American Currents

Publication of the North American Native Fishes Association

Volume 49 Number 2 Spring (April) 2024

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The North American Native Fishes Association

Est. 1972 — John Bondhus, founder

Mission: The North American Native Fishes Association (NANFA) is dedicated to the appreciation, study and conservation of the continent's native fishes. NANFA is a 501(c)(3) not-for-profit, tax-exempt corporation chartered in the State of Maryland. The purposes of the organization are: • to increase and disseminate knowledge about native North American fishes; • to promote practical programs for their conservation and the protection/restoration of their natural habitats; • to advance the educational, scientific and conservation benefits of captive maintenance and husbandry; • to encourage the legal, environmentally responsible collection of native fishes for private aquaria as a valid use of a natural resource; and • to provide a forum for fellowship and camaraderie among its members.

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FRONT COVER: Two Emerald Bowfins *Amia ocellicauda*—including a male in spawning color (top), showing where the species gets its common name—from a wetland slough connected to the Red River in McCurtain County, Oklahoma. (Photos by Brandon Brown)

BACK COVER: A sure sign of spring: a flared-up male Brook Darter *Etheostoma burri* from Indian Creek, Butler County, Missouri. (Photo by Tyler Goodale and Ashlee Burchett)

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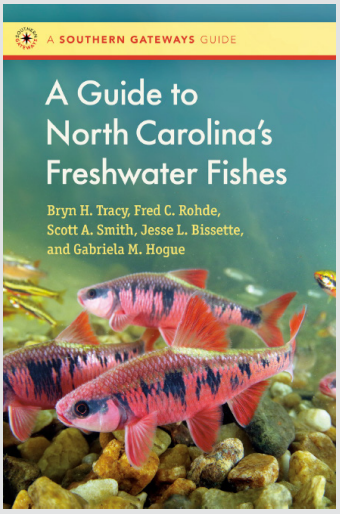
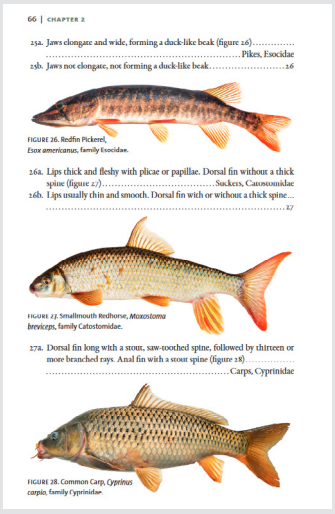
NANFA News

MEMBERS, EVENTS, ACCOMPLISHMENTS, AND ADMINISTRIVIA

NORTH CAROLINA FISHES BOOK NOW AVAILABLE

The initial get together to discuss this book was in 2012, but work didn't begin in earnest until 2020. After four years of serious effort traversing the state photographing fishes, preparing distribution maps, and constructing detailed identification keys, *A Guide to North Carolina's Freshwater Fishes* is now available through the University of North Carolina Press or Amazon. Authors are NANFA members Bryn Tracy, Fritz Rohde, and Scott Smith, along with fellow NCFishes.com team members Jesse Bissette and Gabriela Hogue. The 454-page book contains the history of ichthyology in North Carolina, information on the 40 families found in the state, updated taxonomy and detailed identification keys, maps, full-color images for all 258 fishes found in North Carolina, a photo glossary of morphological characters, and an appendix explaining the meanings behind scientific names. The paperback and an e-book are available from https://uncpress.org/book/9781469678115/a-guide-to-north-carolinas-freshwater-fishes/. Please use the friends promo code 01UNCP30 to get a 30% discount.

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MINNESOTA'S "NATIVE FISH BILL" UPDATE

In 2023, the Minnesota legislature passed a law that supporters promoted with this catchy name. The intent was to remove the negative term "rough fish" from laws and rules so native fishes are no longer managed with invasive species such as carp. As it stands, "rough" will remain, but the distinction will be made. It is the first comprehensive native fish conservation legislation in any state.

As of late March 2024, relevant committees in both chambers of the Minnesota legislature have held hearings on new bills that make a number of changes to state statutes to continue the process. Among them is the addition of the word "native" to mentions of "rough fish" anywhere the phrase appears, and the explicit separation of carp from native rough fish when appropriate. Importantly, "native rough fish" are added to the list of animals that have restitution values, meaning that anyone who violates regulations (such as possession or bag limits, seasons, etc.) can be effectively prosecuted. Previously, only "game fish" and minnows had this protection.

It is also notable that fish species are scientifically defined in this legislation, rather than being listed by common names. Where the statute currently says "'Rough fish' means carp, buffalo, sucker, sheepshead, bowfin, gar, goldeye, and bullhead," the new language will read, "'Native rough fish' means Amiidae (bowfin), Catostomidae (bigmouth, smallmouth, and black buffalo; white, blue, spotted, and longnose sucker; northern hogsucker; quillback; river and highfin carpsucker; and black, river, shorthead, golden, silver, and greater redhorse), Hiodontidae (goldeye and mooneye), Ictaluridae (black, brown, and yellow bullhead), Lepisosteidae (longnose and shortnose gar), and Sciaenidae (freshwater drum), except for any fish species listed as endangered, threatened, or of special concern [which are regulated separately]."

In February 2024, Jay Hatch (Minneapolis) attended the annual meeting of the Minnesota Chapter of the American Fisheries Society. He provided the following abstract (edited for length) of a presentation updating on progress of implementing the law thus far:

"Towards a Sustainable Future for Minnesota's Native Rough Fish" was presented by Shannon J. Fisher of the Minnesota Department of Natural Resources (DNR). The abstract began, "Attitudes have shifted and creating a sustainable future for Minnesota's native rough fish has become a higher priority. In a public questionnaire (N=592), 91% of respondents indicated that they believe native rough fish are critically important to lake and stream ecology." The survey also showed that 79% supported regulations to protect native fishes. The "legislature agrees…that it is time to take a hard look at how we manage native rough fish species." Legislation passed in 2023 tasked the DNR with developing "recommendations for statutory/rule changes, research needs, and outreach efforts to create a sustainable future for native rough fish." The DNR "brought together an internal technical team, established an external work group, provided a public input opportunity, mined available data, and considered peer-reviewed literature" to come up with a set of recommendations. The DNR's report is at https://files.dnr.state.mn.us/aboutdnr/reports/legislative/2023/fy23-native-fish-conservation-report.pdf

The legislation will continue to develop in 2024, as the new bills progress through both the House and Senate. Numerous NANFA members are involved in working toward these changes, and we hope that a more detailed article about the process of getting a state to enact (and enforce) native fish conservation will appear soon in *AC*. To stay abreast of developments, follow @nativefish4tomorrow on Instagram or visit their website at nativefishfortomorrow.org.

In March, Fritz Rohde submitted a letter to the House Environment and Natural Resources Finance and Policy committee on behalf of NANFA in support of the bill and "Minnesota's efforts to manage and delegate value to these important native species."

Please forward news items about NANFA and NANFA members to Konrad Schmidt: ssminnow@usfamily.net

VERY FEW PEOPLE KNOW IOWA DOES NOT YET HAVE AN OFFICIAL STATE FISH!

Male Iowa Darter from Fish Lake, Le Sueur County, MN. (Photo by Konrad Schmidt)

In 2021, NANFA member Mike Hawkins (Iowa Department of Natural Resources Fisheries Biologist, Spirit Lake, Iowa) began campaigning with the Iowa Chapter of the American Fisheries Society (AFS) to nominate the Iowa Darter as the Iowa State Fish. There is obviously no better choice! In 1889, David Starr Jordan and Seth Meek described the species, erroneously believing it was endemic to Iowa. It proved to be a very widespread species in Upper Midwestern states. In January 2024, the Iowa state legislature filed a joint resolution (HJR 2021) to make it so. The bill had a great deal of momentum, but stalled in the Natural Resources Committee and will not be brought to a vote this year. Mike hopes they will try again next year.

NATIVE FISH OUTREACH IN THE NORTHERN MIDWEST

Dylan Bane (NANFA's Illinois rep) had originally reached out to me (Tony Long, Hayfield, Minnesota) asking if I was interested in helping him host a NANFA table at the Southern Wisconsin Fish Swap on February 18th. This was that group's first swap, and I happily agreed. Not long after that, I found out that the Minnesota Aquarium Society (MAS) was going to hold their first fish swap on February 11th, so I secured a table there as well. I had never done anything like this, but ideas for what a NANFA display could look like were flying through my head.

The MAS swap turned out to be a great practice run for how to organize a display table. I wanted to showcase what we are about and that NANFA has something to offer everyone, so I created a poster and had it printed, got some *American Currents* to hand out, and gathered an array of native fish books. Our table also had a 10-gallon tank with locally sourced fish from my aquariums—including Rainbow *Etheostoma caeruleum,* Fantail *E. flabellare,* and Johnny *E. nigrum* darters—my Perfect Dipnet, and a screen playing my video from the 2023 NANFA convention on a loop. Andrew Herberg joined me for the swap, and we had a lot of folks gather around to see the fishes, watch the video, and ask questions. It went great and I had a good game plan for the Wisconsin swap.

Now, the Wisconsin swap was going to be quite a bit larger, but I streamlined my process, knew what to expect, and was ready. I met Dylan there, and Johnathan Butkus joined us in the beginning as well. We were quickly set up and ready to tell folks what we are all about. I had made a few pre-orders for live food cultures, plants, and some livestock, so we walked around a bit prior to opening to see what everyone had to offer, bought a few more things, and then settled in as the public started to line up at the entrance. We had constant engagement almost the entire time. It was AWESOME! Dylan and I could hardly catch our breath as we talked to so many people. People loved our display and the fish in the tank, grabbed copies of *American Currents,* thumbed through the books, and asked a million questions. Later, we heard there were over 1,000 attendees. It was an incredibly fun time with friends, and we all look forward to doing more in the future.

Tony, Dylan, and Johnathan at the Southern Wisconsin Fish Swap.

CONSERVATION FISHERIES (CFI) ANNUAL STOCKING REPORT

CFI is a non-profit organization in Knoxville, Tennessee, that was founded in 1986 by J.R. Shute and Pat Rakes. CFI is a captive propagation facility dedicated to the preservation of aquatic biodiversity in streams and rivers. Over the last few decades, CFI has developed techniques to propagate more than 80 non-game fishes, including some of the most imperiled species in the southeastern United States. CFI was the first private facility in the Southeast to propagate rare, non-game fishes for recovery work.

Spotfin Chub (Photo by Derek Wheaton, a member of the NANFA Board of Directors and part of the CFI team)

Boulder Darter (Photo by Zach Alley)

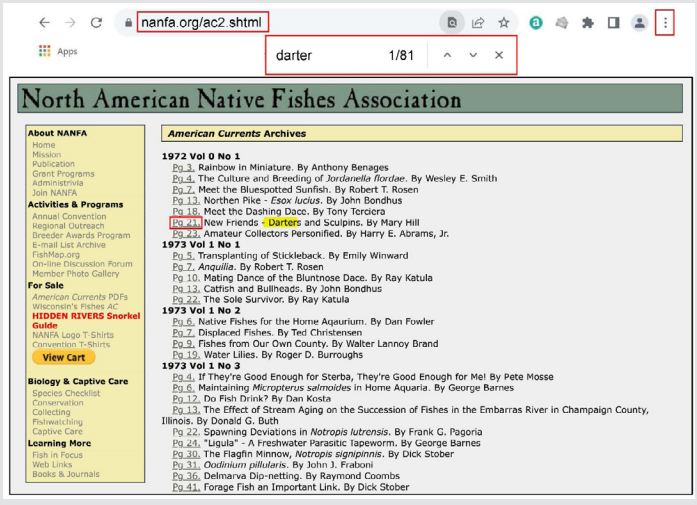
CFI's primary goal is to restore fish populations that have been eliminated due to various anthropogenic impacts. The facility also produces many rare or difficult-to-collect species for other purposes related to aquatic conservation.

In 2023, CFI worked with 15 species representing 19 wild populations and released a total of 14,187 fish into the wild for restoration projects. Species and numbers released include:

- Spotfin Chub *Erimonax monachus* (10,962)
- Tennessee Dace *Paranotropis leuciodus* (998)
- Carolina Madtom *Noturus furiosus* (453)
- Yellowfin Madtom *N. flavipinnis* (302)
- Boulder Darter *Nothonotus wapiti* (453)
- Buck Darter *Etheostoma nebra* (433)
- Duskytail Darter *E. percnurum* (386)
- Roanoke Logperch *Percina rex* (190)

You can find CFI on social media or visit them on the web at https://www.conservationfisheries.org

A HIDDEN FISHY TREASURE TROVE



Buried on the NANFA website is a goldmine of information about native fishes. There is a link provided on the Publication page and the URL (nanfa.org/ac2.html) can be found at the bottom of the Member Services section of *American Currents*. The Archives page lists articles published from the first issue in 1972 up to the current year. A Google search will find most of the articles if the entire title is known, but, as in the above image, using your browser's search function on the page allows you to find any title that includes the word(s) you want. Search terms can be full or partial titles or author names, common or scientific names of fishes, or activities such as collecting, micro-fishing, photography, or snorkeling.

In most browsers all you have to do to search any page is hit ctrl-f (Windows)/command-f (Mac). On mobile devices there is usually a menu (often shown as three horizontal lines or three dots), in which there is a choice similar to "find in page." In the example, searching for "darter" found 81 articles and highlighted the matching keyword everywhere it appeared on the page. There are usually up and down arrows to navigate through the results. Clicking the page numbers next to an article title loads a PDF that can be read online or downloaded.

The archives are invaluable to researchers performing literature reviews, fisheries biologists managing lesser-known species, naturalists looking for background information to use in interpretive programs, and anyone wishing to learn more about the aquatic world or looking for new ways to follow their pursuits.

A FISHY READING LIST FROM ZOOLOGY 510: ECOLOGY OF FISHES

John Lyons teaches this course at the University of Wisconsin – Madison, and one of the assignments for his students is reading one of 50 non-technical, "popular" books about fishes and fishing and writing a report. You can skip the not-so-fun report, but may enjoy picking up one or more of these. No one is ever too old to learn something new! The following are John's top 10 titles from the full list. Note that only the Brown, Cook, Halverson, and Carey books (in part) deal with North American freshwater fishes (including anadromous species).

- **Kevin C. Brown, *Devils Hole Pupfish: The Unexpected Survival of an Endangered Species in the Modern American West*** (2021)
  The story of a tiny fish restricted to a small hot spring in a sinkhole in the Nevada desert in Death Valley National Park—the smallest natural habitat for any vertebrate in the world—and how the fight to preserve it has had broad and important implications for conservation and water policy in dry areas of the United States.
- **Richard Adams Carey, *The Philosopher Fish: Sturgeon, Caviar, and the Geography of Desire*** (2005)
  A journey across the globe to uncover the secrets of the highly endangered sturgeons, meeting the real-life characters profiting from their scarcity and those fighting to save them.
- **Langdon Cook, *Upstream: Searching for Wild Salmon from River to Table*** (2017)
  An investigation into the role of Pacific salmon in their environment and in human culture, from Native Americans to commercial fisheries, from government biologists to chefs and fine restaurants, and a discourse on the future of wild salmon and how they might be saved.

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Oklahoma is home to about 175 species of fish, including **Golden Topminnows, Bluehead Shiners, Creole Darters, Red River Pupfish, Cardinal Shiners, Banded Pygmy Sunfish, Paddlefish,** and **Alligator Gar.** This high species number is due largely to Oklahoma's varied climate, geology and topography, all of which contribute to its high habitat diversity. Although few people realize it, Oklahoma is **one of only four states with more than 10 ecoregions** (or broad habitat types) and, **per square mile, is the most habitat-diverse state in the contiguous United States**.

