little opportunity for re-oxygenation. Distance between riffles divided by average width of the stream is greater than 25.

5 – Re-oxygenation areas are high quality cobble riffles.

4 – Re-oxygenation areas are gravel riffles.

3 – Re-oxygenation areas are not high quality cobble/gravel riffles but provide productive habitat (may include cobble runs or lower quality cobble riffles).

2– Re-oxygenation areas are primarily bedrock, large boulders, or other relatively unproductive habitat.

1 – Re-oxygenation areas are deep bends.

0 – Re-oxygenation areas are shallow bends.

8. Channel Flow Status

This metric approximates the degree to which the channel is filled with water. Category will be selected based on the amount of the streambed covered by water. Rank within category will be determined by how much productive habitat is exposed. If water has been backed up by obstructions (such as beaver dams, log jams, debris plugs), move assessment reach above or below the affected area. If this is not possible, determine whether sampling is appropriate or should be postponed until conditions are more representative of actual stream conditions. Use comment field to explain, if necessary. Assess flow status based on what is submerged during normal flow conditions. For example, naturally exposed gravel beds do not indicate exposed habitat. Use comment field to note if flow is reduced due to natural low flow conditions, drought, irrigation, municipal water withdrawal, impoundment, etc.

Optimal—Water reaches base of both lower banks, and streambed is covered by water throughout the reach. Minimal amount of productive habitat is exposed. Riffle areas are fully submerged.

20 – Water is above the base of each bank. No productive habitats are exposed.

19 – Productive habitats, including tree roots and riffles, are submerged, but some undercut areas may be above water. Riffle areas are fully submerged.

18 – Some tree roots are exposed, but there is plenty of submerged root habitat available. Riffle areas are fully submerged. (If rooted bank habitat is naturally not present, score 16.)

17 – Rooted bank habitat is present, and some tree roots are exposed, but there is plenty of submerged root habitat available. Small areas of riffles may be minimally affected due to shallow water depth, but riffle habitat is not compromised.

16 – Water reaches base of both banks, and water still covers streambed. Root, riffle, or other habitat is compromised due to water depth, but it is still available for colonization.

Sub-optimal—Water covers more than 75% of the streambed but is less than 100%; OR 25% of productive habitat is exposed.

15 – One or more habitats may be absent due to water depth, but riffle areas are not affected. (If productive riffle habitat is naturally not present score 11.)

14 – Water depth in riffles is reduced, but this has not affected size or frequency of riffles.

13 – Some riffle areas have become limited in size but none are totally exposed.

12 – A few smaller riffles have become exposed.

11 – Up to 25% of small riffles have become exposed; OR productive riffle habitat not naturally available.

Marginal—Water covers 25-75% of the available channel, AND/OR stable habitat is mostly exposed.

10 – Water covers 75% of channel. Most small riffles are exposed. (If productive riffle habitat is naturally not present score 11.)

9 – Water covers 60-70% of streambed. All smaller riffles are exposed. Large riffles do not have significant exposed areas.

8 – Water covers about 50% of the streambed. Larger riffles are still present but are reduced in size.

7 – Water covers 30-40% of the streambed. Majority of riffle areas are exposed, although small areas of largest riffles are still submerged.

6 – Water covers about 25% of streambed. Riffle areas are exposed, although other rock habitat is available in run areas.

Poor—Very little water in channel. Most available water is present as standing pools. Little or no productive habitat due to lack of water.

5 – All riffles exposed. Runs reduced. Very limited rock habitat available in running water.

4 – All riffles exposed. Runs extremely reduced. No rock habitat available in running water.

3 – All riffles and runs exposed. Long stretches of pooled water provide some productive habitat.

2 – All riffles and runs exposed. Stream may be flowing below surface between pools.

1 – Stream reduced to isolated pools with no productive habitat.

0 – Channel is dry.

9. Condition of Banks

This metric evaluates whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks and are, therefore, considered unstable. Bedrock/large boulder stream banks are given a high score no matter what the slope. Signs of erosion include crumbling, unvegetated banks, sloughing, exposed tree roots, and exposed soil. Eroded banks indicate a problem with sediment movement

and deposition and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately on a scale of 0 to 10 and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream. Banks primarily stabilized with riprap or other artificial stabilizers should be categorized as “poor.”

Optimal—Banks stable. Evidence of erosion or bank failure absent or minimal. Little potential for future problems. < 5% of the bank affected.

10 – No signs of instability evident. Banks sloping. Little erosion potential.
9 – Some erosion evident; OR steep banks; OR some potential for erosion.

Sub-optimal—Moderately stable. Infrequent, small areas of erosion. 5-30% of bank in reach has areas of erosion.

8 – 5-15% of bank has areas of healed over erosion.
7 – 5-15% of bank has areas of erosion or other signs of instability. Some are not healed over.
6 – 20-30% of bank has areas of erosion or other signs of instability. If approaching 30%, score lower if banks are steep.

Marginal—Moderately unstable. 30-60% of bank in reach has areas of erosion or other signs of instability. High erosion potential during floods.

5 – 30-40% of bank has areas of erosion or other signs of instability. If approaching 40%, score lower if banks are steep.
4 – 40-50% of bank has areas of erosion or other signs of instability. If approaching 50%, score lower if banks are steep.
3 – 50-60% of bank has areas of erosion or other signs of instability. If approaching 60%, score lower if banks are steep or sloughing.

Poor—Unstable. Many eroded areas. Raw areas frequent along straight sections and bends. Obvious bank sloughing. Over 60% of bank has areas of erosion or other signs of instability.

2 – 60-75% of bank has areas of erosion or other signs of instability.
1 – 80-90% of bank has areas of erosion or other signs of instability; or banks primarily stabilized with riprap or other artificial stabilizers with some niches for fish and macroinvertebrates.
0 – There are no stable areas on bank; or banks stabilized with cement or other artificial stabilizers with no niches for fish and macroinvertebrates.

10. Bank Vegetative Protection

This metric estimates the amount of vegetative protection afforded to the stream bank. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion, as well as the ability of the plants to uptake nutrients, to control instream scouring, and to provide stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap. Adjustments should be made in areas with clay banks where steep, raw areas may not be as susceptible to erosion as other soil types. This parameter is made more effective by defining the natural vegetation for the region and stream type (e.g., shrubs, trees, etc.). Each bank is evaluated separately on a scale of 0 to 10 and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—More than 90% of the streambank surfaces covered by undisturbed vegetation. A variety of vegetation present (e.g., trees, shrubs, understory, or nonwoody macrophytes). Any bare or sparsely vegetated areas are small and evenly dispersed. Vegetation is highly resistant to erosion.

10 – No disruption. All banks in reach well-vegetated and natural.

9 – Minimal disruption affecting less than 10% of stream bank. Banks are well vegetated and natural.

Sub-optimal—70-90% of streambank surface covered by undisturbed vegetation. A variety of vegetation is present, but one class of plants is not well-represented. Some open areas with unstable vegetation are present. Vegetation is resistant to erosion.

8 – Up to 90% of bank area covered by vegetation. Minimal bare spots may be visible, but not significantly impacting the integrity of the stream bank.

7 – 80-90% of bank area covered by vegetation.

6 –70-80% of bank area covered by vegetation.

Marginal—50-70% of streambank surface covered by vegetation; typically composed of scattered shrubs, grasses, and forbes. Thin or bare spots visible. Vegetation is less resistant to erosion.

5 – 60-70% of bank area covered by vegetation.

4 – 50-60% of bank area covered by vegetation.

3 – About half of bank area covered by vegetation. Large bare areas are obvious throughout reach.

Poor—Less than 50% of the bank is covered by vegetation; typically composed of scattered shrubs, grasses, and forbes. Shrubs or trees on bank exist as individuals or widely scattered clumps. Vegetation is less resistant to erosion.

2 – 25-49% of bank area covered by vegetation.

1 – Less than 25% of bank area covered by vegetation.

0 – Bank vegetation is absent or too sparse to provide bank protection or habitat.

11. Grazing or Other Disruptive Pressure

This metric approximates the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. Therefore, disrupting the natural growth of riparian vegetation, especially via man-induced factors such as grazing, mowing, or silviculture, can have significant impacts to the stream reach. This parameter supplies information on the ability of the bank to resist erosion, as well as the ability of the plants to uptake nutrients, control instream scouring, and provide stream shading. This parameter is made more effective by defining the natural vegetation for the region and stream type (e.g., shrubs, trees, etc.). Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—Vegetative disruption, through grazing or mowing, minimal or not evident. Almost all plants allowed to grow normally.

10 – No vegetative disruption. No evidence of grazing, mowing, or other disruptive activities.

9 – Minimal disruption affecting less than 10% of the stream reach. Grazing, mowing, or other disruptive activities appear to have very little impact on stream reach.

Sub-optimal—Disruption evident, but not affecting full growth potential to any great extent. > ½ of the potential plant stubble height remaining.

8 – 10-20% of the vegetation of the near-stream riparian area disturbed.

7 – 10-20% of the vegetation at the stream bank disturbed.

6 – 10-20% of the vegetation of the near-stream riparian area AND the vegetation at the stream bank disturbed.

Marginal—Disruption obvious. Patches of bare soil or closely cropped vegetation common. < ½ of the potential plant stubble height remaining.

5 – 20-50% of the vegetation of the near-stream riparian area disturbed.

4 – 20-50% of the vegetation at the stream bank disturbed.

3 – 20-50% of the vegetation of the near-stream riparian area AND the vegetation at the stream bank disturbed.

Poor—Disruption of stream bank vegetation is very high. Vegetation has been removed to ≤ 2 inches average stubble height.

2 – >50% of the vegetation of the near-stream riparian area disturbed.

1 – >50% of the vegetation at the stream bank disturbed.

0 – >50% of the vegetation of the near-stream riparian area AND the vegetation at the stream bank disturbed.

12. Riparian Vegetative Zone Width

This metric estimates the width of natural vegetation from the edge of the stream bank out through the riparian zone. A vegetated riparian zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system. Narrow riparian zones occur when roads, parking lots, fields, lawns, parks, power lines, bare soil, logging, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and rangeland are common causes of anthropogenic degradation of the riparian zone. The presence of old field (i.e., previously developed fields not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged inconsequential to the destruction of the riparian zone if they are unpaved, narrow, and show no evidence of erosion. Condition category is determined by estimating the average width of the riparian zone from the top of the stream bank, outward. Generally, the riparian ends at first indication of human disturbance, with the exception of unpaved footpaths or trails in an otherwise undisturbed riparian zone. Scoring within the category should be based on the level of impact the disturbance has. For example, ungrazed fields would score higher than actively grazed fields. Lawns would score higher than paved areas. Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—Width of riparian zone > 60 feet throughout reach. Human activities (e.g., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone.

10 – There is no human disturbance.

9 – Human disturbance minimal (e.g., an unpaved footpath).

Sub-optimal—Width of riparian zone 60-40 feet throughout reach. Human activities have impacted zone only minimally.

8 – After 40 feet of undisturbed riparian, human disturbance is minimal (e.g., an ungrazed hay field) OR areas of riparian that are less than 60 feet wide are small.

7 – After 40 feet of riparian, human disturbance is vegetated but has frequent use or is closely cropped (e.g., lawns, golf courses, row crops, active pasture).

6 – After 40 feet of riparian, human disturbance is not vegetated (e.g., paved or gravel lots, roads, bare dirt).

Marginal—Width of riparian zone 40-20 feet throughout reach. Human activities have impacted zone a great deal.

5 – After 20 feet of undisturbed riparian, human disturbance is minimal (e.g., an ungrazed hay field) OR areas of riparian that are less than 40 feet wide are small.

4 – After 20 feet of riparian, human disturbance is vegetated but has frequent use or is closely cropped (e.g., lawns, golf-courses, row crops, active pasture).

3 – After 20 feet of riparian, human disturbance is not vegetated (e.g., paved or gravel lots, roads, bare dirt).

Poor—Width of riparian zone <20 feet throughout reach. Little or no riparian vegetation due to human activities.

2 – Human disturbance is minimal (e.g., an ungrazed hay field) OR areas that are less than 20 feet are small.

1 – Human disturbance is vegetated but has frequent use or is closely cropped (e.g., lawns, golf courses, row crops, active pasture).

0 – Human disturbance has removed all vegetation (e.g., paved or gravel lots, roads, bare dirt).

13. Riparian Zone Vegetative Quality

This metric evaluates the presence (in percent) of normal/undisturbed expected plant community for given sunlight and habitat conditions. Streams that have various classes of native vegetation providing full, natural plant growth, including groundcover, shrubs, understory trees, and large trees, will score the highest. In some regions, the introduction of exotics, such as kudzu, privet, or honeysuckle, has virtually replaced all native vegetation. Although exotics may provide erosion control, they do not provide the ideal food and habitat to stream organisms that have evolved to utilize native species. Banks that are dominated by non-native vegetation should score lower. Condition category is determined by estimating the amount of bank covered by undisturbed, native vegetation. Rank is determined by complexity of vegetation type. Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—Over 80% of riparian zone covered by undisturbed, native vegetation. All four classes (mature trees, understory trees, shrubs, and groundcover) are represented. All plants are native.

10 – 90-100% of riparian zone covered by native vegetation. All classes of vegetation (mature trees, understory trees, shrubs, and groundcover) are represented.

9 – 80-90% of riparian zone covered by native vegetation. All classes of vegetation are represented.

Sub-optimal—The majority (50-80%) of riparian zone covered by undisturbed, native vegetation. One class may not be well represented. Non-native vegetation may be present, but rare (<30%).

8 – Over 80% of riparian zone covered by native vegetation, but one class not well represented.

7 – 50-80% of riparian zone covered by native vegetation. All classes of vegetation (mature trees, understory trees, shrubs, and groundcover) are well represented.

6 – 50-80% of riparian zone covered by native vegetation, but one class not well represented. Non-natives may be present, but do not affect natural vegetation growth.

Marginal—25-50% of riparian zone covered by undisturbed, native vegetation. Two classes of vegetation may not be well represented. Non-native vegetation may be common (30-50%).

5 – All classes of vegetation (mature trees, understory trees, shrubs, and groundcover) are represented (if approaching 50%).

4 – One class of vegetation not well represented.

3 – Two classes of vegetation not well represented OR non-native vegetation is common.

Poor—Less than 25% of riparian zone covered by undisturbed, native vegetation OR more than two classes of vegetation are not well represented. Non-native vegetation may be dominant (>50%).

2 – Vegetation that is present is mostly native.

1 – Non-native vegetation is dominant.

0 – Vegetation is absent or too sparse to provide bank protection or habitat.

Glide/Pool Habitat Survey Rules

The low gradient habitat field sheet is used for low gradient streams. This will include streams in ecoregion 65 (except for 65j) and 75. This assessment may also be appropriate in lower reaches of larger streams in other ecoregions. Glide/pool streams are naturally slow moving, tend to have benthic substrates of fine sediment or infrequent aggregations of more coarse sediment (gravel or larger), and tend to meander across the floodplain.

1. Instream Cover

This metric estimates the quantity and types of natural structures available to bugs and fish. Natural habitats include bedrock with crevices or aquatic plants, decaying leaf litter, undercut banks, root mats, macrophytes, large rocks, etc. Snags and submerged logs are among the most productive habitats for macroinvertebrate colonization and fish refugia in low gradient streams. Variable and abundant habitat increase the potential for recovery from disturbance. To assign a condition category, look at how much of the stream reach is covered by natural, stable, productive habitat. The numeric score within the condition category is assigned based on the variety and quality of habitat. Variations in habitat that provide niches for different faunal types should be considered as different habitat types (e.g., rootmats in flowing water and pools). Bedrock with natural aquatic plants is included as stable habitat by estimating percent bedrock, then estimating percent covered by vegetation. Filamentous and other nuisance algae should not be included in this estimate. Habitat that is not of sufficient quantity to support faunal populations (<5%), is not colonized (newly fallen leaves), is not productive (seamless bedrock), or is likely to wash out should not be included. Artificial or manmade structures, such as riprap, tires, etc., are not included since the goal is to evaluate natural habitat.

Optimal—Over 50% of the stream reach has natural, stable habitat available for colonization by macroinvertebrates and/or fish. Three or more productive habitats are present. Deadfall, leaf litter, snags, etc., are not new-fall, but show evidence of decay. If less than three habitats are present, score as Sub-optimal.

20 – 7 habitats present.
19 – 6 habitats present.
18 – 5 habitats present.
17 – 4 habitats present.
16 – <4 habitats present.

Sub-optimal—Natural, stable habitat covers 30-50% of stream reach OR less than three habitats are present. If nearing 30% and only one habitat is present, score as Marginal.

15 – 7 habitats present.
14 – 6 habitats present.
13 – 5 habitats present.
12 – 4 habitats present.
11 – <4 habitats present.

Marginal—Natural, stable habitat covers 10-30% of stream reach. Availability is less than desirable. Substrate frequently disturbed or removed. Habitat diversity is reduced. If near 10% and only one habitat, score as Poor.

10 – 7 habitats present.
9 – 6 habitats present.

8 – 5 habitats present.
7 – 4 habitats present.
6 – 3 habitats present.

Poor—Less than 10% of stable habitat. Lack of habitat is obvious. Substrate unstable or lacking.

5 – 2 habitats present; additional habitats rare, but also present.
4 – Only 2 habitats present.
3 – 1 habitat present, additional habitat rare.
2 – Only 1 habitat present, but common.
1 – 1 habitat present, but rare.
0 – No natural, stable, productive habitat within reach.

2. Pool Substrate Characterization

This metric evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (e.g., gravel and packed sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock with no plants. In addition, a stream that has a uniform substrate in its pools will support far fewer types of organisms than a stream that has a variety of substrate types. Root mats for this parameter are those within the bottom substrate of the channel and should not be confused with rooted undercut banks. Firm sand is desirable while soft sand will score lower. Fissured bedrock with crevices and rock shelves will score higher than smooth bedrock. The type of substrate will determine the condition category. Rank within the category will be based on the ratio of substrate type.