NANFA's 2024 Convention will be held in far southeast OK where the Ouachita Mountains meet the Gulf Coastal Plain. This area holds **one of the state's most diverse fish assemblages,** and **both upland and lowland species** can be collected within a short drive of each other. **Species likely to be encountered include Orangethroat, Orangebelly, Slough, Cypress, Dusky, Channel, Harlequin and Creole darters, Western Starhead and Golden topminnows, Banded Pygmy, Longear and Bantam sunfish, Flier, Ouachita Mountain Shiners, and Grass Pickerel**.

The park is holding **30 cabins** for NANFA members until **March 1, 2024.** They cost approximately $115 – $170/night and can hold multiple guests. The Beavers Bend Lodge is holding **27 rooms** for NANFA members until **April 6, 2024.** They cost approximately $132 (2 queens) – $185 (suites). **Any cabins or rooms not reserved with deposits by the deadlines will be released.** Cheaper rooms are available in Broken Bow and Idabel. A new Choctaw Nation Lodge, scheduled to open in April, might be a good option. We're also working on a few low-cost (maybe even free) rooms for students approximately half an hour away. Beavers Bend State Park has seen a dramatic increase in visitation the past few years and is the most-visited state park in Oklahoma. **Rooms and cabins will fill quickly, so please make reservations as early as possible.**

Beavers Bend State Park Cabins (where the meeting room is): **580-494-6300.**

Beavers Bend Lakeview Lodge (a few miles away): **580-494-6179.**

Or reserve at **https://www.travelok.com/state-parks/beavers-bend-state-park**

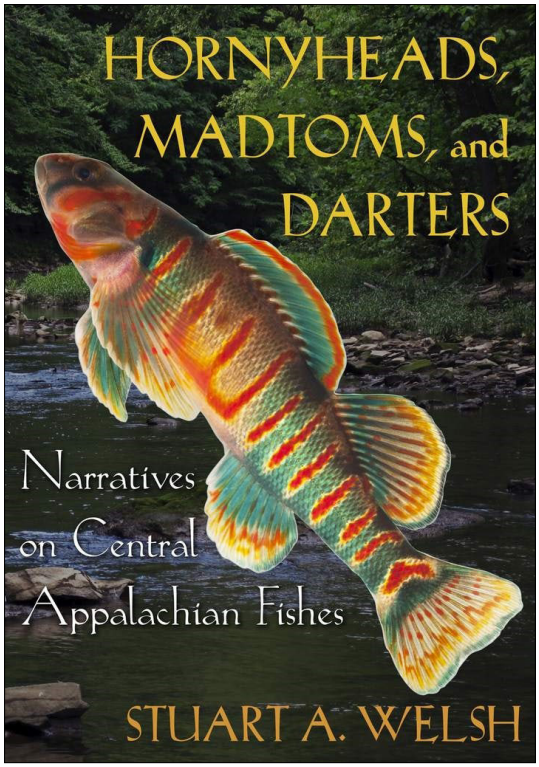
BOOK REVIEW

HORNYHEADS, MADTOMS, AND DARTERS: NARRATIVES ON CENTRAL APPALACHIAN FISHES

Christopher Scharpf

The ETYFish Project

Birders have lots of books detailing the behavior and ecology of their subjects. After all, birds are easily seen and observed. North American freshwater fishes, not so much. Many "Fishes of …" books tend to be field and identification guides. Diagnostic characters. Distribution. Habitat. And maybe a short paragraph on the fish's life history or ecology. *Hornyheads, Madtoms, and Darters: Narratives on Central Appalachian Fishes*[1] is a welcome departure. It's a full-bodied natural history, written by a fisheries research scientist, Stuart A. Welsh, who prefers to study fishes in the wild, not the lab.



Welsh's writing style harkens back to, and includes numerous excerpts from, naturalists of the 19th and early 20th centuries. Welsh says these naturalists wrote when "science writing was less concise." Yes, maybe so. But no one can deny their writings are more fun to read than papers in contemporary academic journals. Welsh admirably continues their tradition, penning what he calls "narratives," short but detailed essays on the fishes of Central Appalachia, a region he defines to encompass the eastern parts of Kentucky and Ohio, West Virginia, western Virginia, parts of southern and central Pennsylvania, western Maryland, and a small part of southern New York.

While emulating the "less concise" style of "old-school" naturalists, Welsh doesn't skimp on concise modern-day science. His essays are jam-packed with the latest research and insights into fish ecology, ethology, and physiology. In the essay on Logperch *Percina caprodes*, for example, Welsh delves into physics, mathematics, and optical illusions to explain how the Logperch's vertical stripes confound potential predators. In the next chapter, Welsh uses game theory and the Prisoner's Dilemma to explain "predator inspection," which is when one or more potential prey fishes leave the safety of their shoal to get a closer look at the bigger fish that's trying to eat them. And in the chapter on Eastern Sand Darter *Ammocrypta pellucida*, Welsh uses aerodynamics to explain how the darter, not a particularly strong swimmer, can nevertheless remain motionless in swift water. All fascinating stuff.

Here's a small sampling of some of the other topics Welsh covers: The role of lampreys in stream nutrient cycling. The vital link between Hemlock trees and Brook Trout populations. The head-scratching riddle of the Trout-perch, which is neither trout nor perch. "Cross-dressing" Bluegills. And why the Smallmouth Bass is the "gamest fish that swims." No fish is too obscure or too well-known. They're all worthy of study and admiration, and they all have revelatory stories ("narratives") to tell.

For me, personally, Welsh's most revelatory narrative is the one on the Creek Chub *Semotilus atromaculatus*. As regular readers of *American Currents* might know, my research focus is the etymology of fish names. One of my unbreakable rules in conducting this research is never to rely on secondary sources, such as regional "Fishes of …" books, no matter how good they are. Instead, I should always begin with the original publication in which the name was proposed. I broke this rule with *Semotilus atromaculatus*.

Physician-politician-naturalist Samuel L. Mitchill (1764–1831) described the species as *Cyprinus atromaculatus* in 1818. The specific name means "black spotted." At my ETYFish Project website (etyfish.org), I said that the black spot in question is the black spot at the anterior edge of the dorsal-fin base. This explanation is given in two major books: *Freshwater Fishes of Virginia* (Jenkins and Burkhead, 1994) and *Fishes of Alabama* (Boschung and Mayden, 2004). Indeed, the dorsal-fin spot is a major diagnostic character of the species. The trouble is, Mitchill never mentioned this dorsal spot in his brief description. Instead, he mentioned that the fish's back, sides, belly, and fins are "marked by black dots, consisting of a soft or viscous matter, capable of being detached by the point of a knife without lacerating the skin …".

In the chapter titled "Spots and Dots," Welsh sets me straight on the meaning of the name. He explains that the "black dots" of Mitchill's specimen are external black cysts that contain a parasit-

[1] *Hornyheads, Madtoms, and Darters: Narratives on Central Appalachian Fishes*. Stuart A Welsh. 2023. Ohio University Press. xvi + 320 p. ISBN: 9780821426104 $26.95 (softcover).

ic flatworm called a trematode. This condition is often called Black Spot Disease, caused by digenean trematodes (flukes) of the families Diplostomatidae and Heterophyidae. The raised black "spots" (actually nodules) are where the parasite has encysted itself in the skin of the fish. The fish serves as a second intermediate host for the trematode. They acquire the parasite from infected snails, the first intermediate host. When fish-eating birds and mammals eat the infected fish, trematode eggs within the feces are released into the water. When the eggs hatch, they parasitize the snails. Then the larvae transform into a free-swimming form, whereupon they infect fish. The cycle then continues. I have collected many Creek Chub (a common fish where I live) and several other species covered with these unsightly black spots. I have not conducted an exhaustive literature search, but I believe Welsh is the first person to offer the trematode explanation for "*atromaculatus*." It clearly makes sense, especially since Mitchill described the black dots as "soft or viscous matter, capable of being detached by the point of a knife without lacerating the skin …". The ETYFish Project entry has since been revised.

The book is well illustrated. An attractive black-and-white sketch-like rendering of a photograph, showing both fish and habitat, opens every chapter. Hardly a spread of the main text goes by without a photo, drawing, diagram, chart, or map illustrating a key concept in the text. The book concludes with 10 pages of appendices, a 16-page glossary for those unfamiliar with ichthyological parlance, 35 pages of bibliographic notes, and an index. Some of the definitions in the glossary seem unnecessary (e.g., caterpillar, renaissance man).

Welsh ends the book mentioning some of the central Appalachian fishes he didn't include (e.g., sturgeons, mudminnows, killifishes). "I hope to write a future companion volume," he says. Put me down for a copy.

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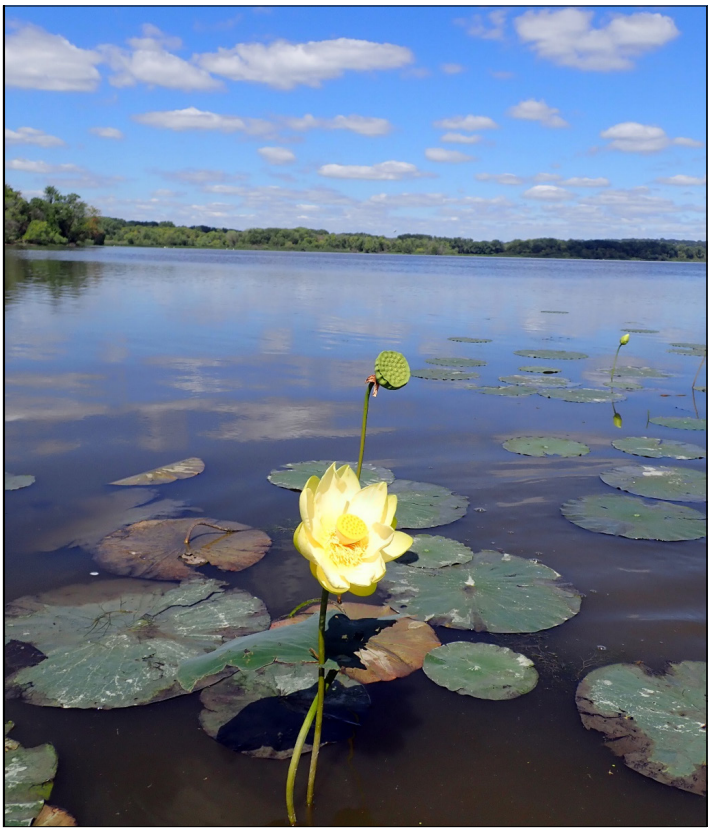
THE FISHES OF PIGS EYE LAKE

Konrad Schmidt

St. Paul, Minnesota

SUMMARY

Pigs Eye Lake is a 629-acre shallow backwater in upper Pool 2 of the Mississippi River downstream of St. Paul, Minnesota. In 2022, artificial islands were constructed in the lake (Figure 1) to reduce wind fetch that has caused chronic and severe turbidity from the resuspension of bottom sediments and erosion of the shoreline (Pigs Eye Lake Master Plan Amendment Draft 2020). There have been very few fish surveys in the study area. The Minnesota Department of Natural Resources (MDNR) conducted the most recent fish survey of the lake in 1999 and the Minnesota Pollution Control Agency (MPCA) surveyed one site in the lower one-mile reach of Battle Creek in 2000 (Figure 3). Fish surveys prior to construction would have been beneficial to assess the efficacy of the project with follow-up monitoring, but MDNR did not schedule a survey beforehand. In 1987, the author was a biologist with the US Fish and Wildlife Service and conducted monitoring surveys following island construction in Weaver Bottoms, a backwater in Pool 5 of the Mississippi River south of Wabasha, MN. He realized the value of having fish survey data from both before and after construction. He learned of the Pigs Eye Lake project in 2019 and decided to conduct fish surveys on a volunteer basis beginning in September 2019 and again from June through September 2020. Multiple sampling gears were deployed, collecting 54 species in 14 families, including one state-threatened species (Black Buffalo *Ictiobus niger*) and one special concern species (Yellow Bass *Morone mississippiensis*) (MDNR 2020).



Pigs Eye Lake Lotus Lily.

Photos by Jennifer Kruckenberg unless otherwise indicated.

PIGS EYE LAKE HISTORY

Pigs Eye Lake is named after Pierre "Pigs Eye" Parrant, who had a defective eye described as having a "sinister white ring around the pupil, giving it a kind of piggish expression." He is believed to be the first European settler to live in what is now St. Paul, where he operated a saloon in Fountain Cave in the late 1830s selling bootleg whiskey to early St. Paul residents and soldiers stationed at Fort Snelling (Wikipedia contributors 2019; Minnesota Fun Facts 2020). Pigs Eye Lake was called Grand Marais (the Great Marsh) by early

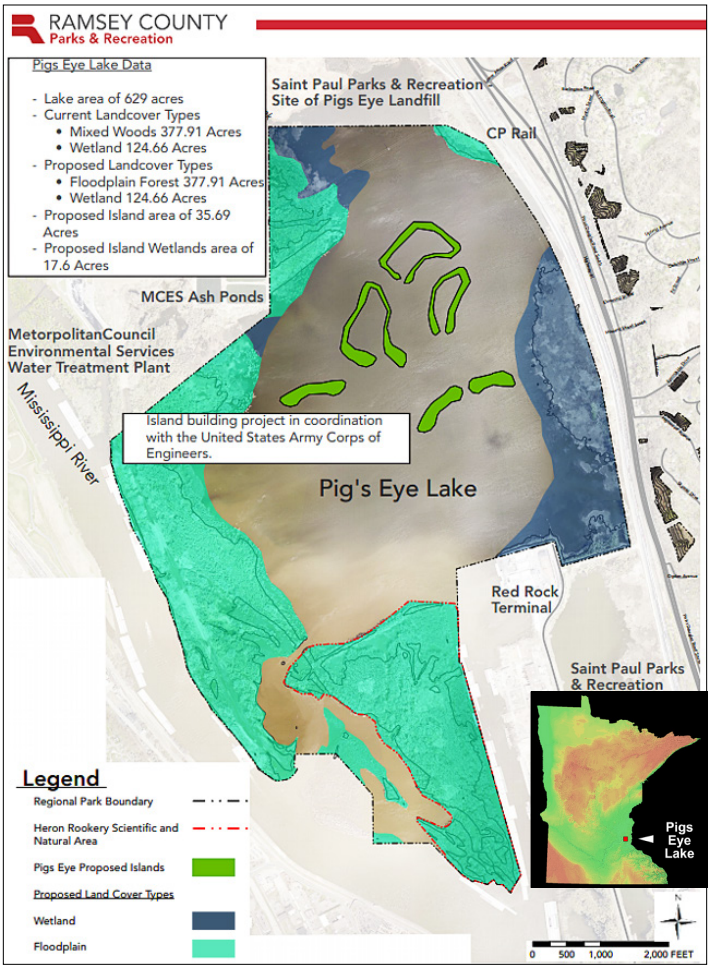


Figure 1. Proposed layout of island construction that began in 2022 and the lake's location in Minnesota (inset).

French fur traders. Battle Creek is named after the Battle of Kaposia between the Dakota and Ojibwe in 1842 (Upham 1969; History of Maplewood 2020). A topographical map of Pigs Eye Lake in 1896 (TopoView 2020) depicts a much smaller lake with an extensive marsh fringe (Figure 2). The accuracy of this map is unknown, but it is georeferenced and importable as a KMZ file to Google Earth Pro. The open water surface area was about 288 acres, which is less than half the size of the lake today. In 1930, the construction of US Lock and Dam 2 on the Mississippi River at Hastings, MN, raised the river level several meters and is responsible for Pigs Eye Lake's current size and depth (Wikipedia contributors 2020).

The Mississippi River, Pigs Eye Lake, and the shared floodplain have incurred multiple and major environmental impacts. The side channels shown on the 1896 map from the Mississippi River that enter and exit Pigs Eye Lake no longer exist. With the rapid development of the Minneapolis-St. Paul urban area in the late 19th and early 20th centuries, the river from the Twin Cities to Hastings became one of the most polluted reaches, with 65 million gallons of raw sewage discharged daily (Anfinson 2003). In 1926, the US Bureau of Fisheries surveyed almost 100 miles of the Mississippi River from St. Paul to Red Wing, MN. Dissolved oxygen levels were less than 1 mg/l and only three fish were found (Rogacki 2017). In the 1960s, the Army Corps of Engineers dredged a channel out of the lake's southwest corner to the Mississippi River and another south to the river for barge traffic. Dredge spoils were used to develop an industrial park along the east bank of the channel (Wikipedia contributors 2020). Battle Creek was re-routed west into an artificial channel through the site of the 236-acre Pigs Eye Dump that operated from 1956 to 1972. The area was then used to dispose of sludge ash from wastewater treatment until 1985 (Metropolitan Council 2023; Starbuck 2013). Following the Clean Water Act of 1972 and improved treatment of waste water, the Mississippi River at St. Paul exhibited a rebirth in the mid-1980s when massive mayfly hatches returned after a decades-long absence (Sector 1987).

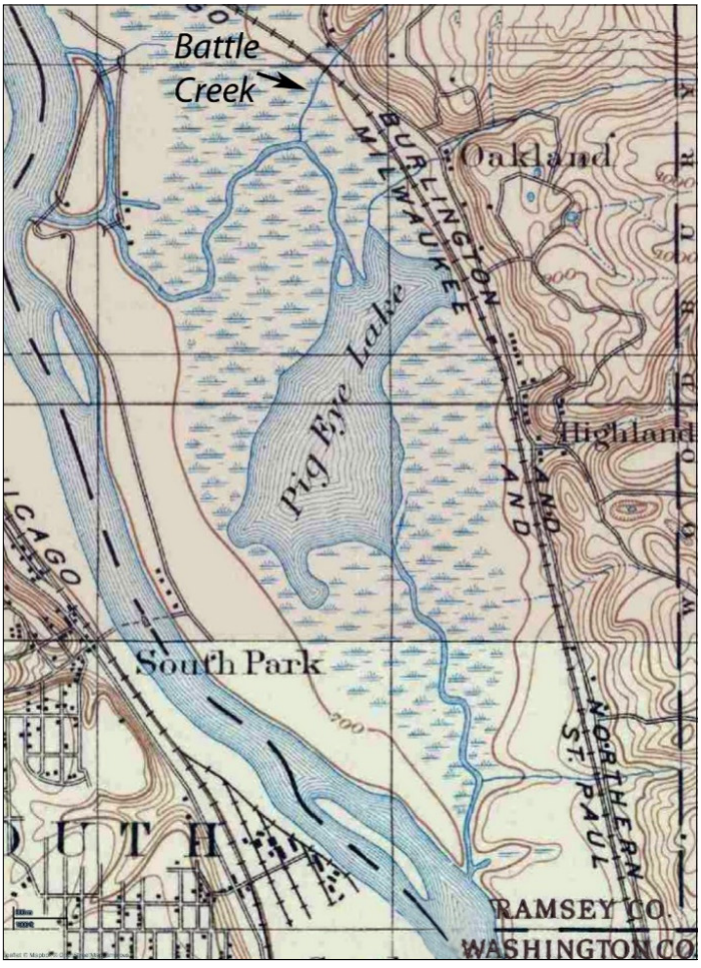


Figure 2. A modified 1896 US Geological Survey (USGS) topographical map of Pigs Eye Lake and the historical stream course of Battle Creek.

PIGS EYE LAKE HABITATS

Four habitat types were sampled in the Pigs Eye Lake study area: (1) the shallow main basin of Pigs Eye Lake, (2) a deep bay off the southwest corner of the lake (AKA Hog Lake), (3) Battle Creek, and (4) a stream tributary entering the lake in the northeast corner (Figure 3). The latter two are channelized streams but have not been recently maintained.

The main basin of Pigs Eye Lake had a maximum depth of about 1.5 m for most of the 2020 field season. Nearshore areas were less than a foot deep. The substrate was predominately silt throughout the lake, but there were pockets of sand at the mouth of Battle Creek

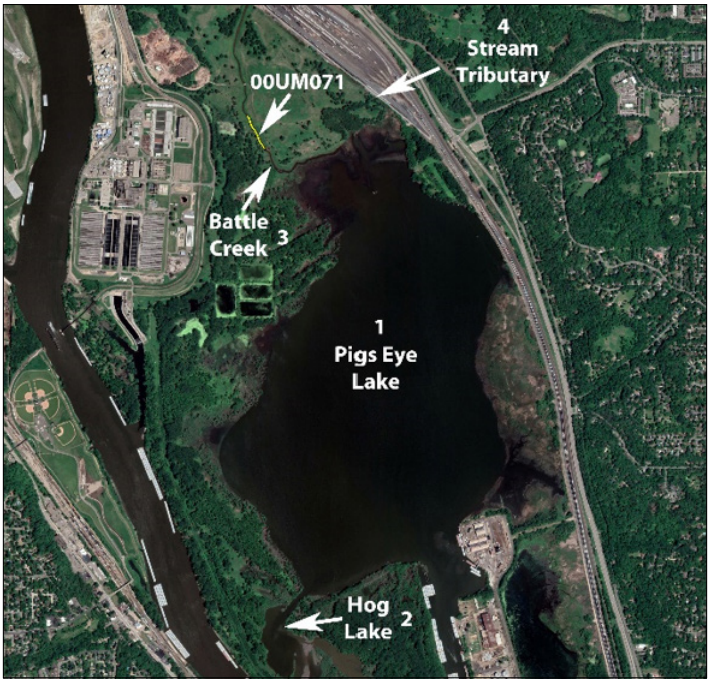


Figure 3. Top: The four habitat types in the Pigs Eye Lake study area. Bottom: Battle Creek at MPCA station 00UM071.

and along the south shore of the heron rookery island. The Central Pacific railroad grade along the northeast shore was the source of a narrow band of gravel and cobble. Floating and submergent aquatic vegetation was restricted to one Lotus Lily bed and Sago Pondweed. The latter was sparsely distributed throughout the lake with one exception in the southwest corner, where it was very dense and filled in the slightly deeper water beyond the Lotus bed.

Hog Lake has the deepest habitat in the study area. A sonar depth of 6.4 m was found on a trawling transect in 2020. However, a dissolved oxygen profile in the most recent (i.e., 1999) MDNR lake survey reported a depth of 8.3 m. The channel connecting Pigs Eye to Hog Lake and most of the lake itself was deeply incised with a hard substrate, likely of clay. The shallow shoreline substrate at the head of the lake was deep silt. The lake's outlet had filled in with sediment and had no connection with Mississippi River during summer flows. Floating aquatic vegetation included very small beds of Smartweed, Lotus Lily, and Yellow Water Lily. Submergent aquatic vegetation included sparse Sago Pondweed, Wild Celery, and Coontail. One active beaver lodge and remnants of others provided habitat for bass, crappie, sunfish, and likely other species.

Battle Creek between the Canadian Pacific railroad and Pigs Eye Lake is about one mile in length. For most of this reach, the stream has very few meanders or riffles and is generally a continuous sand glide with some slightly deeper runs. There are two short reaches of toe wood (MDNR 2010) where the current slows, forming pools that provide excellent fish habitat with woody cover and structure. The stream's edges are lined with aquatic vegetation (Figure 3), which is probably Longleaf Pondweed (Jay Hatch, personal communication). The stream banks have been stabilized with a mixture of limestone, cobble, and small boulders and show very little erosion, with the restored terrestrial vegetation anchoring the soil in place. Where the current slows, the stream turns east to its mouth and the channel widens to a long, sandy run. There are, however, a few pools in this reach that are too deep to wade.

The stream tributary that flows into the northeast corner of Pigs Eye Lake is a straight-line ditch for most of its length impinged against the Canadian Pacific railroad grade. It is a cold, groundwater-fed stream. The channel is a shallow, sandy glide with a few pools formed from woody debris and one scour pool from a culvert downstream of the railroad. Where the stream turns west, the depth increases and small beaver dams impound the channel.

Secchi disk and Secchi tube water transparencies were measured in Pigs Eye and Hog lakes with only the tube used in Battle Creek. Battle Creek was greater than 100 cm, with just one exception following a rain event (25 cm). The main basin of Pigs Eye Lake was

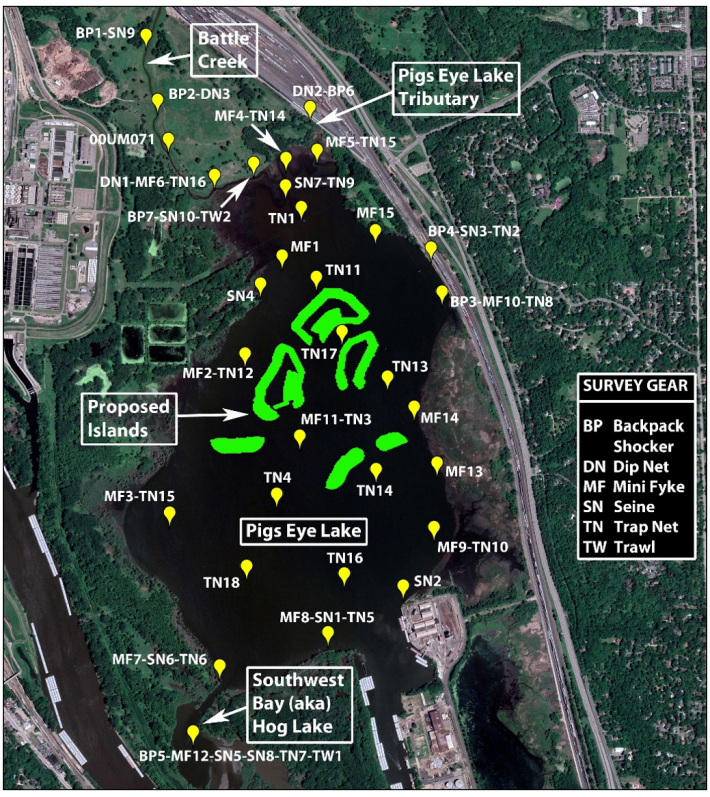


Figure 4. Fish survey stations by sampling gear.

Figure 5. Top: trawling lower Battle Creek. Middle: seining Pigs Eye Lake. Bottom: pulling trap net at entrance to bay.

Figure 6. Some large fishes from Pigs Eye Lake.

always extremely turbid, ranging from 20–31 cm (disk) and 9–14 cm (tube). Only one tube reading (95 cm) was taken near the north end where Battle Creek enters the lake. This clearer water zone extended well southward of station TN1 (i.e., powerline tower). Hog Lake ranged from 56–64 cm (disk) and 25–26 cm (tube).

PIGS EYE LAKE SURVEY STATIONS AND SAMPLING GEAR

Depending on the habitat, survey stations were sampled with multiple types of sampling gear (Figure 4). Gear types included a 12-volt backpack electroshocker (seven stations), three-quarter-inch mesh trap nets (18 stations, single sets), three-eighth-inch mesh minnow seines (10 stations), one-eighth-inch mesh mini-fyke nets (15 stations, single sets), dip nets (three stations), and Missouri trawl (two stations). One-quarter-inch mesh double-funnel minnow traps were used near trap net stations, but these typically produced very low catches. Seining at stations 1–4 and 6 was repeated at least once in 2020. Trawl station 1 was also sampled multiple times and consisted of four transects in Hog Lake and one transect through the channel from Pigs Eye Lake.

Multiple sampling gears were used in the study area (Figure 5). The backpack shocker, seine, and dip net were used in streams and near-shore (wadable) areas of lakes. The dip net was used to rake submergent vegetation or scoop terrestrial vegetation overhanging from stream banks. This gear was also used as a kick net in riffles, root wads, and undercut banks. A trawl was used only in two habitats that were too deep to wade. It was deployed from the bow of the boat. Nearshore areas were too shallow to set trap and mini-fyke nets for most of the 2020 field season. Attempts at sets were made when the water levels briefly rose, but Snapping Turtles damaged the nets and injured or consumed the catch. However, both sampling gears performed very well in deeper water throughout the main basin despite the lack of cover and structure.

All species were identified and tallied from trap and mini-fyke net catches, and fish with total lengths 9 cm and larger were measured. Sampling of the MPCA station survey in Battle Creek (00UM071) followed the same Index of Biotic Integrity (IBI) protocols used by MPCA in 2000. The remaining gear types were used to record only species presence at stations, but were also used to record high and low abundance (i.e., high: estimated catch greater than 50 and low: one to three specimens). Station location, fish species present, and comments were compiled in a database.

THE FISHES OF PIGS EYE LAKE

The 2019 and 2020 fish surveys found 54 species in 14 families (Figure 6, Appendix I), which is an incredible diversity for what appears to be extremely poor habitat and water quality. However, 13 species were extremely rare, having met all of the following criteria: (1) comprised a total catch of one to three specimens during the entire study, (2) found only once or twice, and (3) were restricted to a single habitat type.

The author's assumption before beginning this study was that the fish community would be dominated by an abundance of Common Carp *Cyprinus carpio* and Black Bullheads *Ameiurus melas*. Both are extremely tolerant species that thrive under the worst environmental conditions. The survey results revealed otherwise, with only 21 adult Common Carp and one Black Bullhead captured. Young of the year (YOY) Common Carp were common in June and July but were very rare by August. The presence of Burbot *Lota lota* was unexpected because the species typically inhabits coolwater to coldwater lakes and streams of excellent water quality. There were also several game fish species of harvestable size present that could support recreational angling (Figure 6).

The distribution and diversity of species in the four habitat types varied greatly (Appendix 1). The very poor environmental conditions in Pigs Eye Lake cannot be ignored, but the lake had the greatest number of species (45) of the four habitat types. Hog Lake was second at 34 species, followed by Battle Creek (28), and the stream tributary to Pigs Eye Lake (12). Eight species were found in all four habitats, 11 species in three, 16 in two, and 18 in one. The occurrences of Burbot and Iowa Darters *Etheostoma exile* in Pigs Eye Lake were very unusual; however, both species were restricted to cold, groundwater-fed microhabitats adjacent to the Canadian Pacific railroad.

The composition of fish communities in habitat types typically changes throughout the year (Schmidt 1988, 2013). Adult fish briefly utilize spawning habitats in the spring and early summer, and YOY remain in nursery areas into late summer and early fall. Thirteen species were sampled only during one month from June through September, while 16 species were present every month of the survey.

The minnow seine sampled the most species at 39, followed by the backpack shocker (33), mini-fyke net (27), trap nets (21), trawl (20), and dip net (19). Total catch data were recorded from mini-fyke and trap nets. The mini-fykes were most effective at capturing Emerald Shiner *Notropis atherinoides* (340), followed by Bigmouth Buffalo *Ictiobus cyprinellus* (87), Bluegill *Lepomis macrochirus* (72), Gizzard Shad *Dorosoma cepedianum* (56), and Yellow Perch *Perca flavescens* (52). The trap nets were effective on Bluegill (144), Gizzard Shad (75), Silver Redhorse *Moxostoma anisurum* (29), Black Crappie *Pomoxis nigromaculatus* (25), and Freshwater Drum *Aplodinotus grunniens* (20).

Specimens of most species sampled have been cataloged in the Etnier Ichthyological Collection at the University of Tennessee in Knoxville, where a staff ichthyologist verified identification. The collection database is available online and can be accessed at https://tennfish.utk.edu/catalog.php.

Additional species have been reported in Pigs Eye Lake from other sources. In the early 1990s, Jack Enblom (MDNR Major River Surveys Project Leader, retired) had a discussion with a commercial operator who annually seined Pigs Eye Lake in the spring while the water level was still high. He mentioned at least once his crew seined several juvenile Paddlefish *Polyodon spatula,* all about 70 cm long. Incidental catches of Paddlefish captured with very large commercial seines represent the bulk of known distribution records for this species in Minnesota (Schmidt 1995). More recently, Joel Stiras (MDNR Fisheries Specialist in St. Paul) has been conducting research on movements of several species throughout Mississippi River Pool 2. Fish are captured, implanted with radio transmitters, and released. Monitoring buoys with acoustic receivers detected Paddlefish in Pigs Eye Lake eight times from 2017–2020. In 2018, two Paddlefish were captured and implanted with transmitters in Pigs Eye Lake. Lake Surgeon *Acipenser fulvescens* were detected there three times from 2019–2020. In 2019, one Lake Sturgeon was captured in the lake and added to the study. The MDNR lists Paddlefish as threatened and Lake Sturgeon as special concern (MDNR 2020).