Optimal—Good mixture of substrate materials with gravel and firm sand prevalent. Root mats and submerged vegetation are common.

20 – Even mix of gravel and firm sand. Both root mats and submerged vegetation are common.
19 – Mixture of substrates, including firm sand. Gravel is dominant. Both root mats and submerged vegetation are common.
18 – Mixture of substrates, including firm sand. Gravel is dominant. Either root mats or submerged vegetation is missing.
17 – Mixture of substrates, including gravel. Firm sand is dominant. Both root mats and submerged vegetation are common.
16 – Mixture of substrates, including gravel. Firm sand is dominant. Either root mats or submerged vegetation is missing.

Sub-optimal—Mixture of soft sand, mud, or clay. Substrate may also be fissured bedrock. Some root mats and submerged vegetation present.

15 – Mixture of soft sand, mud, and clay. No substrate dominant. Both root mats and submerged vegetation present.
14 – Mixture of soft sand, mud, and clay. Mud is dominant. Both root mats and submerged vegetation present.
13 – Mixture of soft sand and mud. Mud is dominant. Either root mats or submerged vegetation is missing.
12 – Mixture of soft sand and clay OR substrate is fissured bedrock with frequent fissures and shelves. Some root mats and submerged vegetation present.
11 – Mixture of soft sand and clay OR substrate is fissured bedrock with frequent fissures and shelves. Either root mats or submerged vegetation is missing.

Marginal—All mud or clay or soft sand bottom. Substrate may also be fissured bedrock. Little or no root mat. No submerged vegetation present.

10 – Mud bottom. Some root mat present.
9 – Soft sand bottom. Some root mat present.
8 – Clay bottom. Some root mat present.
7 – Mud or fissured bedrock bottom. Little to no root mat present.
6 – Soft sand or clay bottom. Little to no root mat present.

Poor—Hard-pan clay, conglomerate, or flat bedrock bottom. No root mat or vegetation present.

5 – Predominantly soft clay bottom. No root mat.
4 – Predominantly flat bedrock bottom. Other non-bedrock substrate available.
3 – Predominantly flat bedrock bottom. Infrequent crevices and/or shelves provide some habitat.
2 – Predominantly conglomerate substrate.
1 – Predominantly flat bedrock substrate.
0 – Predominantly hard-pan clay substrate.

3. Pool Variability

Pool variability rates the overall mixture of pool types found in streams according to size and depth. A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and uniform pool characteristics do not have sufficient quantities and types of habitat to support a diverse aquatic community. The four basic types of pools are large-shallow, large-deep, small-shallow, and small-deep. Any pool dimension (i.e., length, width, oblique) greater than half the cross-section of the stream is large, and any pool > 1 m in depth is deep. The variety of pool types will determine condition category. The quality of these pools and their relation to reaeration areas in the stream will determine rank within the category. Reaeration is defined as the oxygen transfer from the atmosphere to the stream. Reaeration points are areas where the stream surface is disturbed (e.g., gravel riffles; turbulence from dams, snags, logs or other debris).

Optimal—Even mix of large-shallow, large-deep, small-shallow, and small-deep pools present.

20 – All pool sizes well represented and below areas of reaeration.
18 – All pool sizes well represented but can be found below and above areas of reaeration.
16 – All pool sizes well represented but not below areas of reaeration.

Sub-optimal—Majority of pools large-deep. Very few shallow pools.

15 – Large and small deep pools evenly mixed and all below areas of reaeration.
14 – Majority of pools are large-deep and below areas of reaeration.
13 – Large and small deep pools evenly mixed and above and below areas of reaeration.
12 – Majority of pools are large-deep and found above and below areas of reaeration.
11 – Majority of pools are large-deep and NOT below areas of reaeration.

Marginal—Shallow pools much more prevalent than deep pools.

10 – Large and small shallow pools evenly mixed and all below areas of reaeration.
9 – Majority of pools are large-shallow and below areas of reaeration.
8 – Large and small shallow pools evenly mixed and above and below areas of reaeration.
7 – Majority of pools large-shallow and found above and below areas of reaeration.

6 – Majority of pools large-shallow and NOT below areas of reaeration.

Poor—Majority of pools small-shallow or pools absent

5 – Majority of pools are small-shallow and all below areas of reaeration.
4 – Majority of pools are small-shallow and above and below areas of reaeration.
3 – Majority of pools are small-shallow and all above areas of reaeration.
2 – Pools absent, although there are depth changes within channel.
1 – Channel is a continuous run with little or no changes in velocity or depth.
0 – None of the velocity-depth regimes is present (no water, or separated pools).

4. Man-made Channel Alteration

This metric measures large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been widened, straightened, deepened, and/or diverted into concrete channels for flood control or irrigation. Such streams have fewer habitats than naturally meandering streams. Channel alteration may include artificial embankments, riprap, or other forms of artificial bank stabilization structures; reaches with very straight pattern for significant distances; dams and bridges. Consider man-made structures present upstream or downstream of the reach if they affect flow patterns. Scouring is often associated with channel alteration. Beaver activity is natural condition and is not accounted for in this metric. It should be noted on the field form, however.

Optimal—Stream follows a normal, meandering pattern; alteration other than restoration is absent or minimal; shoring structures absent; no artificial structures present; structures upstream or downstream not affecting reach.

20 – No evidence of channelization, no artificial structures, in reach or its impact area. No evidence of past or present gravel dredging or rock removal or off-road vehicle activity. Stream has normal meander pattern.
19 – No evidence of channelization, no artificial structures in reach or its impact area. Minimal evidence of past rock removal. No evidence of gravel/sand dredging or off-road vehicle activity. Meander pattern and habitat unaffected.
18 – No evidence of channelization; no artificial structures in reach. Evidence of past gravel/sand dredging is minimal. No evidence of off-road vehicle activity. Stream flow pattern and habitat not affected.
17 – Evidence of past channel alteration is <5% of reach. Stream flow pattern not affected. Modification is stable, well-vegetated with natural vegetation, and low erosion potential. No artificial structures in reach or its impact area. No evidence of off-road vehicle activity.
16 – Evidence of past off-road vehicle activity. Riffle and run areas intact, contours not affected. Artificial structures may be present outside reach, but not affecting flow patterns, habitat, or contours in reach.

Sub-optimal—<40% of reach channelized and disrupted; channel stabilized; altered flow not affecting biology; artificial structures in or outside of reach not affecting flow.

15 – Historic channelization stabilized (may also include pre-Civil War rock walls). Modification is stable, well-vegetated with natural vegetation, and no erosion potential.
14 – Bridge, culverts, shoring, or artificial structures may be present but do not affect natural flow patterns. (Includes structures upstream or downstream, as well as within reach.)
13 – Recent off-road vehicle activity in stream. Riffle or run areas slightly disturbed. Natural stabilization and recolonization expected.

12 – Evidence of recent rock removal or gravel/sand dredging has had slight impact on reach. Natural stabilization and recolonization expected.

11 – New channelization in up to 40% of stream reach. Modification is stable, well vegetated with natural vegetation, no erosion potential. (If not stable, score 10.)

Marginal—40-80% of reach channelized and disrupted; some channelization may not have stabilized; artificial structures within or outside reach may slightly affect flow.

10 – Less than 40% of reach altered, but has not stabilized.

9 – 40-80% of reach has been channelized, but is stable with natural vegetation.

8 – Bridge, culverts, shoring, or artificial structures have slight effect on natural flow patterns in reach. (Includes structures upstream or downstream, as well as within reach.)

7 – 40-80% of reach affected by dredging, rock removal, off-road vehicle activity, or other instream disruptive activity.

6 – 40-80% of reach has been altered and has not stabilized.

Poor—>80% of reach channelized or disrupted; instream habitat greatly altered or removed entirely OR artificial structures within reach or upstream or downstream have greatly affected flow.

5 – Over 80% of the stream reach has been channelized but is stable with natural vegetation.

4 – Over 80% of the stream reach is channelized and has been stabilized with artificial shoring (riprap, cement, etc.).

3 – Over 80% of the stream reach is channelized and has not stabilized.

2 – Impoundment, bridge, or other artificial structure has high level of impact on normal flow and/or channel pattern. Include upstream or downstream structures that have seriously affected the reach.

1 – At least part of stream bottom substrate is in concrete or other artificial channel (including culverts).

0 – 100% of stream bottom substrate is in concrete or other artificial channel (including culverts).

5. Sediment Deposition

This metric assesses the amount of sediment that has accumulated and the changes that have occurred to the stream bottom as a result of the deposition gravel, sand, and silt. Deposition occurs from large-scale movement of sediment caused by erosion. Sediment deposition may cause the formation of islands, point bars, or shoals. It may also result in the filling of pools. Usually deposition is evident in areas that are obstructed by natural or man-made debris and in areas where the stream flow decreases, such as bends. High levels of sediment deposition create an unstable and continually changing environment that becomes unsuitable for many organisms. Select condition category by estimating the percent of stream bottom that is affected by sediment deposition. Only areas of new, unvegetated deposition on point bars and islands should be considered when scoring. Rank within each category is determined by the areas most affected by sediment deposition. Sediment in pools or slow areas will score higher than sediment on point bars and islands.