Last, but not least, empty mussel shells were collected throughout the field season and forwarded to Bernard Sietman (MDNR malacologist in Lake City) for identification. Relic shells preserve a historical record of species which once occurred in Pigs Eye Lake, and fresh and recent shells reveal the present community. Bernard's species list includes 17 species (Appendix 2); however, this list includes relic shells of eight species considered rare or extirpated in Pool 2. Bernard defined relic as, "Very old shells often lacking periostracum (outer layer), flaking or fragmented shell. Sometimes, if they are buried, the periostracum is intact but it is faded and discolored. Sometimes these are referred to as subfossil shells which isn't really an accurate term." The MNDR lists four of the eight species as threatened and one as special concern (MDNR 2020). There have been restoration efforts in Mississippi River Pool 2 for all five species.

RECOMMENDATIONS

The Pigs Eye Lake complex provides important spawning and rearing habitats for many species. A long-term monitoring program should be implemented to assess how effectively the proposed islands reduce turbidity and soil erosion and how the fish community responds to these conditions. The MPCA's Citizens Lake Monitoring Program oversees a network of volunteers, who measure water transparencies in Minnesota lakes, and perhaps someone can be recruited for Pigs Eye Lake. Fish surveys should be conducted every five to 10 years. However, the monitoring could be scaled back to the one electrofishing survey in Battle Creek at MPCA station 00UM071 and to the MDNR historical trap netting stations in Pigs Eye Lake. It may be impossible to develop proven and reliable Index of Biological Integrity (IBI) matrices for lakes and streams located so close to the Mississippi River. Instead, a much simpler but coarser filter to assess both habitats would be tracking trends in species diversity (both richness and evenness) and the abundance of extremely tolerant fishes. The list of tolerant species includes Black Bullhead, White Sucker *Catostomus commersonii*, Common Carp, Fathead Minnow *Pimephales promelas*, and, if the species is found in future surveys, Creek Chub *Semotilus atromaculatus*. A desired trend would be higher species richness, increasing index of evenness (e.g., Shannon-Wiener index) (Wikipedia contributors 2021), and low abundance of tolerant species. A negative trend would be a reduction of species diversity and an increase in tolerant species. The concept of evenness has been applied regionally as a fish IBI metric in Minnesota streams (Goldstein et al. 2021).

Aquatic macroinvertebrates are also environmental indicators of recovery, such as the return of mayfly hatches in the Mississippi River during the mid-1980s (Sector 1987). Conversely, the presence and abundance of tolerant species would indicate a negative trend. The MPCA has developed an Invertebrate Community Index (ICI) for streams and the ICI metric lists could serve as a guide to the "good and bad" species. Again, scoring habitats in the study area would present challenges. However, monitoring surveys of the aquatic macroinvertebrate community that coincide with fish community surveys could be one more resource to use in revealing general trends occurring in the ecology of Pigs Eye Lake.

ACKNOWLEDGEMENTS

First and foremost, I must thank Jennifer Kruckenberg (Figure 7). She not only provided the excellent photos used in this report, but also volunteered many days assisting with the surveys. Without her help, it would have been impossible to use most of the sampling gear and there would be very few results to report. Maggie

Figure 7. Jennifer Kruckenberg with a couple of "friends" on Pigs Eye Lake. (Photo by Konrad Schmidt)

Barnick (City of St. Paul) assisted with the Battle Creek survey, and her supervisor, Adam Robbins, helped with locating access to Battle Creek. Scott Mackenthum, (MDNR Hutchinson Area Fisheries Supervisor) loaned the trap nets used in the survey. Without them, this report would have been titled "The *Little Fishes* of Pigs Eye Lake." Joel Stiras (MDNR East Metro Area Fisheries Specialist) provided the historical trap netting data and a summary of Paddlefish and Lake Sturgeon movements in Pigs Eye Lake. Aaron McFarlane (US Army Corp of Engineers) answered many questions about island building and provided the GIS data for the proposed islands used in Figure 4. Bernard Sietman (MDNR Malacologist) identified mussel shells and provided all the information in Appendix 2. Bruce Bauer (UTEIC Ichthyologist in Knoxville, Tennessee) verified my field identifications and Jennifer Parris Brummett (UTEIC Collection Manager) cataloged specimens into the collection. Robert Jenkins (Roanoke College Ichthyologist, now deceased) followed up with final determinations of several troubling YOY redhorse specimens. And Jay Hatch (University of Minnesota) and John Olson (Iowa Department of Natural Resources, retired) reviewed and edited this report.

ADDENDUM

On May 12, 2021, Bernard Sietman and Zeb Secrist (MDNR Center for Aquatic Mollusk Programs) used their electroshocking boat (Figure 8) to conduct fish surveys in Pigs Eye and Hog lakes (KPS21-006-010). The cumulative catch tallied from five transects (Figure 9) was 25 species in nine families. There were no new species added to the 2020 fish survey results (Schmidt 2021b), but one Yellow Bass, a special concern species, was collected off the north shore of the MDNR Pigs Eye Island Heron Rookery Scientific and Natural Area. In 2020, one specimen was also collected off the Canadian Pacific rail grade along the east shore. These are a very significant range extensions north of their currently known distribution in Minnesota. This was the final survey done in Pigs Eye Lake before construction of artificial islands began in 2022.

Figure 8. 2021 Pigs Eye Lake fish survey using a boat shocker.

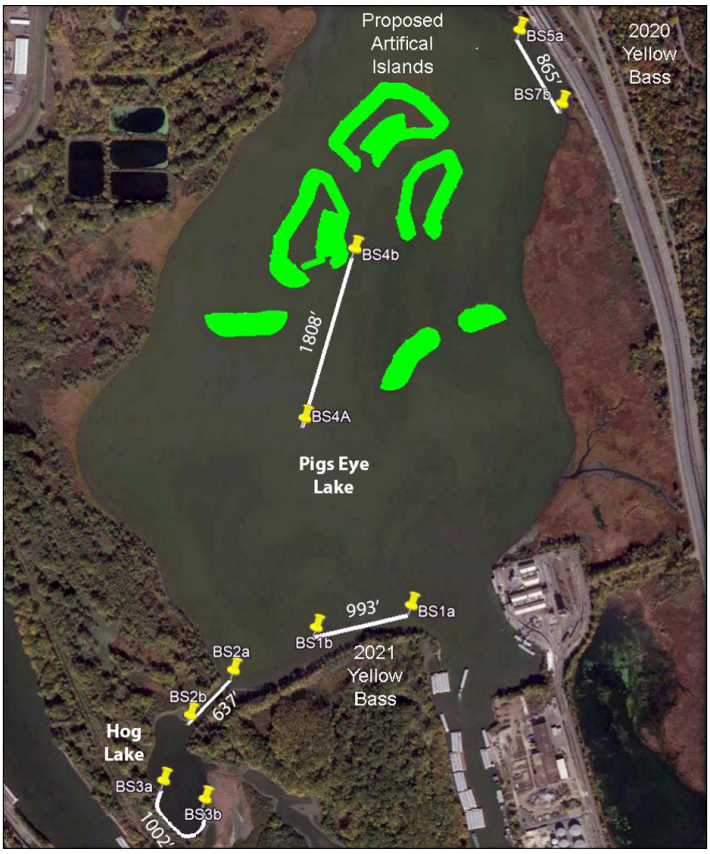


Figure 9. 2021 Pigs Eye Lake boat shocking stations.

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Appendix 1. Species distribution and frequency in Pigs Eye Lake habitats.

Common Name	Scientific Name	Pigs Eye Lake	Hog Lake	Pigs Eye Tributary	Battle Creek	Frequency Total
Gar Family - Lepisosteidae						
Shortnose Gar	*Lepisosteus platostomus*	1				**1**
Bowfin Family - Amiidae						
Emerald Bowfin	*Amia ocellicauda*	5	3			**8**
Thread Herring Family - Dorosomatidae						
Gizzard Shad	*Dorosoma cepedianum*	12	2			**14**
Minnow Family - Leuciscidae						
Central Stoneroller	*Campostoma anomalum*				2	**2**
Spotfin Shiner	*Cyprinella spiloptera*	6	1	1	4	**12**
Common Shiner	*Luxilus cornutus*				2	**2**
Hornyhead Chub	*Nocomis biguttatus*				1	**1**
Golden Shiner	*Notemigonus crysoleucas*	4	2	1	2	**9**
Emerald Shiner	*Notropis atherinoides*	15	4		5	**24**
Spottail Shiner	*Hudsonius hudsonius*	8	3		1	**12**
Weed Shiner	*Alburnops texanus*	2	3			**5**
Channel Shiner	*Paranotropis wickliffi*	2				**2**
Bluntnose Minnow	*Pimephales notatus*				2	**2**
Fathead Minnow	*Pimephales promelas*	8	2	2	3	**15**
Bullhead Minnow	*Pimephales vigilax*	8	3			**11**
Carp Family - Cyprinidae						
Common Carp	*Cyprinus carpio*	21	2	2	6	**31**
Sucker Family - Catostomidae						
River Carpsucker	*Carpiodes carpio*	1	1			**2**
Quillback	*Carpiodes cyprinus*	8	3			**11**
Carpsucker (YOY)	*Carpiodes* sp.	1				**1**
White Sucker	*Catostomus commersonii*	7	1	2	6	**16**
Smallmouth Buffalo	*Ictiobus bubalus*	2				**2**
Bigmouth Buffalo	*Ictiobus cyprinellus*	13	3	1		**17**

Common Name	Scientific Name	Pigs Eye Lake	Hog Lake	Pigs Eye Tributary	Battle Creek	Frequency Total
Black Buffalo	*Ictiobus niger*	1				**1**
Silver Redhorse	*Moxostoma anisurum*	8	2			**10**
Golden Redhorse	*Moxostoma erythrurum*	2				**2**
Shorthead Redhorse	*Moxostoma macrolepidotum*	3	1		3	**7**
Northern Hog Sucker	*Hypentelium nigricans*	1	1			**2**
Redhorse (YOY)	*Moxostoma* sp.					
North American Catfish Family - Ictaluridae						
Black Bullhead	*Ameiurus melas*	1				**1**
Yellow Bullhead	*Ameiurus natalis*				7	**7**
Channel Catfish	*Ictalurus punctatus*	6				**6**
Tadpole Madtom	*Noturus gyrinus*	3			8	**11**
Flathead Catfish	*Pylodictis olivaris*		1			**1**
Pike Family - Esocidae						
Northern Pike	*Esox lucius*	8	1	3	6	**18**
Central Mudminnow	*Umbra limi*			1	5	**6**
Trout-perch Family - Percopsidae						
Trout-perch	*Percopsis omiscomaycus*		2			**2**
Cod Family - Gadidae						
Burbot	*Lota lota*	1			4	**5**
Stickleback Family - Gasterosteidae						
Brook Stickleback	*Culaea inconstans*				1	**1**
Temperate Bass Family - Moronidae						
White Bass	*Morone chrysops*	6	1			**7**
Yellow Bass	*Morone mississippiensis*	2				**2**
Sunfish Family - Centrarchidae						
Green Sunfish	*Lepomis cyanellus*	6	5		6	**17**
Pumpkinseed	*Lepomis gibbosus*	4	4		9	**17**
Orangespotted Sunfish	*Lepomis humilis*	5	1			**6**
Bluegill	*Lepomis macrochirus*	17	4	1	12	**34**
Sunfish (YOY)	*Lepomis* sp.	1				**1**
Hybrid Sunfish	*Lepomis* sp. x *Lepomis* sp.	1	1		1	**3**
Smallmouth Bass	*Micropterus dolomieu*	1				**1**
Largemouth Bass	*Micropterus nigricans*	9	4	2	10	**25**
White Crappie	*Pomoxis annularis*	8	4	1		**13**
Black Crappie	*Pomoxis nigromaculatus*	12	4		2	**18**
Perch Family - Percidae						
Iowa Darter	*Etheostoma exile*	3			8	**11**
Johnny Darter	*Etheostoma nigrum*	2	4			**6**
Yellow Perch	*Perca flavescens*	19	4	3	13	**39**
Logperch	*Percina caprodes*	9	4		4	**17**
Slenderhead Darter	*Percina phoxocephala*	1				**1**
River Darter	*Percina shumardi*	2	3			**5**
Sauger	*Sander canadensis*	2	1			**3**
Walleye	*Sander vitreus*	4	3		4	**11**
Drum Family - Sciaenidae						
Freshwater Drum	*Aplodinotus grunniens*	9	1		1	**11**
Species Total:	**54**	**45**	**34**	**12**	**28**	

Appendix 2. Pigs Eye Lake mussel species identified from empty shells. Identification, shell condition, status, and comments provided by Bernard Sietman (MDNR malacologist). Location coordinates of relic shells are 44.90757/-93.02692 and fresh and recent 44.90619/-93.03336.

Common Name	Scientific Name	Condition	Pool 2 Status	Comments
Mucket	*Actinonaias ligamentina*	Relic	Rare	State threatened. Translocated to Upper Pool 2
Threeridge	*Amblema plicata*	Recent	Common	Young
Asian Clam	*Corbicula fluminea*	Weathered	Exotic	
Wartyback	*Cyclonaias* (formerly *Quadrula*) *nodulata*	Recent	Common	State threatened. Young
Pimpleback	*Cyclonaias* (formerly *Quadrula*) *pustulosa*	Relic	Common	
Butterfly	*Ellipsaria lineolata*	Relic	Very Rare	State threatened. Adults translocated to Upper Pool 2
Elephant Ear	*Elliptio crassidens*	Relic	Extirpated	State endangered
Spike	*Eurynia* (formerly *Elliptio*) *dilatata*	Relic	Very Rare	State threatened. Adults translocated to Upper Pool 2
Wabash Pigtoe	*Fusconaia flava*	Recent	Common	Young
Fragile Papershell	*Leptodea fragilis*	Recent	Common	Young
Threehorn Wartyback	*Obliquaria reflexa*	Recent	Common	Young
Hickorynut	*Obovaria olivaria*	Relic	Extirpated	Present in Pool 3
Round Pigtoe	*Pleurobema sintoxia*	Relic	Very Rare	State special concern. Adults translocated to Upper Pool 2
Giant Floater	*Pyganodon grandis*	Fresh	Common	
Ebonyshell	*Reginaia* (formerly *Fusconaia*) *ebenus*	Relic	Extirpated	State endangered
Monkeyface	*Theliderma* (formerly *Quadrula*) *metanevra*	Relic	Very Rare	State threatened. Reintroduced in 2002.
Deertoe	*Truncilla truncata*	Recent	Common	Young

FIRST REPORT OF ROBUST REDHORSE *MOXOSTOMA ROBUSTUM* SERVING AS HOST FOR SEA LAMPREY *PETROMYZON MARINUS*

Bryn H. Tracy and Brena K. Jones

Apex, North Carolina

North Carolina Wildlife Resources Commission, Aquatic Wildlife Diversity Program, Creedmoor, NC

INTRODUCTION

Research on the distribution, population size, habitat preferences, and tissue contaminants of Robust Redhorse *Moxostoma robustum* in North Carolina has been conducted since the early 2000s. During this time, researchers have sporadically recorded generic wounds that have been observed on Robust Redhorse, most attributable to spawning-related activity or the occasional Otter attack, but the researchers have never observed wounds specifically attributed to Sea Lamprey *Petromyzon marinus*. Here we provide evidence of the first observations of three Robust Redhorse serving as hosts for Sea Lamprey.