Optimal—Sediment deposition affects less than 20% of stream bottom in quiet areas. New deposition on islands and point bars is absent or minimal.

20 – No islands or point bars. No sediment in pools or slow areas.

19 – No new deposition on stable islands or point bars. No sediment in pools or slow areas.

18 – No new deposition on islands or point bars. Small amount of sediment in pools or slow areas.

17 – Slight amount of new deposition on islands or point bars. No sediment in pools or slow areas.

16 – Slight amount of new deposition on islands or point bars. Small amount of sediment in pools or slow areas. Up to 20% of bottom area affected. (As deposition approaches 20%, if most of deposition is an increase in island or bars, score as Sub-optimal.)

Sub-optimal—20-50% of the bottom affected. Some new increase in bar formation, mostly from gravel, sand, or fine sediment. Slight deposition in pools.

15 – Sediment deposition affects 20-30% of the bottom substrate. Most deposition is in pools or bends, with little new accumulation on islands or point bars.

14 – Sediment deposition affects 20-30% of the bottom substrate. Deposition occurs both in pool areas and as new accumulation on bars and islands.

13 – Sediment deposition affects 35-45% of the bottom substrate. Most of the deposition is in pools or bends with little new accumulation on islands or point bars.

12 – Sediment deposition affects 35-45% of the bottom substrate. Deposition occurs both in pool areas and as new accumulation on bars and islands.

11 – Sediment deposition affects 50% of the bottom substrate. Deposition occurs primarily in pool areas. As new accumulation of bars and islands approaches 50%, score as Marginal.

Marginal—50-80% of the bottom affected. Moderate deposition of new gravel, sand, or fine sediment on old and new bars. Deposits at obstructions, constrictions, and bends. Moderate pool deposition prevalent.

10 – Sediment deposition affects 50% of stream bottom. Deposits on bars and islands and pools and bends.

9 – Sediment deposition affects 55-65% of stream bottom. Most of deposition is in pools, rather than build-up of bars and islands.

8 – Sediment deposition affects 55-65% of stream bottom. Moderate deposition of pools, as well as new deposition on bars and islands.

7 – Sediment deposition affects 70-80% of stream bottom. Most of deposition is in pools, rather than new deposition on bars and islands.

6 – Sediment deposition affects 70-80% of stream bottom. New sediment accumulation on bars and islands, as well as in pools.

Poor— More than 80% of the stream bottom changing frequently. Heavy deposits of fine material. Increased bar development. Pools almost absent due to substantial sediment deposition.

5 – Approximately 80-85% sediment deposition. Pools heavily affected, but present OR pools naturally absent.

4 – Approximately 80-85% of the bottom substrate is affected by sediment deposition. Pools absent.

3 – Approximately 85-90% sediment deposition. Pools heavily affected, but present OR pools naturally absent.

2 – Approximately 85-90% of the bottom substrate is affected by sediment deposition. Pools absent.

1 – Approximately 90-95% sediment deposition. Pools absent.

0 – Sediment blankets 100% of stream bottom. Pools absent.

6. Channel Sinuosity

This metric evaluates the meandering, or sinuosity, of the stream. A high degree of sinuosity provides diverse habitat for aquatic organisms, and the stream is better able to handle surges caused by increased flow during storm events. A run/bend ratio can be used as a measure of sinuosity. The ratio is calculated by dividing the distance between the bends by the stream width. To estimate this parameter, a longer reach than that designated for the sampling should be incorporated in the evaluation. This will vary by site but should include at least two bends. Maps may be used to estimate the sinuosity of larger streams where field evaluations are not practical. The amount the meanders increase the stream length determines the condition category. The quality of the meander (whether additional habitat is provided) determines the rank.

Optimal—Bends in the stream increase the stream length 3-4 times longer than if it was in a straight line.

20 – Stream meander increases stream length more than 4 times longer than a straight line.

19 – Stream meander increases stream length 4 times longer than a straight line.

18 – Stream meander increases stream length 3.5 times longer than a straight line. Bends provide productive macroinvertebrate habitat.

17 – Stream meander increases stream length 3.5 times longer than a straight line. Bends do not provide additional macroinvertebrate habitat.

16 – Stream meander increases stream length 3 times longer than a straight line. Bends provide productive macroinvertebrate habitat.

Sub-optimal—Bends in the stream increase the stream length 2-3 times longer than if it was in a straight line.

15 – Stream meander increases stream length 3 times longer than a straight line. Bends do not provide additional macroinvertebrate habitat.

14 – Stream meander increases stream length 2.5 times longer than a straight line. Bends provide productive macroinvertebrate habitat.

13 – Stream meander increases stream length 2.5 times longer than a straight line. Bends do not provide additional macroinvertebrate habitat.

12 – Stream meander increases stream length 2 times longer than a straight line. Bends provide productive macroinvertebrate habitat.

11 – Stream meander increases stream length 2 times longer than a straight line. Bends do not provide additional macroinvertebrate habitat.

Marginal—Bends in the stream increase the stream length 1-2 times longer than if it was in a straight line.

10 – Stream meander increases stream length 1.5 times longer than a straight line. Bends provide additional macroinvertebrate habitat.

9 – Stream meander increases stream length 1.5 times longer than a straight line. Bends do not provide productive macroinvertebrate habitat.

8 – Stream meander increases stream length 1 time longer than a straight line. Bends provide additional macroinvertebrate habitat.

7 – Stream meander increases stream length 1 time longer than a straight line. Bends do not provide productive macroinvertebrate habitat.

6 – Stream meander increases stream length <1 time longer than a straight line. Bends do not provide additional macroinvertebrate habitat.

Poor—Channel straight. Waterway has been channelized for a long distance (>25X stream width).

5 – Straight channel is offset by some slight curves which, though not meanders, do serve to provide some habitat and some energy dissipation during surges.

4 – Straight channel with more than one slight curve.

3 – Straight channel with a single slight curve

2 – Straight channel with no curves but some bank indentations providing habitat. These are stable indentations not subject to erosion.

1 – Channel completely straight with no curves or stable indentations. Waterway has been channelized for a long distance (>30X stream width).

0 – Channel completely straight with no curves or stable indentations. Waterway has been channelized for a long distance (>40X stream width).

7. Channel Flow Status

This metric appraises the degree to which the channel is filled with water. Condition category will be selected based on the amount of the streambed covered by water. Rank within the category will be determined by how much productive habitat is exposed. If water has been backed up by obstructions (such as beaver dams, log jams, debris plugs), move assessment reach above or below the affected area. If this is not possible, determine whether sampling is appropriate or should be postponed until conditions are more representative of normal stream conditions. Use comment field to explain, if necessary. Assess flow status based on what is submerged during normal flow conditions. For example, naturally exposed gravel beds do not indicate exposed habitat. Use comment field to note if flow is reduced due to natural low flow conditions, drought, irrigation, municipal water withdrawal, impoundment, etc.

Optimal—Water reaches base of both lower banks, and streambed is covered by water throughout the reach. Minimal amount of productive habitat is exposed.

20 – Water is above the base of each bank. No productive habitats are exposed.

19 – Roots are submerged, but some undercut areas may be above water. Other productive habitats are not affected.

18 – Some shallow roots are exposed, but there is plenty of submerged root habitat available. Other habitats are not affected.

17 – Most shallow roots are exposed, but there is plenty of submerged root habitat. Other habitats are not affected.

16 – Some larger rooted areas are partially exposed, but there is plenty of submerged root habitat. Other productive habitats are not affected.

Sub-optimal—Water covers >75% of the streambed, and less than 25% of productive habitat is exposed.

15 – Some submerged rooted areas are totally exposed although the habitat is still plentiful. Other productive habitats are not affected.

14 – Most root habitat is exposed. Other productive habitats are available.

13 – All root habitat is exposed. Other productive habitats are available.

12 – A second near-shore habitat, such as macrophyte beds, is partially exposed. Other mid-channel habitats, such as fallen trees, are available for full colonization.

11 – All near-shore habitat is compromised, although some is available. Other mid-channel habitats, such as fallen trees, are available for full colonization.

Marginal—Water covers 25-75% of the streambed, AND/OR productive habitat is mostly exposed.

10 – Water covers 75% of the streambed. All near-shore habitat is exposed. Mid-channel habitats are available and not affected.

9 – Water covers 60–70% of the streambed. All near-shore habitat is exposed. Some mid-channel habitat, such as fallen trees and snags, are compromised, but still available for full colonization.

8 – Water covers about 50% of the streambed. Mid-channel habitat is compromised, but at least one productive habitat is still common.

7 – Water covers 30–40% of the streambed. Most habitat is exposed, but at least one productive habitat is still common.