Observations were made between late April and early May 2023 during the collection of ripe male and female Robust Redhorse in the Pee Dee River downstream from Blewett Falls Dam in an effort to augment and re-introduce at a future date their progeny back into the Pee Dee River. Efforts were organized by Brena Jones (North Carolina Wildlife Resources Commission [NCWRC]) with assistance from the staffs of Duke Energy, South Carolina Department of Natural Resources, NCWRC's McKinney Lake Fish Hatchery and Aquatic Wildlife Diversity Program, the South Carolina Aquarium, Todd Pusser, and Bryn H. Tracy. All fish collections were made with boat electrofishers.

BACKGROUND ON THE DISTRIBUTIONS OF SEA LAMPREY AND ROBUST REDHORSE IN NORTH CAROLINA

The Sea Lamprey (Figures 1 and 2) is an anadromous species, meaning it spawns in fresh water and juveniles and adults migrate downstream to marine environments to continue feeding and maturing before returning upstream to spawn. The larvae, termed ammocoetes, are free swimming and are found buried in the silts and fines along the stream bank. The transformed juveniles and adults are parasitic, attaching to their host with their toothy and suction-like oral disc (Figure 3). Reported hosts in North Carolina include American Shad *Alosa sapidissima* and Hickory Shad *A. mediocris*.

In North Carolina, the Sea Lamprey is widely distributed in the Coastal Plain, where it has been documented from the Albemarle, Chowan, Roanoke, Tar, Neuse, Cape Fear, Shallotte, and Yadkin basins, as well as in the Atlantic Ocean (Map 1; Tracy et al. 2020). Ammocoetes and adults have been collected from the Yadkin-Pee Dee River drainage in smaller creeks in Anson County, such as Bailey, South Fork Jones, North Fork Jones, and Mill creeks. Although there are five species of lampreys in North Carolina, Sea Lamprey is the only species of found in the Yadkin-Pee Dee River drainage (Tracy et al. 2020).

In North Carolina, Robust Redhorse (Figure 4), a big-river species, is now only found only in the lower Yadkin-Pee Dee River drainage downstream from Blewett Falls Dam (Map 2). It was originally found in the Catawba River basin at Morganton in Burke County and in the Yadkin basin upstream into the South Yadkin River system (Hunting Creek) in Davie and Rowan counties and in the Yadkin River near Donnaha in Forsyth and Yadkin counties (Tracy et al. 2020). Its distribution in the lower Yadkin-Pee Dee River is sympatric with that of the Sea Lamprey (Maps 1 and 2).

Figure 1. Adult Sea Lamprey, 610 mm total length and 51 mm in circumference, netted in Bear Swamp, Halifax County, May 01, 2008, Tar River basin. Fish was captured by backpack shocking into a seine by Chris Eads, Megan McCormick, Sarah McCrae, Rob Nichols, Renee Greiner, and Chris Wood. (Photo by Rob Nichols)

Bryn H. Tracy was the project leader for the wadeable stream fish community assessment program. He has worked in the aquatic sciences field in North Carolina since 1983. His interests in retirement have continued to focus on the history and distribution of the state's indigenous freshwater fish fauna and on the introduction, dispersal, and impact of the ever-increasing list of nonindigenous species.

Brena Jones is the Central Aquatic Wildlife Diversity Coordinator for the Division of Inland Fisheries, North Carolina Wildlife Resources Commission.

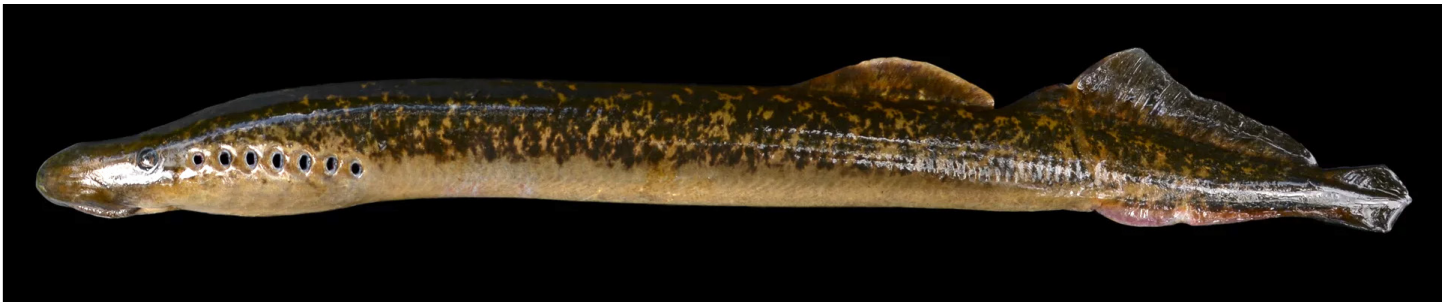
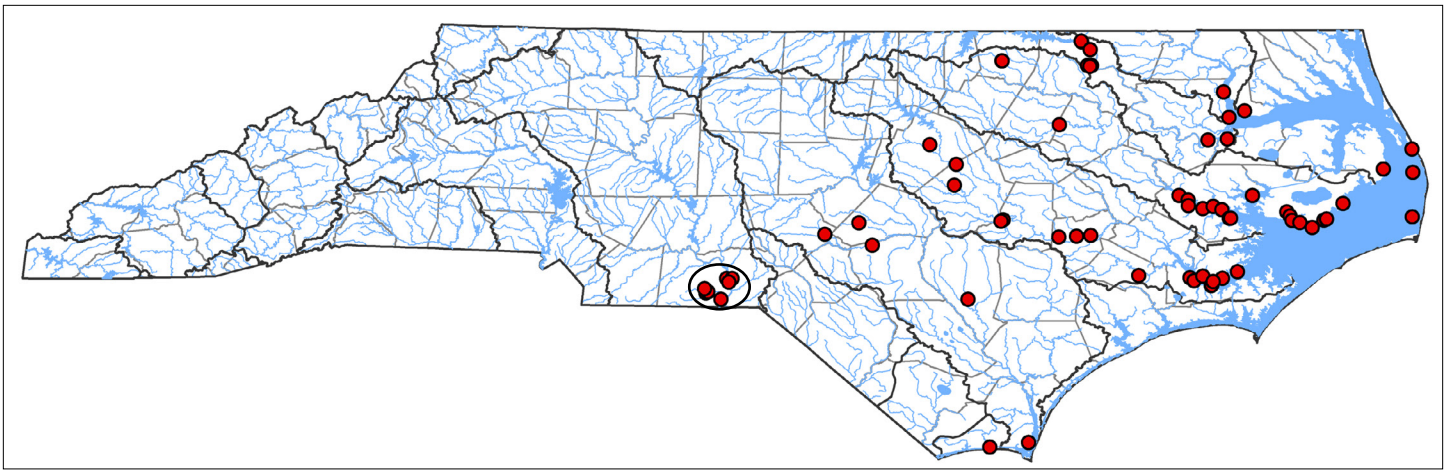
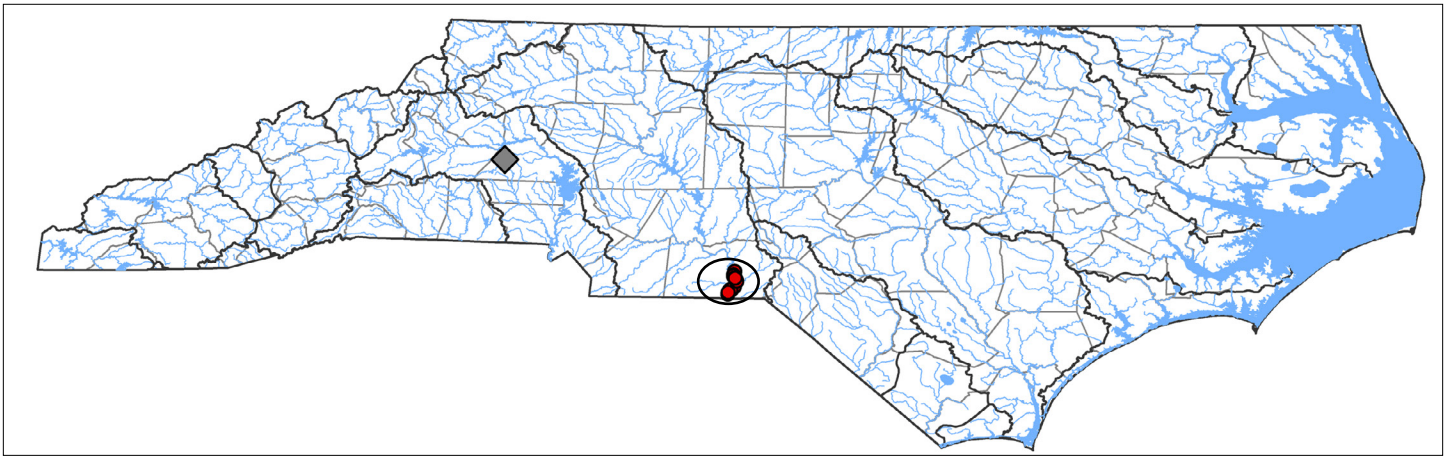


Figure 2. Adult Sea Lamprey. (Photo by Brian Zimmerman)



Map 1. Distribution of Sea Lamprey in North Carolina (Tracy et al. 2020). Records from the Yadkin-Pee Dee River drainage are enclosed within the black oval.



Map 2. Current distribution of Robust Redhorse in North Carolina. Gray diamond indicates presence in that basin (extirpated; no vouchered museum specimens) (Tracy et al. 2020). Records from the Yadkin-Pee Dee River drainage are enclosed within the black oval.

Table 1. Collections of Robust Redhorse from the Pee Dee River in North Carolina showing wounds made by Sea Lamprey.

Fish ID No.	Sex	Total Length (mm)	Weight (g)	Age (yrs.)	Location	County	Location of Wound	Diameter of Wound (mm)
43152D7D1C	Female	692	4910	9	Shoal just above US 74	Richmond	Postero-medial to left pelvic fin	~ 15
444317161A	Male	635	3975	9	Hitchcock Creek Shoal	Richmond	Antero-medial to right pelvic fin	Unknown
486B0A4F0B	Female	675	6065	9	Side channel at Big Island, near the dam	Anson	Medial right caudal peduncle	~ 10

Figure 3. Close-up of oral disk of Sea Lamprey. (Photo by Brian Zimmerman)

Figure 4. Adult male Robust Redhorse. (Photo by Scott A. Smith)

ROBUST REDHORSE SERVING AS HOST FOR SEA LAMPREY

In late April-early May 2023, three adult Robust Redhorse exhibited unusual wounds that differed from the abrasions, fin damage, and occasional punctures seen in the past (Table 1; Figures 5–7). After discussions amongst ourselves, we concluded that the wounds might have been caused by Sea Lamprey due to their characteristic shape and cleanly incised edges. However, without actual Sea Lamprey specimens that were attached to a fish for positive determinations, we had to rely on circumstantial evidence for this conclusion.

The images were verified as Sea Lamprey wounds by staff from National Oceanic and Atmospheric Administration's Maine Field Station (Jeff Murphy) and Maine's Department of Marine Resources (Mitch Simpson) who have years of experience in the identification of Sea Lamprey wounds (Fritz Rohde, personal communication). From Figure 6, Mitch reported to us that: "It looks like the lamprey originally attached above the pectorals and slid back before it could get good penetration. I've seen many fish with scars from lamprey that show how the lamprey moves (downstream [posteriorly]) before attaching securely."

Figure 5. Female Robust Redhorse, Fish No. 43152D7D1C, showing wound made by Sea Lamprey. Top: whole body image; bottom: close-up of wound. (Photos by Brena K. Jones)

Figure 6. Male Robust Redhorse, Fish No. 444317161A, showing wound made by Sea Lamprey. Top: whole body image; bottom: close-up of wound. (Photos by Brena K. Jones)

Despite years of surveys and research activities spanning many thousands of person-hours boat electrofishing the Pee Dee River in North Carolina and South Carolina or other big

Figure 7. Female Robust Redhorse, Fish No. 486B0A4F0B, showing wound made by Sea Lamprey. Top: whole body image; bottom: close-up of wound. (Photos by Vann Stancil)

rivers in in South Carolina and Georgia in search of Robust Redhorse, no Sea Lampreys have ever been reported from Robust Redhorse, either attached or evidence of existing wounds or healed scars. Lamprey parasitism may not kill the fish but may lead to secondary infections or overall poor health and condition of its host.

CONCLUSIONS

With the return and slow increase in population size of the Robust Redhorse to the Yadkin-Pee Dee River drainage, Sea Lampreys may have once again found another one of their ancestral hosts, besides American Shad, after surviving for more than 100 years on large, introduced species such as Blue Catfish *Ictalurus furcatus*, Channel Catfish *I. punctatus*, Smallmouth Buffalo *Ictiobus bubalus*, Common Carp *Cyprinus carpio*, and Grass Carp *Ctenopharyngodon idella*. With its long-lost host having a lifespan of more than 20 years, there will be plenty of time and opportunity for more observations by future researchers of Sea Lamprey attached to, or evidence of prior attachment to, Robust Redhorse in the Pee Dee River in North Carolina and South Carolina.

Reference

Tracy, B.H., F.C. Rohde, and G.M. Hogue. 2020. An annotated atlas of the freshwater fishes of North Carolina. Southeastern Fishes Council Proceedings. No. 60. Volume 1. 198pp.

KEEPING AND CULTURING THE LAKE CHUB: THE GREAT NORTHERN LEUCISCID

Ray Katula

Onalaska, Wisconsin

INTRODUCTION

The Lake Chub *Couesius plumbeus* is an interesting minnow, being the only species in its genus. It is widespread throughout northern regions of North America and is the only minnow found in all of Alaska (Yukon River system), making it the northernmost species of minnow in North America. It also has the widest range of any native North American leuciscid (Page and Burr 2011). Lake Chubs have interesting and endearing behavior in the aquarium and overall make peaceful and hardy community tank co-inhabitants with similar-sized fishes. The genus *Couesius* is named for Elliot Coues (1842–1899), who collected the holotype specimen; *plumbeus* is Latin for lead-colored. NANFA member Konrad Schmidt collected the fish in this article from the Pigeon River system in Cook County, Minnesota. This locality is an isolated population above barrier falls and live fish exhibit some red on the body throughout the year that is slightly enhanced while spawning (Figure 1). Selective breeding may produce a more colorful strain. In comparison, Lake Superior specimens are lead-colored with the exception of some fish that exhibit a red spot only at the base of the pectoral fin.

DIET

The fish I received were juveniles at the time, but they grew very quickly and, like any chub species, had enormous appetites and accepted a wide variety of food items including freeze dried krill, frozen brine shrimp, blood worms, glass worms, and just about any dried food available. Despite their large size—up to 230 mm—they have a moderate-sized mouth. Because Lake Chubs have large optic lobes and only a moderate number of taste buds, Davis and Miller (1967) concluded that the species feeds primarily by sight. Smaller individuals feed on zooplankton, such as cladocerans, and algae; large fish feed on zooplankton as well as terrestrial and aquatic insects. The largest Lake Chubs are reported to consume small fish.