6 – Water covers about 25% of the streambed. Isolated areas of productive habitat.

Poor—Very little water in channel. Most available water is present as standing pools. Little or no productive habitat due to lack of water.

5 – Very little flow evident. Isolated patches of productive habitat.

4 – Very little flow evident. Remaining habitat is unproductive.

3 – Water reduced to long stretches of pooled water. Isolated patches of productive habitat.

2 – Water reduced to isolated pools. Stream may be flowing below surface between pools.

1 – Water reduced to isolated pools with no productive habitat.

0 – Stream is dry.

8. Condition of Banks

This metric evaluates whether the stream banks are eroded or have the potential for erosion. Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks and are, therefore, considered unstable. Bedrock/large boulder stream banks are given a high score no matter what the slope. Signs of erosion include crumbling, unvegetated banks, sloughing, exposed tree roots, and exposed soil. Eroded banks indicate a problem with sediment movement and deposition and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream. Banks primarily stabilized with riprap or other artificial stabilizers should be categorized as “poor.”

Optimal—Banks stable. Evidence of erosion or bank failure absent or minimal. Little potential for future problems. < 5% of the bank affected.

10 – No signs of instability evident. Banks sloping. Little erosion potential.

9 – Some erosion evident; OR steep banks; OR some potential for erosion.

Sub-optimal—Moderately stable. Infrequent, small areas of erosion. 5-30% of bank in reach has areas of erosion.

8 – 5-15% of bank has areas of healed over erosion.

7 – 5-15% of bank has areas of erosion or other signs of instability. Some are not healed over.

6 – 20-30% of bank has areas of erosion or other signs of instability. If approaching 30%, score lower if banks are steep.

Marginal—Moderately unstable. 30-60% of bank in reach has areas of erosion or other signs of instability. High erosion potential during floods.

5 – 30-40% of bank has areas of erosion or other signs of instability. If approaching 40%, score lower if banks are steep.

4 – 40-50% of bank has areas of erosion or other signs of instability. If approaching 50%, score lower if banks are steep.

3 – 50-60% of bank has areas of erosion or other signs of instability. If approaching 60%, score lower if banks are steep or sloughing.

Poor—Unstable. Many eroded areas. Raw areas frequent along straight sections and bends. Obvious bank sloughing. Over 60% of bank has areas of erosion or other signs of instability.

2 – 60-75% of bank has areas of erosion or other signs of instability.

1 – 80-90% of bank has areas of erosion or other signs of instability; or banks primarily stabilized with riprap or other artificial stabilizers with some niches for fish and macroinvertebrates.

0 – There are no stable areas on bank; or banks stabilized with cement or other artificial stabilizers with no niches for fish and macroinvertebrates.

9. Bank Vegetative Protection

This metric approximates the amount of vegetative protection afforded to the stream bank. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion, as well as the ability of the plants to uptake nutrients, to control instream scouring, and to provide stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete or riprap. Adjustments should be made in areas with clay banks where steep, raw areas may not be as susceptible to erosion as other soil types. This parameter is made more effective by defining the natural vegetation for the region and stream type (e.g., shrubs, trees, etc.). Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal— More than 90% of the streambank surface covered by undisturbed vegetation. A variety of vegetation present (e.g., trees, shrubs, understory, or nonwoody macrophytes). Any bare or sparsely vegetated areas are small and evenly dispersed. Vegetation is highly resistant to erosion.

10 – No disruption. All banks in reach well-vegetated and natural.

9 – Minimal disruption affecting less than 10% of stream bank. Banks are well vegetated and natural.

Sub-optimal— 70-90% of streambank surface covered by undisturbed vegetation. A variety of vegetation is present, but one class of plants is not well-represented. Some open areas with unstable vegetation are present. Vegetation is resistant to erosion.

8 – Up to 90% of bank area covered by vegetation. Minimal bare spots may be visible, but not significantly impacting the integrity of the stream bank.

7 – 80-90% of bank area covered by vegetation.

6 –70-80% of bank area covered by vegetation.

Marginal— 50-70% of streambank surface covered by vegetation; typically composed of scattered shrubs, grasses, and forbes. Thin or bare spots visible. Vegetation is less resistant to erosion.

5 – 60-70% of bank area covered by vegetation.

4 – 50-60% of bank area covered by vegetation.

3 – About half of bank area covered by vegetation. Large bare areas are obvious throughout reach.

Poor— Less than 50% of the bank is covered by vegetation; typically composed of scattered shrubs, grasses, and forbes. Shrubs or trees on bank exist as individuals or widely scattered clumps. Vegetation is less resistant to erosion.

2 – 25-49% of bank area covered by vegetation.

1 – Less than 25% of bank area covered by vegetation.

0 – Bank vegetation is absent or too sparse to provide bank protection or habitat.

10. Grazing or Other Disruptive Pressure

This measure estimates the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. Disrupting the natural growth of riparian vegetation, especially via man-induced factors such as grazing, mowing, or silviculture, can have significant impacts to the stream reach. This parameter supplies information on the ability of the bank to resist erosion, as well as the ability of the plants to uptake nutrients, control instream scouring, and provide stream shading. This parameter is made more effective by defining the natural vegetation for the region and stream type (e.g., shrubs, trees, etc.). Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—Vegetative disruption, through grazing or mowing, minimal or not evident. Almost all plants allowed to grow normally.

10 – No vegetative disruption. No evidence of grazing, mowing, or other disruptive activities.

9 – Minimal disruption affecting less than 10% of the stream reach. Grazing, mowing, or other disruptive activities appear to have very little impact on stream reach.

Sub-optimal—Disruption evident, but not affecting full growth potential to any great extent. > ½ of the potential plant stubble height remaining.

8 – 10-20% of the vegetation of the near-stream riparian area disturbed.

7 – 10-20% of the vegetation at the stream bank disturbed.

6 – 10-20% of the vegetation of the near-stream riparian area AND the vegetation at the stream bank disturbed.

Marginal—Disruption obvious. Patches of bare soil or closely cropped vegetation common. < ½ of the potential plant stubble height remaining.

5 – 20-50% of the vegetation of the near-stream riparian area disturbed.

4 – 20-50% of the vegetation at the stream bank disturbed.

3 – 20-50% of the vegetation of the near-stream riparian area AND the vegetation at the stream bank disturbed.

Poor—Disruption of stream bank vegetation is very high. Vegetation has been removed to ≤ 2 inches average stubble height.

2 – >50% of the vegetation of the near-stream riparian area disturbed.

1 – >50% of the vegetation at the stream bank disturbed.

0 – >50% of the vegetation of the near-stream riparian area AND the vegetation at the stream bank disturbed.

11. Riparian Vegetative Zone Width

This metric estimates the width of natural vegetation from the edge of the stream bank out through the riparian zone. A vegetated riparian zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system. Narrow riparian zones occur when roads, parking lots, fields, lawns, parks, power lines, bare soil, logging, or buildings are near the stream bank. Residential developments, urban centers, golf courses, and rangeland are common causes of anthropogenic degradation of the riparian zone. The presence of old field (i.e., previously developed fields not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged inconsequential to the destruction of the riparian zone if they are unpaved, narrow, and show no evidence of erosion. Condition category is determined by estimating the average width of the riparian zone from the top of the stream bank, outward. Generally, the riparian ends at first indication of human disturbance, with the exception of unpaved footpaths or trails in an otherwise undisturbed riparian zone. Scoring within the category should be based on the level of impact the disturbance has. For example, ungrazed fields would score higher than actively grazed fields. Lawns would score higher than paved areas. Each bank is evaluated separately on a scale of 0 to 10 and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—Width of riparian zone > 60 feet throughout reach. Human activities (e.g., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone.

10 – There is no human disturbance.

9 – Human disturbance minimal (e.g., an unpaved footpath).

Sub-optimal—Width of riparian zone 60-40 feet throughout reach. Human activities have impacted zone only minimally.

8 – After 40 feet of undisturbed riparian, human disturbance is minimal (e.g., an ungrazed hay field) OR areas of riparian that are less than 60 feet wide are small.

7 – After 40 feet of riparian, human disturbance is vegetated but has frequent use or is closely cropped (e.g., lawns, golf courses, row crops, active pasture).

6 – After 40 feet of riparian, human disturbance is not vegetated (e.g., paved or gravel lots, roads, bare dirt).

Marginal—Width of riparian zone 40-20 feet throughout reach. Human activities have impacted zone a great deal.

5 – After 20 feet of undisturbed riparian, human disturbance is minimal (e.g., an ungrazed hay field) OR areas of riparian that are less than 40 feet wide are small.

4 – After 20 feet of riparian, human disturbance is vegetated but has frequent use or is closely cropped (e.g., lawns, golf courses, row crops, active pasture).

3 – After 20 feet of riparian, human disturbance is not vegetated (e.g., paved or gravel lots, roads, bare dirt).

Poor—Width of riparian zone <20 feet throughout reach. Little or no riparian vegetation due to human activities.

2 – Human disturbance is minimal (e.g., an ungrazed hay field) OR areas that are less than 20 feet are small.

1 – Human disturbance is vegetated but has frequent use or is closely cropped (e.g., lawns, golf courses, row crops, active pasture).

0 – Human disturbance has removed all vegetation (e.g., paved or gravel lots, roads, bare dirt).

12. Riparian Zone Vegetative Quality

This metric estimates the presence (in percent) of normal/undisturbed expected plant community for given sunlight and habitat conditions. Streams that have various classes of native vegetation providing full, natural plant growth, including groundcover, shrubs, understory trees, and large trees, will score the highest. In some regions, the introduction of exotics, such as kudzu, privet, or honeysuckle, has virtually replaced all native vegetation. Although exotics may provide erosion control, they do not provide the ideal food and habitat to stream organisms that have evolved to utilize native species. Banks that are dominated by non-native vegetation should score lower. Condition category is determined by estimating the amount of bank covered by undisturbed, native vegetation. Rank is determined by complexity of vegetation type. Each bank is evaluated separately on a scale of 0 to 10, and the cumulative score of both banks is used for this parameter. Left and right banks are determined by facing downstream.

Optimal—Over 80% of riparian zone covered by undisturbed vegetation. All four classes (mature trees, understory trees, shrubs, and groundcover) are represented. All plants are native.

10 – 90-100% of riparian zone covered by native vegetation. All classes of vegetation (mature trees, understory trees, shrubs, and groundcover) are represented.

9 – 80-90% of riparian zone covered by native vegetation. All classes of vegetation are represented.

Sub-optimal—The majority (50-80%) of riparian zone covered by undisturbed, native vegetation. One class may not be well represented. Non-native vegetation may be present, but rare (<30%).

8 – Over 80% of riparian zone covered by native vegetation, but one class not well represented.

7 – 50-80% of riparian zone covered by native vegetation. All classes of vegetation (mature trees, understory trees, shrubs, and groundcover) are well represented.

6 – 50-80% of riparian zone covered by native vegetation, but one class not well represented. Non-natives may be present but do not affect natural vegetation growth.

Marginal—25-50% of riparian zone covered by undisturbed, native vegetation. Two classes of vegetation may not be well represented. Non-native vegetation may be common (30-50%).

5 – All classes of vegetation (mature trees, understory trees, shrubs, and groundcover) are represented.

4 – One class of vegetation not well represented.

3 – Two classes of vegetation not well represented OR non-native vegetation is common.

Poor—Less than 25% of riparian zone covered by undisturbed, native vegetation OR more than two classes of vegetation are not well represented. Non-native vegetation may be dominant (>50%).

2 – Vegetation that is present is mostly native.

1 – Non-native vegetation is dominant.

0 – Vegetation is absent or too sparse to provide bank protection or habitat.

APPENDIX F —
LIST OF SELECTED REPORTS, PUBLICATIONS, AND INFORMATION FOR ALABAMA AQUATIC BIODIVERSITY, CONSERVATION, STRATEGIC HABITAT UNITS, AND STRATEGIC RIVER REACH UNITS

The following list of reports is grouped by Strategic Habitat Unit/Strategic River Reach Unit (SHU/SRRU) name and number (see Wynn and others, 2018) and drainage-specific surveys, assessments, and studies.

BEAR CREEK SHU (1)

- McGregor, S. W., Shepard, T. E., and Garner, J. T., 1996, A qualitative assessment of the mussel fauna of the Bear Creek system of northwest Alabama and northeast Mississippi, 1996: Alabama Geological Survey Open-File Report to Alabama Department of Conservation and Natural Resources.
- McGregor, S. W., 2003, A review of the factors affecting the freshwater mussel (Bivalvia: Unionidae) fauna in the Bear Creek system, Alabama and Mississippi: Alabama Geological Survey Open-File Report to National Fish and Wildlife Foundation.
- McGregor, S. W., and Garner, J. T., 2004, Changes in the freshwater mussel (Bivalvia: Unionidae) fauna of the Bear Creek system of northwest Alabama and northeast Mississippi: American Malacological Society Bulletin, v. 18, nos. 1, 2, p. 61-70.
- McGregor, S. W., and Cook, M. R., 2004, An analysis of rates of sedimentation loading at selected stations in the Bear Creek system, Alabama and Mississippi, 2003-2004: Alabama Geological Survey Open-File Report 0501.
- McGregor, S. W., and Cook, M. R., 2005, A preliminary analysis of sedimentation loading rates in the upper Buttahatchee River, Alabama, 2004-2005: Alabama Geological Survey Open-File Report 0512.
- McGregor, S.W., O'Neil, P. E., and Moss, N. E., 2006, An analysis of sedimentation loading rates in Cedar Creek, Franklin County, Alabama, 2005-2006: Alabama Geological Survey Open-File Report 0602.
- McGregor, S.W., and Cook, M. R., 2006, An analysis of sedimentation loading for selected tributaries to the Bear Creek floodway, Alabama and Mississippi, 2005-2006: Alabama Geological Survey Open-File Report 0612.
- Shepard, T. E., McGregor, S. W., O'Neil, P. E., Mettee, M. F., Smith, J. B., Johnson, C. C., and Hunter, J. H., 2009, Survey of the Bear Creek system for fish species of moderate to highest conservation concern, Report of results for 2007-08: Alabama Geological Survey Open-File Report 0901.

TENNESSEE RIVER SRRU (2)

- Garner, J. T., and McGregor, S. W., 2001, Current status of freshwater mussels (Unionidae, Margaritiferidae) in the Muscle Shoals area of Tennessee River in Alabama (Muscle Shoals revisited again): American Malacological Bulletin, v. 16, p. 155-170.
- Garner, J. T., and Holifield, J. T., 2011, Tennessee River Freshwater Mussel Survey: Alabama Department of Conservation and Natural Resources Section 6 report to U.S. Fish and Wildlife Service, 8 p.

CYPRESS CREEK SHU (3)

- McGregor, S. W., and Shepard, T. E., 1992, Investigations of slackwater darter, *Etheostoma boschungi*, populations in the Cypress Creek, Swan Creek, and Flint River systems of North Alabama, 1991-92: Alabama Geological Survey Open-File Report to ADCNR.
- McGregor, S. W., and Shepard, T. E., 1995, Investigations of slackwater darter, *Etheostoma boschungi*, populations, 1992-94: Alabama Geological Survey Circular 184, 33 p.

- Ray, J. M., Lovell, M. S., Wilson, B. S., McGregor, S. W., and Hastert, G. A., 2021, Fishes of the Cypress Creek system, Tennessee River drainage, historical records, recent fish fauna, and index of biotic integrity assessment: Alabama Geological Survey Bulletin 190, 215 p.

ELK RIVER SHU (5)

- Shepard, T. E., O'Neil, P. E., McGregor, S. W., and Mettee, M. F., 2009, Survey of the Elk River system in Alabama for fish species of moderate to highest conservation concern, 2004-06: Alabama Geological Survey Bulletin 180, 124 p.

PAINT ROCK RIVER SHU (9)

- McGregor, S. W., and Shelton, D. N., 1995, A qualitative assessment of the unionid fauna of the headwaters of the Paint Rock and Flint Rivers of North Alabama and adjacent areas of Tennessee, 1995: Alabama Geological Survey Section 6 report to Alabama Department of Conservation and Natural Resources.
- Shepard, T. E., McGregor, S. W., and O'Neil, P. E., 1997, Status survey of the palezone shiner (*Notropis albizonatus*) in the Paint Rock River system 1997: Alabama Geological Survey Section 6 report to Alabama Department of Conservation and Natural Rersources.
- O'Neil, P. E., and Mettee, M. F., 1997, Water-quality assessment of the Paint Rock River watershed, Alabama: Alabama Geological Survey Section 6 report to Alabama Department of Conservation and Natural Resources, 47 p.
- Fobian, T. B., Buntin, M. L., Garner, J. T., and Johnson, P. D., 2008, Assessment of freshwater mussel populations in the Paint Rock River Basin, Jackson, Madison, and Marshall Counties, Alabama: Alabama Department of Conservation and Natural Resources Section 6 report to the U.S. Fish and Wildlife Service, 49 p.
- O'Neil, P. E., Shepard, T. E., Powell, J. R., Spadgenske, E. W., Henderson, A. R., and Freeman, P. L., 2013, A survey of fishes in the Paint Rock River system, Alabama: Alabama Geological Survey Open-File Report 1213, 26 p.
- Fobian, T. B., Buntin, M. L., Holifield, J. T., Tarpley, T. A., Garner, J. T., and Johnson, P. D., 2014, Freshwater mussels in the Paint Rock River (Jackson, Madison, and Marshall Counties), Alabama: Southeastern Naturalist, v. 13, no. 2, p. 347-366.