DESCRIPTION

Despite the chub name, this monotypic species looks more like a large minnow. The body, while not quite as stout as a *Nocomis* chub, is moderately stout. The mouth is slightly subterminal. Lake Chubs have a mid-lateral black stripe, which can have a thin green stripe just above it. Their upper body tends to be a dull gray. Below the black lateral line, the belly is usually white to cream in color, and occasionally yellow. The black lateral stripe is more distinctive in the fry of this species. Most of the fins are either clear or slightly reddish with breeding males' fins displaying more red. The dorsal fin is always clear. During breeding, the red coloration becomes more intense in the males, especially ventrally, and is often most intense

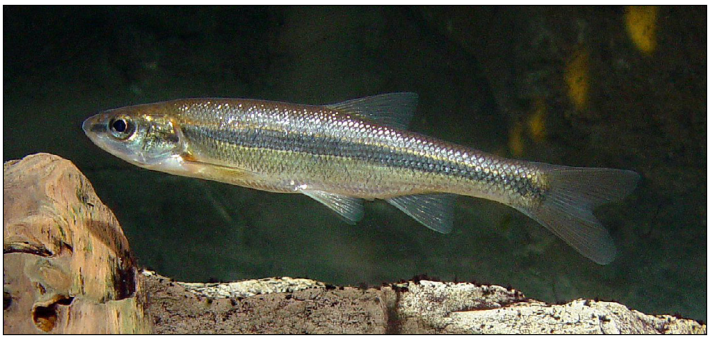


Figure 1. Lake Chubs from above barrier falls in the Pigeon River system (top) and from Lake Superior (bottom). (Photos by Konrad Schmidt)

NANFA Fellow (and past president) Ray Katula is an R&D Technician at Celanese Corporation. He has a degree in Business Management from Minnesota Southeastern Technical College. He had his first exposure to North American fishes while growing up literally on the banks of the Mississippi River. Ray is a charter member of NANFA: he joined at age 11 and at 13 attended NANFA's first annual meeting with founder John Bondhus, who flew them in his private plane. In the 1970s he dabbled in selling fish for the aquarium trade. Ray lived for several years in California and Oregon, where he collected and studied native fishes of the west coast and traded, when possible, for eastern species. He has written several scientific publications and contributed articles to *Tropical Fish Hobbyist, Freshwater and Marine Aquarium Magazine,* and, last but not least, *American Currents*. He has kept fish for almost 60 years and was John Bondhus' fish hatchery manager in southeastern Minnesota. Ray's primary focus is studying fish behavior and breeding native fishes.

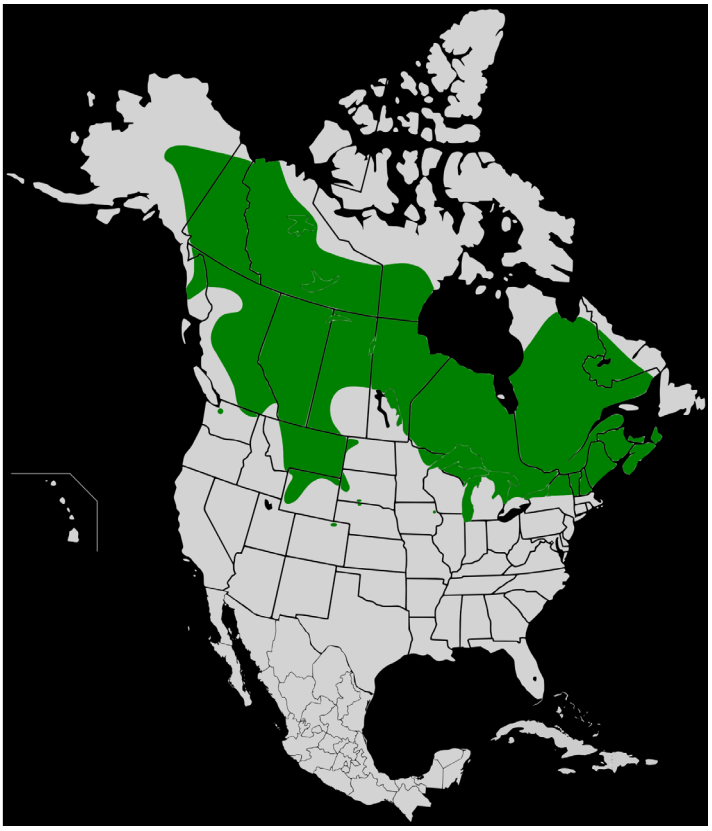


Figure 2. Lake Chub distribution in North America. (Map from Wikimedia Commons)

Figure 3. Lake Chub from Boxelder Creek, Lawrence County, South Dakota. 10/21/2020. (Photo by Matt Wagner, USFWS)

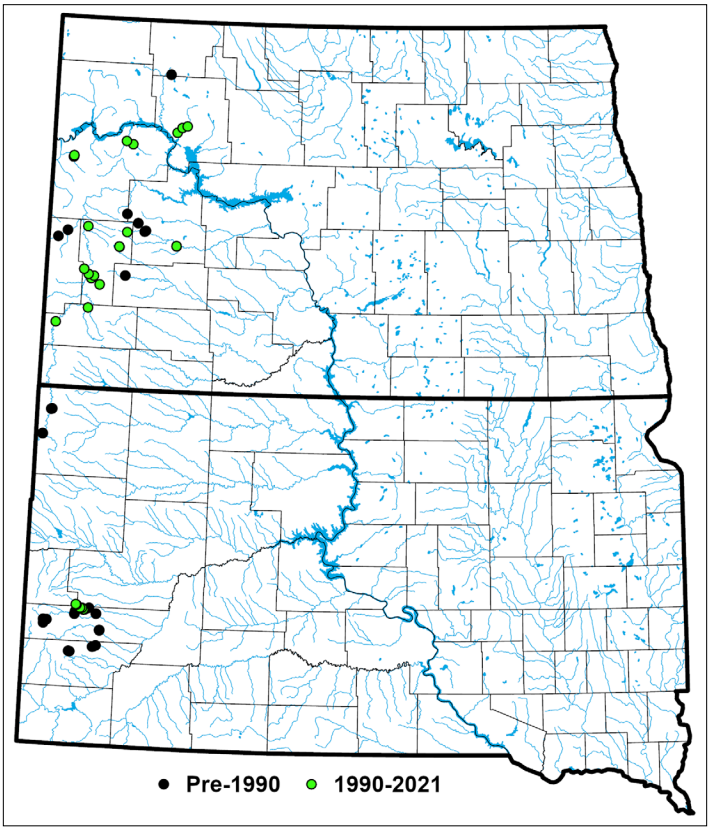


Figure 4. Lake Chub distribution in North and South Dakota. (Map from *Fishes of the Dakotas* [forthcoming])

behind the pectoral fin. Lips can be red, as can areas on their heads. Females sometimes display subtle colors. There is a small barbel at the corner of the mouth; the eye is relatively large. Lake Chubs range from 100–175 mm in length. The largest known specimens were nearly 230 mm (nine inches) long (Seafish Fish Blog 2021). According to Geen (1955), Lake Chubs do not live beyond five years. In aquaria, however, they typically live six to eight years if properly cared for.

RANGE

As mentioned, the Lake Chub has a very wide northern distribution range in North America. They range throughout much of Canada and in portions of the extreme northern US. Looking at the Lake Chub's range map, it is interesting that it might be the only native minnow species to range from the Atlantic Coast to the Pacific Coast (Figure 2), which emphasizes its claim to the widest range of any native leuciscid species in North America. They are found in all the Great Lakes and are said to be common throughout most of their range. In the US, they are found south to the Delaware River in New York, Lake Michigan, and the Platte River system of Wyoming. Relic populations occur in the upper Missouri River drainage in South Dakota, Nebraska, Colorado, and Wyoming, and in the Mississippi River drainage at one locality: Twin Springs Creek in Dubuque County, Iowa. NANFA member John Olson authored an interesting paper documenting efforts in 2015 to find the original location of the 1954 Lake Chub record in Iowa and to capture more current specimens (Olson 2016). Due to extensive habitat alterations, no Lake Chubs were found at the Twin Springs site; thus, they may be extirpated from their sole Mississippi River Drainage locality. According to Lyons and Schmidt (2022), Lake Chubs are found in nearshore areas of Lake Superior and Lake Michigan and in the lower reaches of their tributaries during spring spawning. They were unaware of any year-round tributary populations in Wisconsin, so the distribution, relative abundance, and population trends of Wisconsin Lake Chubs are currently undetermined. According to a National Park Service website (NPS 2024), Lake Chubs have been introduced into certain waters. While native to the Missouri and Yellowstone drainages in Montana and Wyoming, the Lake Chub is not native to Yellowstone Park but was likely introduced there by anglers. It would seem probable that, given its optimum bait size, it has been—and will likely continue to be—introduced into other waters.

In South Dakota, the Lake Chub is considered rare, with historical reports from the Little Missouri and Cheyenne rivers. Recent surveys of the Little Missouri river system yielded no Lake Chubs (Magruder 2022; Hrabik and Cunningham 2024). Bob Hrabik believes the species is likely extirpated from the Little Missouri system, where it once

Figure 5. Stream habitat of Lake Chubs. Top: Stump River (Cook County, MN). Bottom: micro-habitat of slackwater. (Photos by Konrad Schmidt)

Figure 6. Lake Superior habitats of Lake Chub. Top: surf pool (Cook County, MN). Bottom: mouth of Baptism River (Lake County, MN). (Photos by Konrad Schmidt)

found micro-habitats in perennial tributary streams fed by springs and seeps. Loss of this critical habitat can be attributed to climate change (chronic drought), grazing, and dams (Bob Hrabik, personal communication). Recent surveys of the Black Hills found Lake Chubs within a single river system in the Middle Cheyenne–Elk subbasin; more specifically, the species appears to be limited to Boxelder Creek (Figure 3) and Bogus Jim, a tributary to Boxelder Creek (Morben 2023; Schlafke et al., forthcoming). In North Dakota, streams with Lake Chub populations were last surveyed in 2020 and the results were used to update the distribution map for *Fishes of the Dakotas* (forthcoming) (Scott Gangl, North Dakota Fish and Game, personal communication). Lake Chub distribution has declined in North Dakota but much less so than in South Dakota (Figure 4).

The Lake Chub may be disappearing from the periphery of its southern range (e.g., Bestgen et al. 1991). In Nebraska and Iowa, the Lake Chub is considered a glacial relic that is widely separated from its native range. It had been considered extirpated in Nebraska but was collected again in 1985 by Richard Stasiak and Bob Hrabik (Stasiak 1986). In personal communication, Bob Hrabik (December 27, 2023) mentioned that only one specimen was captured in 1985 and that no more specimens have been found since. He speculated that, due to a warming climate, they likely are extirpated from Nebraska again. In personal communication, John Olson (December 28, 2023) said that the Twin Springs, Iowa, information remains unchanged—no specimens have been reported since 1954—though he has not completely accepted that they are gone. Two inland populations in the Great Lakes drainages in Minnesota (i.e., Lake Superior North Shore: Grand Lake, St. Louis County and Poplar River, Cook County) are likely extirpated (Schmidt 2015).

VARIATION

Due to their huge native range, variation among Lake Chub populations should be significant, but there are few if any published reports on variations noted in populations. An unusual occurrence of Lake Chubs occupying hot springs in far northwestern British Columbia was reported by Alexander DeBruyn (DeBruyn 2019). These populations are from the Atlin Warm Springs and the Laird and Deer River Hot Springs, all tributaries of the Yukon River system. In the Atlin Warm Springs, Lake Chubs are found in water at 13–26° C (55–79° F) year-round but are not found in nearby Atlin Lake, which is glacier fed and is at 6° C (43° F) or below. Whether there were outstanding variations in physical characteristics of this form of Lake Chub was not noted in the paper. Specimens at the James Ford Bell Museum collected from the Wheeler River in northern Saskatchewan exhibited morphological characteristics that differed from multiple diagnostic keys for the species (Schmidt 2013).

HABITAT

While I have seen probable habitat locations for Lake Chub, I have not collected this species, so I will defer to literature to describe their habitat: "virtually any body of water, standing or flowing, large or small, usually in gravel-bottomed pools and runs of streams and

along rocky lake margins" (Page and Burr 2011). In Minnesota, Konrad Schmidt has found the populations above barrier falls to inhabit small to medium size streams of high to moderate gradient. However, Lakes Chubs are more often found in micro-habitats of slack water, such as eddies, pools, and sheltered edges (Figure 5). In Lake Superior, they are most abundant in shallow, sheltered habitats of surf pools and North Shore tributary mouths where small estuaries form above sand-gravel bars (Figure 6).

CULTURE TECHNIQUES

In my attempt to spawn Lake Chubs, I placed the adults into a 29-gallon aquarium. Under-gravel filtration was provided with an extra-long air stone placed above a simulated pebble nest. The pebble nest consisted of pebbles from 25 to 50 mm in length placed in a small mound over a small plastic lid (Figure 7). The plastic lid facilitated easier extraction of ova when it came time to siphon the ova out. In the aquarium, Lake Chubs bred very early in the season compared to other leuciscid species. Late March and early April were the typical spawning times with temperatures around 18° C (64° F) being optimal, but spawning was observed from 14–21° C (57–70°F). Males would form loose territories around the pebble nest, but once spawning commenced, it was more of a communal spawning event as several males would join a ready female. Eggs were laid above the pebble nest areas and would drift into the nest. Females spawned several times during the spawning season. On April 14, 2023, eggs were siphoned out of the mimicked chub nest. Eggs were round and had a hazy white color to them, giving them the appearance of being fungused or non-viable (Figure 8). The majority of these eggs, however, still developed and hatched. Eggs averaged 2 mm across. The temperature of the tank at this time was 19° C (66° F). Another spawning occurred on April 30, 2022. Tank temperature was 18° C (64° F) and eggs were 2.25 mm with some at 2.10 mm. Once they were free swimming, the Lake Chub fry consumed freshly hatched brine shrimp. The fry grew quickly and soon started consuming various high-protein flake foods as well as frozen fish food such as glass worms and frozen brine shrimp. I occasionally offered them a bloodworm treat. By October 10, 2022, the fry were 38 mm long. Since my fish room is independent of house heat and is thus vulnerable to natural cooling, the fry showed little additional growth going into the next spring. At just over 50 mm TL is when I first saw them reproductively viable. Under these conditions, the fry would take two years to reach maturity in captivity. Ashan (1966) reported males reached maturity at greater than 57 mm TL in British Columbia, but age was not indicated. Lake Chubs reached maturity in three years in Saskatchewan (Brown et al. 1970) and Lake Michigan (Becker 1983). According to Richardson (1935), females at 71 mm were estimated to contain 500 eggs. However, depending on the length of the fish, egg counts varied from 650–2,400 in Saskatchewan (Brown et al. 1970) and 214–1,540 in Labrador (Bruce and Parsons 1976). The Lake Chub is not an obligatory chub nest spawner, nor have they ever been recorded to construct their own nests, but they do prefer to spawn over gravel beds, rock substrates, or pebbles.

CAPTIVE PARAMETERS AND CONCLUSION

For the aquarist wanting to keep an interesting, somewhat colorful, non-aggressive species of leuciscid, the Lake Chub certainly fits the bill. It is a great community tank fish, though as adults they need plenty of room to school. A 55-gallon or larger aquarium is recommended. As with any large and sometimes fast swimming minnow, a good cover for the aquarium is needed. The Lake Chub appears to be a hardy species, but I have never kept this species above 24° C (75° F) and suggest that they be kept cool, with a tank temperature of 20–21° C (68–70° F) likely being optimal. This is a northern species and is probably rarely subjected to high temperatures in the wild. Regarding pH, mine were raised at a pH of 7.8 to 8.0 and did well, but I am not sure of their total tolerances of pH. The water current in the aquarium need not be strong for this species, as their known habitat preferences suggest gentle currents. An increase in current flow around spawning time, however, appears to promote spawning behavior.

Figure 7. Pebble nest. (Photo by Ray Katula)

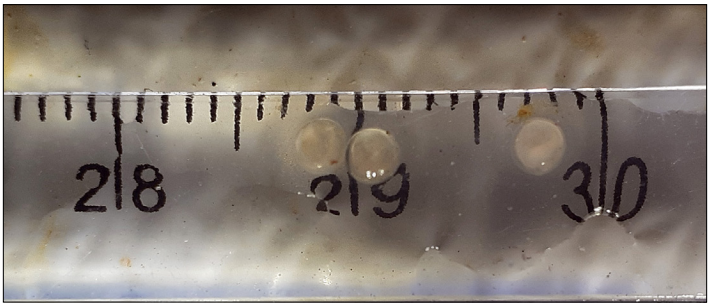


Figure 8. Lake Chub ova. (Photo by Ray Katula)

Aside from being a great community aquarium fish, the Lake Chub serves several roles in the wild. It surely serves as a forage fish for many other species of fishes and for terrestrial and avian predators. I believe this species, given its desirable bait size, fecundity, and ease of culture, could make a serviceable baitfish. As reported previously, it has been utilized as a bait fish in certain portions of its range. All in all, the Lake Chub is a great larger species of leuciscid to keep. They quickly recognize their owner and grow on you in several ways.

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(Continued on page 29)

FINDING AND PHOTOGRAPHING THE FABLED FIVE PUPFISHES OF THE MOJAVE AND COLORADO DESERTS IN CALIFORNIA AND NEVADA

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INTRODUCTION

Pupfishes of the genus *Cyprinodon* comprise 45 extant and three extinct species of small, short-lived fishes that range from California and Massachusetts in the US southward through Central America and the Caribbean islands to Colombia and Venezuela (Esmaeili et al. 2018). They are renowned for tolerating environmental extremes, with temperatures ranging from below freezing (-1.9°C) to about 46°C (Bennett and Beitinger 1997; Clark 2014), and salinities ranging from fresh water to four times (142 ppt) that of sea water (35 ppt) (Simpson and Gunter 1956). But despite their uncanny ability to adapt to harsh environments, many species are restricted to only one or a few small pools of water, with some having the smallest habitats of any animal species. Two of the extant species are extinct in the wild (the Potosi Pupfish *C. alvarezi* and La Palma Pupfish *C. longidorsalis* in Mexico) and more than a third are classified by the International Union for the Conservation of Nature (IUCN) as either Critically Endangered or Endangered (Esmaeili et al. 2018).

The topography of both the Mojave Desert in eastern California and western Nevada and the Colorado Desert of southeastern California is punctuated by rugged mountain ranges and dusty basins. Few people driving on highways through these parched desert landscapes are aware that some of the world's rarest and most interesting fishes thrive in nearby desert oases, some only a few minutes' walk from a parked car. These include five species of *Cyprinodon* pupfishes: the Devils Hole Pupfish *C. diabolis*, Desert Pupfish *C. macularius*, Amargosa Pupfish *C. nevadensis*, Owens Pupfish *C. radiosus*, and Death Valley Pupfish *C. salinus*. Today's populations of these species are relicts of those that inhabited the large pluvial lakes and rivers that once filled deep basins of western North America during the Pleistocene and subsequently receded as the glaciers retreated and vanished. The IUCN classifies the Devils Hole Pupfish as Critically Endangered, the Owens Pupfish and Death Valley Pupfish as Endangered, and the Desert Pupfish and Amargosa Pupfish as Vulnerable (Emaeili et al. 2018). The ecology of four of these species in the northern Mojave Desert and the history of the heroic efforts of biologists to protect them are eloquently described in a hefty tome by biologist Christopher Norment (2014).

Few people can name the five pupfish species of California and Nevada's deserts and even fewer have managed to see them all. In this article, I hope to inspire others to search for them by describing my quest to find and photograph all five species, and I hope to increase public awareness and demand for protecting their populations from the threats of introduced species and increased water consumption due to the growing demands of agriculture and urban/residential development.

Photos by the author.

Floyd Hayes has been a professor of biology at Pacific Union College since 2003. He previously spent a year as a primary school teacher in Micronesia, three years as a US Peace Corps vertebrate biologist at the National Museum of Natural History of Paraguay, nine years as a biology professor at the University of the Southern Caribbean and University of the West Indies in Trinidad, and a year as a wildlife biologist at the Division of Fish and Wildlife in the US Virgin Islands. He has published research on a variety of invertebrates and vertebrates, including coral reef fishes but not freshwater fishes, based on field work in 18 countries.

AMARGOSA PUPFISH

The Amargosa Pupfish comprises five extant and one extinct subspecies in scattered springs and streams in the northern Mojave Desert of eastern California and western Nevada. The Tecopa subspecies, *C. n. calidae*, occurred in two small streams at Tecopa Hot Springs, California, until extensive habitat alteration to accommodate more tourists caused its extinction in the 1970s (Miller et al. 1989). Ignominiously, it became the first federally endangered animal declared extinct. Fortunately, the populations of the other five subspecies are reasonably well protected (Norment 2014).

As a biology professor most familiar with birds, I often visited the deserts of southeastern California while studying for two university degrees in southern California in the mid-1980s and early 1990s and less frequently while teaching at a college in northwestern California since 2003. Yet I knew very little about the region's pupfishes and had never seen one until a memorable day, 8 January 2012. After spending a long weekend with my wife, Marta, in Las Vegas, we were driving home when I saw a sign for Ash Meadows National Wildlife Refuge in western Nevada and decided to check it out. We parked at a trailhead and began hiking on

Figure 1. Kings Pool, a large spring inhabited by the Amargosa Pupfish at Ash Meadows National Wildlife Refuge, Nevada.

Figure 2. An Amargosa Pupfish of the Ash Meadows subspecies.

Figure 3. An Amargosa Pupfish of the Shoshone subspecies at Shoshone Spring, California.

a boardwalk beside a stream, Crystal Spring, where I encountered a sign with information about the Ash Meadows subspecies of the Amargosa Pupfish, *C. n. mionectes*. Pupfish! Suddenly excited by the prospect of seeing my first pupfish, I diligently scanned the crystal-clear water of the hot spring, especially at the aqua blue Crystal Pool at the end of the boardwalk, but disappointingly I was unable to spot one, although I saw some introduced Western Mosquitofish *Gambusia affinis* and managed to photograph one.

Not willing to give up, we visited the Visitor's Center and inquired where we could see a pupfish. After a naturalist provided directions, we drove to the Point of Rocks parking lot and hiked along a short boardwalk crisscrossing a small stream until we arrived at another large spring, Kings Pool (Figure 1), where we were thrilled to see many blue-tinged male and brown-barred female pupfish swimming amidst gobs of green algae and swarms of Western Mosquitofish. Having left my underwater camera case at home, I was unable to take any underwater photos, but I managed to get a few grainy photos with the telephoto lens I use to photograph birds, and I vowed to return one day to get better photos.

Figure 4. Salt Creek, a small stream inhabited by the Death Valley Pupfish in Death Valley National Park, California.

Five years later, on 29 March 2017, I returned to Ash Meadows National Wildlife Refuge with a student. We hiked to Kings Pool and spent a half hour watching the antics of the pupfish. I spent a long time on my belly with an arm extended underwater, striving to obtain photos of the Amargosa Pupfish with an underwater camera, and this time I was happier with the results. But I obtained my best photos four years later when I returned with five students on 22 March 2021 (Figure 2). The following day we drove through the dusty town of Shoshone in the Mojave Desert of California where we encountered a roadside interpretive sign with information about the Shoshone subspecies of the Amargosa Pupfish, *C. n. shoshone*. More pupfish! We followed a short trail winding around the margins of several pools emanating from the Shoshone Spring and saw dozens of pupfish up close, which were easy to photograph with a telephoto lens (Figure 3). The private landowner of the spring is committed to protecting the pupfish and welcoming tourists to see them.

DEATH VALLEY PUPFISH

Death Valley lies at the bottom of a basin once filled by a large pluvial lake, Lake Manly, that once covered a surface area of about 1,600 km² in the Mojave Desert of eastern California. With the lowest elevation (86 m below sea level) and the hottest temperatures (max 56.7° C) in North America, it is a desolate and potentially dangerous place to visit on a hot summer day, but it is a delightful place to visit when the temperatures are cooler, especially in spring when the flowers are blooming. Two populations of the Death Valley Pupfish occur in the basin: the Salt Creek subspecies, *C. s. salinus*, and the Cottonball Marsh subspecies, *C. s. milleri*. Both subspecies are well protected within the boundaries of Death Valley National Park (Norment 2014).

Although I had visited Death Valley several times, I did not search for its iconic pupfish until 28 March 2017, when I took two students with me on a camping trip in the California deserts during spring break. By this time, I had searched online for information about the pupfish and knew where to look for it, so we drove to Salt Creek (Figure 4) and began hiking along a boardwalk beside

Figure 5. A Death Valley Pupfish of the Salt Creek subspecies.

the stream. Small schools of pupfish darted back and forth in the shallow water, frequently chasing each other and some were even spawning. All were brown, but a few males had blue tinges. Within the next month the males would turn deeper blue as the breeding season progressed. I was able to get some decent photos with my telephoto lens (Figure 5), and got even more photos when I returned with five students on 21 March 2021. I have not visited Cottonball Marsh to see its subspecies, which is in a remote area accessible only by a long and arduous hike.

DEVILS HOLE PUPFISH

Devils Hole is a narrow geothermal pool about 22 m long and 3.5 m wide, deep within a rocky cleft in a detached unit of Death Valley National Park in the northern Mojave Desert of western Nevada; it is adjacent to Ash Meadows National Wildlife Refuge. Despite its small surface area, the pool is only a small tip of a large aquifier that branches into numerous subterranean caverns, and it is so deep—divers have descended to 130 m—that its bottom has never been found. The pool is extremely sensitive to seismic activity, with disturbances in the water resulting from earthquakes as far away as Japan, Indonesia, and Chile. Stunning videos of miniature tsunamis caused by large earthquakes can be found online.

Devils Hole is the only natural home of the Devils Hole Pupfish, and it may be the smallest habitat containing the entire natural population of a vertebrate species. When the hole's water level dropped in the 1960s and 1970s due to farmers pumping groundwater to irrigate their crops, the pupfish became the center of acrimonious legal and public relations battles between farmers who demanded more groundwater and conservationists who realized the fish would likely become extinct if the water level receded below a shallow, submerged rock at one end of the pool that provided critical habitat for foraging and spawning. Eventually the conflict was settled by the US Supreme Court, which ruled in favor of the pupfish in 1976. The pupfish population is censused by biologists each spring and fall and is usually much larger in the fall. The population gradually declined from more than 500 individuals in the 1990s to only 35 individuals in 2013 (Brown 2021; Wilson et al. 2021), but it subsequently rebounded to 263 individuals by fall 2022. Several attempts to establish a second population elsewhere failed until a replica of the upper portion of Devils Hole was built at the Ash Meadows Fish Conservation Facility in 2013 (Brown 2021; Wilson et al. 2021). This facility now protects a captive population and provides a refuge in case the wild population is wiped out by a catastrophic event.

I first read about the plight of the Devils Hole Pupfish in my primary school's library while growing up in Maryland in the 1970s,

Figure 6. Dylan Turner searching for Devils Hole Pupfish at Devils Hole, Nevada.

Figure 7. A Devils Hole Pupfish swimming above a small white carpet, which provides a favored substrate for spawning.

Figure 8. Biologists collecting eggs from two white carpets at the shallow end of Devils Hole.

but I never imagined I would ever get to see one until another memorable day, 29 March 2017. After a student and I watched the antics of Amargosa Pupfish at Kings Pool in Ash Meadows National Wildlife Refuge, we searched for Bighorn Sheep *Ovis canadensis* in the nearby hills at Point of Rocks but were unable to find any. Still hoping to find the sheep, we decided to explore the refuge's roads. As we drove up a winding dirt road in the rugged hills, we came across a sign for Devils Hole beside the road. On the slope above us we spotted a chain-link fence, topped by barbed wire, surrounding a large area. Eureka! Surely the fence protected the home of the fabled Devils Hole Pupfish. We parked our car and enthusiastically hiked a short distance up a dirt service road to the fence. A sign guided us to the entrance of an observation platform partially spanning the narrow canyon from which we gazed downward at Devils Hole. An interpretative sign provided information about the iconic pupfish. Eager to see one, I scanned through binoculars for about five minutes until I saw a small fish swimming in shallow water at the near end of the pool. Yipppeee! I was elated to see one. Next, student Dylan Turner scanned the pool with the binoculars (Figure 6) until he, too, spotted a pupfish.

I returned to Devils Hole with five students taking a Desert Biology class on 22 March 2021. This time I brought along a telescope, so we took turns staring through it as several pupfish swam slowly and sometimes chased each other in the shallows at the closest end of the pool. Two mysterious white squares were present in the shallow water, which made it easier to see the fish whenever they swam above one, and I was able to photograph a distant pupfish swimming above a square (Figure 7) with my telephoto lens, but I wished I had a bigger lens! Serendipitously, two vehicles drove up the service road and parked just outside of the fence. Four biologists emerged from the vehicles and carried loads of gear to the pool. While the biologists spanned the pool with metal beams and platforms (Figure 8), one of them, Jennifer Gumm, explained to us that the white squares were carpets providing a soft substrate preferred by the pupfish for spawning. The biologists removed the two carpets, placed them into a container, and transported them to their research lab where the eggs would be removed and incubated in an aquarium. The carpets would be returned to Devils Hole to collect more eggs, and the young, captive-reared fish would be added to the captive population in the replica of Devils Hole at Ash Meadows. Meeting the biologists and observing them in action was a terrific educational experience for my students and me.

DESERT PUPFISH

The Desert Pupfish formerly occupied many springs and streams in several large drainage basins in southeastern California, southern Arizona, and northwestern Mexico. Natural populations currently survive in only three drainage basins: the Salton Sink in southeastern California, the Laguna Salada in Baja California, and the Colorado River Delta in Baja California. However, small populations have been introduced to numerous refugia, some of which have failed, in southern California, southern Arizona, and northwestern Mexico (Bonham 2021; Echelle and Echelle 2021).

In the Colorado Desert of southeastern California, both natural and introduced populations of the pupfish occur in tributaries and agricultural drainage ditches along the shores of the Salton Sea, a large body of water that formed in 1905 when water diverted from the Colorado River burst through an irrigation canal and flowed into the Salton Sink for two years before the canal was repaired. Water levels in the Salton Sea were subsequently maintained by irrigation runoff in the Imperial Valley, but because the "sea" is about 70 m below sea level and has no outlet, the water has gradually become hypersaline (currently about 1.8 times greater than seawater). The Desert Pupfish has an uncanny ability for colonizing irrigation drainage ditches and impoundments along the shores of the Salton Sea, but its ability to do so is increasingly impeded by increasing salinity, toxic chemicals, and frequent algal blooms that have killed most of the introduced fish (Oglesby 2005; Bradley et al. 2022).

When I visited the Salton Sea with a group of five students on 26 March 2021, I was aware that the pupfish occurred in two tributaries, Salt Creek on the east bank and San Felipe Creek on the southwest bank, but I didn't think we would have the time to search for them. My twin brother, William Hayes, is a biology professor at Loma Linda University in southern California, and he had told me about the Cleveland Street Drain, an irrigation drainage ditch at the north end of the Salton Sea, where we could look for amphibians and reptiles. So, I drove there, parked on

Figure 9. Cleveland Street Drain, an agricultural ditch inhabited by the Desert Pupfish at the north end of the Salton Sea.

Figure 10. A school of Desert Pupfish. (Note: Photo adjusted by editors.)

the dirt road, and scrambled about 5 m down the bank to examine the ditch. Although I didn't see any amphibians or reptiles, there were several introduced Sailfin Mollies *Poecilia latipinna*. I drove a short distance to another spot along the road and again scrambled down the bank of the ditch (Figure 9) to see what more I could find. This time there were plenty of fish, including more Sailfin Mollies and introduced Mozambique Tilapia *Oreochromis mossambicus,* plus an unexpected school of several hundred Desert Pupfish with blue-tinged males and brown-barred females (Figure 10). Finding the Desert Pupfish proved much easier than anticipated, requiring no more than 15 minutes of searching! The pupfish remained in the drainage ditch when I checked again with another group of five students on 3 January 2023, and later that day I found several more pupfish in a pool where they had been introduced at the nearby Dos Palmas Preserve.

OWENS PUPFISH

Owens Valley is a deep basin at the northern edge of the Mojave Desert, sandwiched between the Sierra Nevada Mountains to the west and the White Mountains and Inyo Mountains to the east. Situated within the rain shadow of the tallest peaks of the Sierra Nevada range, the valley's natural aridity is exacerbated by a long and sordid history of surface water diversions by the Los Angeles Department of Water and Power. As a consequence of the water diversions and the introduction of predaceous Largemouth Bass *Micropterus nigricans*, the formerly abundant Owens Pupfish, which is endemic to the valley, was considered extinct by 1942. Fortuitously, a few were rediscovered in 1956 followed by the discovery of about 200 individuals in 1964. The pupfish were reintroduced in several places, but one by one the reintroduced populations died out until the fateful day of 18 August 1969, when the last 400 individuals—the entire population of the species—were scooped out of the water in a drying pool, placed in two buckets, and carried by hand across uneven terrain to a nearby spring (Miller and Pister 1971; Pister 1993). Subsequently, the pupfish were reintroduced to several other sites and are now carefully managed (Norment 2014).