TENNESSEEE RIVER SYSTEM

- McGregor, S. W., and Garner, J. T., 1997, A survey of the Tennessee River and its tributaries in north Alabama for freshwater mussels, year three: Alabama Geological Survey Section 6 report to Alabama Department of Conservation and Natural Resources.
- McGregor, S. W., O'Neil, P. E., and Garner, J. T., 1998, A survey of the Tennessee River and its tributaries in North Alabama for freshwater mussels, year 4: Alabama Geological Survey Section 6 report to Alabama Department of Conservation and Natural Resources, 13 p.
- Mettee, M. F., O'Neil, P. E., Shepard, T. E., McGregor, S. W., and Henderson, W. P., 2002, A survey of protected fish species and species of uncommon occurrence in the Tennessee River drainage of north Alabama and northeast Mississippi: Alabama Geological Survey Bulletin 171, 173 p.

SIPSEY RIVER SHU (14)

- McGregor, S. W., and O'Neil, P. E., 1993, The biology and water-quality monitoring in the Sipsey River, Lubbub and Bear Creeks, Alabama, 1990-91: Alabama Geological Circular 169, 29 p.

- McCullagh, W. H., Williams, J. D., McGregor, S. W., Pierson, J. M., and Lydeard, C., 2002, An historic and recent examination of the unionid (Bivalvia: Unionidae) fauna of the Sipsey River in northwestern Alabama, an aquatic hotspot: American Malacological Bulletin, v. 17, nos. 1, 2, p. 1-15.
- Bearden, R. A., McGregor, S. W., O'Neil, P. E., and Wynn, E. A., 2019, A survey of fishes in the Sipsey River watershed, Alabama, 2011-13: Alabama Geological Survey Circular 205.

LUBBUB CREEK SHU (15)

- McGregor, S. W., 1994, A survey of Little Lubbub Creek in the vicinity of Pickens County Road 22 for endangered and threatened species of mussels, March 1994: Alabama Geological Survey Open-File Report to Pickens County, Alabama Engineer's Office.
- McGregor, S. W., and Shepard, T. E., 1995, A survey of the Lubbub Creek system, Pickens County, Alabama, for endangered, threatened, and candidate species of freshwater mussels, 1994-95: Alabama Geological Survey Open-File Report to Pickens County, Alabama Engineer's Office.

BUTTAHATCHEE RIVER SHU (18)

- McGregor, S. W., Cook, M. R., and O'Neil, P. E., 2006, Factors potentially affecting the propagation and reintroduction of freshwater mussels (Bivalvia: Unionidae) into the Buttahatchee River system, Alabama and Mississippi: Alabama Geological Survey Open-File Report 0609.

TOMBIGBEE RIVER SYSTEM

- Malvestuto, S. P., Lucas, G. M., Sullivan, G. M., and Davies, W. D., 1982, Survey of the sport and commercial fisheries of the lower Tombigbee River and Mobile River Delta: Mobile, Alabama, U.S. Army Corps of Engineers, Job Completion Report, Contract No. DACW01-81-C-0047, 163 p.
- Mettee, M. F., O'Neil, P. E., Suttkus, R. D., and Pierson, J. M., 1987, Fishes of the lower Tombigbee River system in Alabama and Mississippi: Alabama Geological Survey Bulletin 107, 186 p.
- McGregor, S. W., and O'Neil, P. E., 1998, A mussel survey of the upper Tombigbee River system of Alabama and Mississippi, year 1: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources, 41 p.
- McGregor, S. W., 1999, A survey of freshwater mussels in selected tributaries of the upper Tombigbee River system, Alabama and Mississippi, 1994-99: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
- McGregor, S. W., 2000, A survey of freshwater mussels in selected tributaries of the upper Tombigbee River system, Alabama and Mississippi, 1994-2000: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
- McGregor, S. W., 2001, A survey of freshwater mussels in selected tributaries of the upper Tombigbee River system, Alabama and Mississippi, 1994-2001: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
- McGregor, S. W., and Garner, J. T., 2001, Results of a preliminary analysis of the freshwater mussels (Bivalvia: Unionidae) at selected stations in the Tombigbee River,

Alabama, 2000-01: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.

- McGregor, S. W., and Garner, J. T., 2002, Results of an analysis of freshwater mussel (Bivalvia: Unionidae) communities at selected stations in the Tombigbee River, Alabama, 2002: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
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- McGregor, S. W., and Haag, W. R., 2004, Freshwater mussels (Bivalvia: Unionidae) and habitat conditions in the upper Tombigbee River system, Alabama and Mississippi, 1993-2001: Alabama Geological Survey Bulletin 176.

NORTH RIVER SHU (21)

- Mettee, M. F., Harris, S. C., and O'Neil, P. E., 1988, Biological monitoring in three tributaries to Lake Tuscaloosa, Tuscaloosa County, Alabama: Alabama Geological Survey Circular 137, 23 p.
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- McGregor, S. W., and Pierson, J. M., 2000, Recent freshwater mussel records from the North River System, Fayette and Tuscaloosa counties, Alabama: Alabama Academy of Science Journal, v. 70, no. 4, p. 215-237.
- O'Neil, P. E., Cook, M. R., Henderson, W. P., and Moss, N. R., 2006, Distribution and concentration of total coliform and *Escherichia coli* bacteria in the North River/Lake Tuscaloosa watershed, 2005: Alabama Geological Survey Open-File Report 0604, 25 p. + plates.
- McGregor, S. W., and Wynn, E. A., 2008, An evaluation of the mussel fauna in the North River system, 2008: Alabama Geological Survey Open-File Report 0814, Section 6 report for the Alabama Department of Conservation and Natural Resources.
- O'Neil, P. E., McGregor, S. W., and Wynn, E. A., 2010, Watershed assessment of the North River system for recovery and restoration of rare mussel species: Alabama Geological Survey Bulletin 183, 65 p.
- O'Neil, P. E., Johnson, C. C., Wynn, E. A., Smith, J. B., McGregor, S. W., Patton, Abner, and Pitts, M. W., 2015, Evaluation of sedimentation risk and habitat threat severity for stream crossings and critical habitat in the North River strategic habitat unit, Alabama, Volume 1 Report: Alabama Geological Survey Open-File Report 1502, 60 p.
- O'Neil, P. E., Johnson, C. C., Wynn, E. A., Smith, J. B., McGregor, S. W., Patton, Abner, and Pitts, M. W., 2015, Evaluation of sedimentation risk and habitat threat severity for stream crossings and critical habitat in the North River strategic habitat unit, Alabama, Volume 2 Supplemental Data Appendix: Alabama Geological Survey Open-File Report 1502, 311 p.

UPPER SIPSEY FORK SHU (22)

- McGregor, S. W., 1992, A mussel survey of streams draining Bankhead National Forest and the Oakmulgee Division of Talladega National Forest, Alabama: Alabama Geological Survey Open-File Report to National Forest Service.

- Mettee, M. F., O'Neil, P. E., Pierson, J. M., and Suttkus, R. D., 1989, Fishes of the Black Warrior River system in Alabama: Alabama Geological Survey Bulletin 133, 201 p.
- Shepard, T. E., O'Neil, P. E., McGregor, S. W., and Henderson, W. P., 2001, Biomonitoring in the upper Mulberry Fork watershed, 1999-2001: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
- Shepard, T. E., O'Neil, P. E., Mettee, M. F., McGregor, S. W., and Henderson, W. P., 2002, Status surveys of the Cahaba shiner (*Notropis cahabae*), coal darter (*Percina brevicauda*), and Tuskaloosa darter (*Etheostoma douglasi*) in the Locust Fork and Valley Creek systems, Alabama, 2001: Alabama Geological Survey Circular 201, 19 p.
- Shepard, T. E., O'Neil, P. E., McGregor, S. W., and Henderson, W. P., 2002, Biomonitoring in the Mulberry Fork watershed, 1999-2002: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
- McGregor, S. W., Wynn, E. A., and Garner, J. T., 2010, Results of a survey of the mussel fauna at selected stations in the Black Warrior River system, Alabama, 2009-2010: Alabama Geological Survey Open-File Report 1006.
- McGregor, S. W., Wynn, E. A., and Garner, J. T., 2011, Results of a survey of the mussel fauna at selected stations in the Black Warrior River system, Alabama, 2009-2011: Alabama Geological Survey Open-File Report 1114.
- Garner, J. T., Holifield, T. H., Fobian, T. B., Tarpley, T. A., and Johnson, P. D., 2012, Survey of Black Warrior River drainage aquatic snails: Alabama Department of Conservation and Natural Resources Section 6 Report to the U.S. Fish and Wildlife Service, 37 p.
- McGregor, S. W., Wynn, E. A., and Garner, J. T., 2013, Results of a survey of the mussel fauna at selected stations in the Black Warrior River system, Alabama, 2009-2012: Alabama Geological Survey Open-File Report 1301, 43 p.
- Garner, J. T., Johnson, P. D., Buntin, M. L., Fobian, T. B., Holifield, J. T., Tarpley, T. A., Whelan, N. V., and McGregor, S. W., 2013, Black Warrior River drainage aquatic snails: Alabama Department of Conservation and Natural Resources Section 6 report to U.S. Fish and Wildlife Service, 19 p.

LOCUST FORK SHU (23)

- Barclay, L. A., and Howell, W. M., 1973, Icthyofauna of the Locust Fork of the Black Warrior River system of Alabama: Journal of the Alabama Academy of Science, v. 44, no. 2, p. 120-146.
- O'Neil, P. E., and Shepard, T. E., 2003, Water-quality assessment of the Locust Fork watershed, Alabama: Alabama Geological Survey Bulletin 172, 60 p.
- Shepard, T. E., O'Neil, P. E., McGregor, S. W., and Mettee, M. F., 2004, Biomonitoring in the Locust Fork watershed, Alabama, 1997-98: Alabama Geological Survey Bulletin 175, 61 p.
- Shepard, T. E., O'Neil, P. E., McGregor, S. W., Johnson, C. C., and Wynn, E. A., 2019, Changes in the distribution of fishes in the Locust Fork system and a comparison of biological and habitat condition between 1997-98 and 2009-11: Alabama Geological Survey Bulletin 188, 186 p.
- Wood, J. E., Pugh, M. W., Harris, P. M., McGregor, S. W., and Sandel, M. W., 2021, Extension of Blackfin Darter and Tennessee Dace, and first collection of Western

Blacknose Dace from Locust Fork of the Black Warrior River in 80 years: Southeastern Naturalist, v. 20, no. 1, p. N30-N36.

- Buntin, M. L., Holifield, J. T., Tarpley, T. A., and Johnson, P. D., 2021, Freshwater mussels and gastropods of the main channel Locust Fork of the Black Warrior River, Alabama: Alabama Department of Conservation and Natural Resources Section 6 report to the U.S. Fish and Wildlife Service, 48 p.

ALABAMA RIVER SRRU (24)

- Shipp, R. L., and Hemphill, A. F., 1974, Effects of by-pass canals on fish populations of the lower Alabama River: Mobile, Alabama, U.S. Army Corps of Engineers, Contract Report No. DACW01-73-C-0017.
- McGregor, S.W., and Shepard, T.E., 1995, A survey of the primary tributaries of the Alabama and lower Tombigbee Rivers for listed and candidate species of freshwater mussels, snails, and crayfish, year two: Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources.
- Mettee, M. F., O'Neil, P. E., Shepard, T. E., and Kilpatrick, P. L., 1995, Status survey of the Gulf Sturgeon *Acipenser oxyrinchus desotoi* and Alabama Shad *Alosa alabamae* in the Choctawhatchee, Conecuh, and Alabama River systems, 1992-95: Alabama Geological Survey Section 6 report, Alabama Department of Conservation and Natural Resources, Montgomery, Alabama, 30 p.
- Mettee, M. F., Shepard, T. S., and O'Neil, P.E., 2001, Smallmouth buffalo (*Ictiobus bubalus*) and river redhorse (*Moxostoma carinatum*) movements in the Alabama River (2000-01): Alabama Geological Survey Section 6 report for the Alabama Department of Conservation and Natural Resources, 29 p.
- Mettee, M. F., Shepard, T. E., O'Neil, P. E., McGregor, S. W., and Henderson, W. P., 2003, Biology of a spawning population of *Cycleptus meridionalis* in the Alabama River: Southeastern Association of Fish and Wildlife Agencies Proceedings, v. 57, p. 59-67.
- Mettee, M. F., Shepard, T. E., O'Neil, P. E., McGregor, S. W., and Henderson, W. P., Jr., 2004, Status survey of the southeastern blue sucker (*Cycleptus meridionalis*) in the Alabama River, 1995-2004: Alabama Geological Survey Open-File Report 0504, 24 p.
- Mettee, M. F., O'Neil, P. E., Shepard, T. E., McGregor, S. W., and Henderson, W. P., 2005, Paddlefish (*Polyodon spathula*) movement in the Alabama River, 2002-2004: Alabama Geological Survey Open-File Report 0503.
- Mettee, M. F., O'Neil, P. E., Shepard, T. E., McGregor, S. W., and Henderson, W. P., 2005, Paddlefish (*Polyodon spathula*) movement in the Alabama River, 2001-2005: Alabama Geological Survey Open-File Report 0523.
- Mettee, M. F., O'Neil, P. E., Shepard, T. E., and McGregor, S. W., 2005, A study of fish movements and fish passage at Claiborne and Millers Ferry Locks and Dams on the Alabama River, Alabama: Alabama Geological Survey Open-File Report 0507.
- Freeman, M. C., Irwin, E. R., Burkhead, N. M., Freeman, B. J., and Bart, H. L., Jr., 2005, Status and conservation of the fish fauna of the Alabama River system: American Fisheries Society Symposium 45, p. 557-585.
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- McGregor, S. W., and Garner, J. T., 2006, An assessment of the freshwater mussel fauna in the Alabama River downstream of Claiborne Lock and Dam, 2006: Alabama Geological Survey Open-File Report 0617.
- Mettee, M. F., O'Neil, P. E., Shepard, T. E., and McGregor, S. W., 2006, Fish movements and fish passage at Claiborne and Millers Ferry Locks and Dams on the Alabama River, Alabama: Alabama Geological Survey Circular 202, 25 p.
- McGregor, S. W., and Garner, J. T., 2007, Results of analysis of the freshwater mussel fauna in the Alabama River downstream of Claiborne and Millers Ferry Locks and Dams, 2006-2007: Alabama Geological Survey Open-File Report 0708.
- Rider, S. J., and Hartfield, P., 2007, Conservation and collection efforts for the endangered Alabama sturgeon (*Scaphirhynchus suttkusi*): Journal of Applied Ichthyology, v. 23, no. 4, p. 489-493.
- McGregor, S. W., and Garner, J. T., 2008, Results of analysis of the freshwater mussel fauna in the Alabama River downstream of Claiborne, Millers Ferry, and Robert F. Henry Locks and Dams, 2006-2008: Alabama Geological Survey Open-File Report 0812.
- Mettee, M. F., O'Neil, P. E., and Rider, S. J., 2009, Paddlefish movements in the lower Mobile River basin, Alabama: American Fisheries Society Symposium 66, p. 63-81.
- Rider, S. J., Henderson, A. R., Powell, T. R., and Ringenberg, T. W., 2010, Status of Alabama Shad (*Alosa alabamae*) in the Alabama River: Montgomery, Alabama Department of Conservation and Natural Resources.
- Buntin, M. L., Fobian, T. B., Garner, J. T., and Johnson, P. D., 2010, Inventory of freshwater mussels in Alabama River Basin tributaries: Montgomery, Alabama Department of Conservation and Natural Resources, Section 6 report to U.S. Fish and Wildlife Service, 23 p.
- Garner, J. T., and Buntin, M. L., 2011, Quantitative sampling of *Pleurobema taitianum* in the Alabama River, Dallas County, Alabama: Montgomery, Alabama Department of Conservation and Natural Resources, Report to the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service, 7 p.
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- Simcox, B. L., DeVries, D. R., and Wright, R. A., 2015, Migratory characteristics and passage of paddlefish at two Southeastern U.S. lock-and-dam systems: Transactions of the American Fisheries Society, v. 143, p. 456-466.
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- McKee, D., 2019, Passage and fine scale movements of Paddlefish and Smallmouth Buffalo near Claiborne Lock and Dam: Auburn, Alabama, Auburn University, unpublished M.S. thesis, 48+viii p.
- Thomas, B. D., 2020, Effects of tagging and translocation on paddlefish in the Alabama River: Auburn, Alabama, Auburn University, unpublished M.S. thesis, 48+vii p.
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- Hershey, H., 2021, Updating the consensus on fishway efficiency, a meta-analysis: Fish and Fisheries, v. 22, p. 735-748.

BOGUE CHITTO CREEK SHU (26)

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CAHABA RIVER SHU (27)

- Van der Schalie, H., 1938, The naiades (fresh-water mussels) of the Cahaba River in northern Alabama: Occasional Papers of the Museum of Zoology, University of Michigan, no. 392, 29 p.
- Baldwin, C. S., 1973, Changes in the freshwater mussel fauna in the Cahaba River over the past 40 years: Tuskegee, Alabama, Tuskegee Institute, unpublished M.S. thesis, 45 p.
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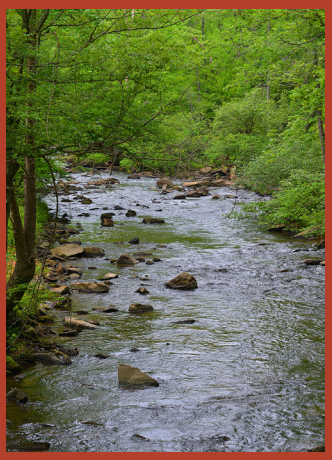

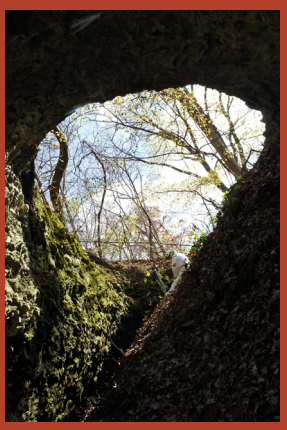

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