After considerable online sleuthing to determine where I could see the pupfish, I arrived at Fish Slough with a group of five students in my Desert Biology class on 20 March 2021. After parking our motor home, we hiked nearly three miles along a dirt road to BLM Spring (Figure 11). We gazed into the depths of the spring as dozens of Western Mosquitofish darted in and out of the profuse tangles of green algae, but disappointingly I couldn't see any fish that resembled pupfish. However, I noticed that some of the fish in deeper water had blue tinges and thought they might be the pupfish. Later, when I downloaded the photos on my laptop and examined them more closely, I realized they were just mosquitofish with blue tinges caused by a quirk of lighting in the green algae (Figure 12). Disappointed by my failure to see a pupfish, I vowed to return for another try.

More than two years passed before I returned to Fish Slough with a student on 20 November 2023. This time we quickly spotted more than a dozen pupfish, which appeared to be more timid than the other species. When we approached the edge of the spring, they quickly fled from the edge into the green algal jungle in deeper water, but as we lay on our bellies and patiently watched, one by one they returned to shallower water where I managed to obtain some photos with my underwater camera (Figure 13). Although it took me more than a decade, I was immensely pleased to have finally found and photographed my fifth and final species of California and Nevada's fabled pupfishes.

Figure 11. BLM Spring, inhabited by the Owens Pupfish at Fish Slough, California.

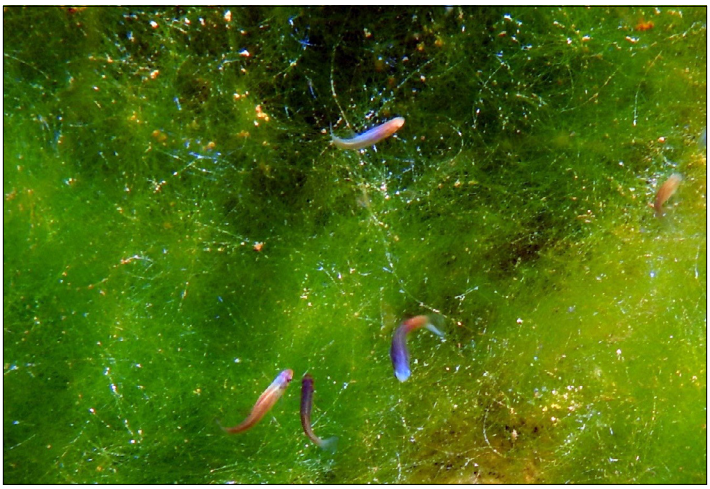

Figure 12. Western Mosquitofish with blue tinges caused by a quirk of lighting. (Note: Photo adjusted by editors.)

Figure 13. An Owens Pupfish. (Note: Photo adjusted by editors.)

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For bravely accompanying me on my desert sojourns, I thank my wife, Marta Hayes, and students Naamah Fidel, Daniella Gurning, Jae Hoon, Brandon Lee, Ryan Lee, Wai Kiu Lee, Justin Ling, Noelle Madrio, Manuel Moreno, Benjamin Rangel, Jonathan Salvador, Dylan Turner, and Darii Vereshchak.

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(Lake Chub, continued from page 23)

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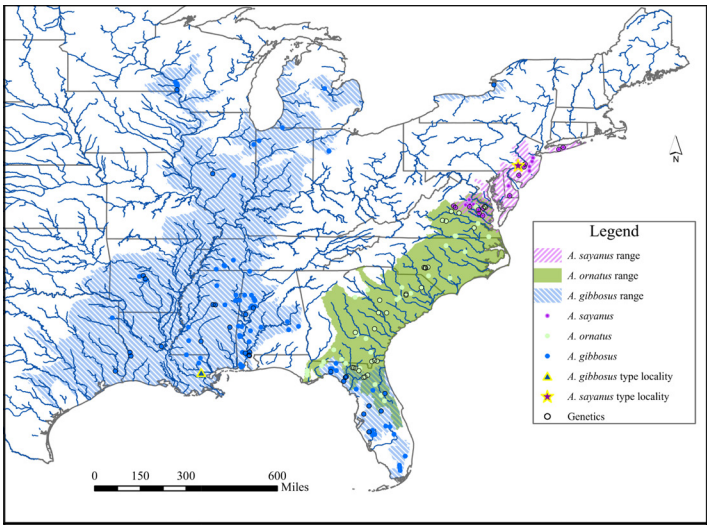
Salt Creek, Brookfield, IL (Olaf Nelson)

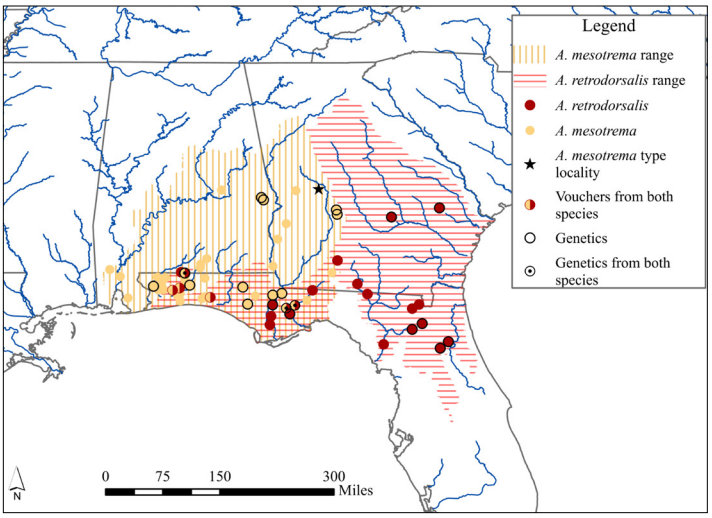
HOW MANY SPECIES OF PIRATE PERCH ARE THERE? NEW RESEARCH SHOWS FIVE SPECIES, NOT JUST ONE!

Pirate Perch, genus *Aphredoderus,* are widespread in the lowlands of the eastern half of the United States, forming a U-shaped distribution in the Great Lakes, Mississippi River Valley, Gulf of Mexico drainages, and Atlantic slope north to Long Island, where peripheral populations terminate. The fish is unusual in having a forward-facing cloaca (anus) under its throat. As described in NANFA's Fish In Focus series, this species maintains a solitary existence, seeking protection during daylight in aquatic plants or organic debris. Then in darkness it feeds on immature aquatic insects, small crustaceans and occasionally on small fishes.

Many people are unhappy with species splitting since it can be challenging to re-learn range information. If you're one of those people, you're likely unhappy with the split of Pirate Perch into five species, as justified as it is. In a recent paper using morphometric measurements and genomic data from 187 Pirate Perch from around their range, authors Tyler Muller and Andrew Simons split the one recognized species, *A. sayanus,* into five species: *A. sayanus, A. gibbosus, A. mesotrema, A. retrodorsalis*, and *A. ornatus* See maps below for species ranges. Note that there is significant overlap between three of the species. All of these species apparently share the same ecological needs and habits as described above.



Map showing range and sampling locations of *A. sayanus*, *A. gibbosus* and *A. ornatus* specimens used in their study.



Range and sampling locations of *A. mesotrema* and *A. retrodorsalis* used in this study. Sampling locations with black outlines indicate genetic sampling.

Aphredoderus ornatus from North Carolina. (Photo by NCFishes)

Aphredoderus gibbosus from Ohio. (Photo by Brian Zimmerman)

Aphredoderus retrodoralis from Suwanee River, Florida. (Photo by Brian Zimmerman)

These changes are published in "Taxonomic revision of the Pirate Perches, *Aphredoderus*, (Percopsiformes: Aphredoderidae) with descriptions of two new species," by Tyler A. Muller and Andrew M. Simons. https://doi.org/10.11646/zootaxa.5415.1.3

BREAKING DOWN THE PROBLEM OF MICROPLASCTICS IN THE GREAT LAKES

Microplastics found on a Great lakes beach. (Photo by Eileen Stegemann)

A very small item is a big threat to the health of the Great Lakes. Microplastics have been found in lakes, oceans, tap and bottled water, sea salt, and other products we eat and drink.

Microplastics are pieces of plastic less than 5 mm in size and can take the form of beads, fragments, pellets, film, foam, and fibers. They may come from the breakdown of bigger pieces of plastic (such as through natural processes such as wave action or sunlight) or be manufactured, such as microbeads and pellets.

A national survey of 37 National Park beaches found microfibers to be present at every one and to make up 97% of the microplastic debris. Wisconsin's Apostle Islands National Seashore was the worst, with an average of 221 pieces of microplastic per kilogram of sand.

Microplastics are ingested at all levels, including zooplankton, fishes, mussels, and birds, which can mistake debris for natural food. Pollution is another aspect of the problem. Pollutants can be spread as they accumulate on and travel with the tiny trash. Additionally, chemicals used in plastic manufacturing (for purposes such as coloring, or increasing flexibility or heat resistance) can be released as the plastic breaks down. Among the repercussions of microplastics that have been shown in lab studies are developmental delays, reproductive problems, and compromised immune responses. More work is needed to determine what effects all of this has on organisms of all kinds and how these effects move up the food chain.

"The US Marine Debris Act (2006) and Save our Seas Acts (2018 and 2020) prioritize the prevention, research, assessment, and removal of marine debris, with specific actions to understand and address microplastics. The US also passed the Microbead-Free Waters Act of 2015, which banned rinse-off cosmetics that contain intentionally added plastic microbeads."

Sarah Lowe, "Breaking down the problem of microplastics in the Great Lakes," https://www.michigan.gov/egle/newsroom/mi-environment/2023/04/04/breaking-down-the-problem-of-microplastics-in-the-great-lakes.
Editor's note: microplastics have also been found in the digestive tracts of preserved specimens in fish collections. See "First-Year Biology Students Investigate Microplastics in a University Ichthyological Collection," *American Currents*, Spring 2023.

CHUM SALMON MOVE NORTH: MAY BE A SIGN OF TROUBLE

The Anaktuvuk River. (Photo by Peter Westley)

Salmon are known for their epic life histories, from hatching hundreds or even thousands of miles from the ocean, migrating to sea and spending several years growing there, then migrating back up the same rivers and streams to the place where they started before spawning a new generation that will repeat the process. It is known, though seldom talked about, that they don't always return to their natal systems, however. In fact, this ability to choose new spawning waters is important to the species' survival by giving them access to new habitats.

It can also be a sign of trouble. In 2023, University of Alaska Fairbanks researchers documented Chum Salmon *Oncorhynchus keta* spawning in the Anaktuvuk and Itkillik rivers on Alaska's North Slope, both of which flow, via the Colville River, into the Arctic Ocean. This may indicate that these far-northern waters are warming to a point where fishes that could not previously survive there are now able to. At the same time, warming waters in this species' normal range have made it harder for them to successfully reproduce.

It has been confirmed that Chum Salmon spawning attempts at these new latitudes have been successful (https://cdnsciencepub.

com/doi/full/10.1139/cjfas-2022-0006). It is not clear what impacts this will have on other species or these rivers' broader ecosystems.

For more details, see https://www.wired.com/story/chum-salmon-are-spawning-the-arctic-its-an-ominous-sign/ and https://www.uaf.edu/news/confirmed-salmon-are-spawning-in-arctic-rivers.php

WATCHDOGS ACCUSE MEXICAN COMPANY OF MARKETING HEALTH SUPPLEMENT MADE OF ENDANGERED FISH

A Totoaba (top) and a Vaquita Porpoise. (Photo by Omar Vidal)

Several environmental organizations (Cetacean Action Treasury, The Center for Biological Diversity, National Resources Defense Council, and Animal Welfare Institute) have charged that a Mexican company, The Blue Formula, is violating the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) by selling a health supplement that is made from the endangered Totoaba *Totoaba macdonaldi* (a member of the drum or sciaenid family). The powder contains collagen from the fish, which users mix into drinks. Export of Totoaba is illegal unless the fish were bred in captivity with a permit, and import into the US is also illegal. The compaint says that the company may be using wild fish.

The Blue Formula claims to use farmed Totoaba and to release some fish into the wild, but the company operating the fish farms has no export permit, the advocates said.

Alejandro Olivera, the Center for Biological Diversity's Mexico representative, is concerned that the fish farm could be a front. "There is no good enforcement of the traceability of Totoaba in Mexico," he said, "so it could be easily used to launder wild Totoaba."

Taking wild Totoaba is illegal and gillnetting them is among the leading killers of the critically endangered Vaquita Porpoise *Phocoena sinus.* The most recent data indicates that as few as a dozen of these small porpoises may be left in the wild. Totoaba bladders can sell for as much as gold in China.

https://apnews.com/article/mexico-endangered-illegal-totoaba-fish-supplement-trade-50bf2a81c5ebd324ecfd3ec4aa8bd053

2022 RESEARCH DEMONSTRATES LIVE BAIT SALES' POTENTIAL TO SPREAD INVASIVE FISHES

A 2022–23 study led by Hannah Mulligan of the Department of Natural Resource Management at South Dakota State University and the South Dakota Department of Game, Fish and Parks, titled "Opportunities for regional collaboration and prevention: Assessing the risk of the live bait trade as a pathway of invasive species" (in the November 2023 *Biological Conservation*), used eDNA to look for traces of invasive Silver *Hypophthalmichthys molitrix* and Bighead *H. nobilis* carp in the tanks of bait retailers in North Dakota, South Dakota, Iowa, Kansas, and Nebraska. Enough samples were positive to show that the bait trade is definitely a potential means by which these species could spread into areas where they are not yet found. Some of the retailers where the eDNA was detected are outside the current known range of these invasive species. It is important to note that no actual specimens of either species were found in bait tanks, though the eDNA shows that they were likely present at some point in the process, whether in the waters where bait was initially collected or in other tanks along the way. They might also have been previously present in the retailers' tanks.

While invasive species like these can be spread by natural events such as flooding, transportation by humans can move them past barriers such as large dams that flooding would not. Mulligan points out that a population could be established by the release of only a few individual fish from anglers' bait buckets.

An article published online by SDSU notes that a "common misconception among anglers is that releasing live bait into waterways benefits the ecosystem. Previous research in Minnesota found that 20% of anglers release their leftover live bait at least some of the time. While well-intentioned, this is one of the ways invasive species…can be introduced to new water bodies."

The research is available at https://www.sciencedirect.com/science/article/pii/S0006320723004433. The SDSU synopsis is at https://www.sdstate.edu/news/2023/12/study-shows-regions-live-bait-trade-potential-pathway-invasive-species

Young-of-year Silver Carp (bottom) can appear similar to native fishes such as (from top) Skipjack Herring *Alosa chrysochloris,* Gizzard Shad *Dorosoma cepedianum,* and Threadfin Shad *D. petenense,* which makes them difficult to differentiate during harvest or in bait shop tanks. (Photo by Nathan Aycock)

SHARKS IN KENTUCKY!!

An illustration of *Strigilodus tollesonae*. The new species is more closely related to modern ratfishes than to other modern sharks and rays. (Illustration by artist Benji Paysnoe)

Cue the music from "Jaws"! Dum, dum… dum, dum… There may be sharks closer to you than you expect! No, not the Bull Shark *Carcharhinus leucas,* which supposedly has swum up the Mississippi River in modern times. This time they're in Kentucky, and they're no danger to swimmers. These ancient sharks lived in the tropical, shallow sea that was Kentucky 300–350 million years ago.

About 70 sharks or shark relatives have been found throughout the Mammoth Cave National Park system. One was recently added to the list when cave guide Kelli Tolleson submitted photos of teeth to J.P. Hodnett, a renowned shark research specialist. Hodnett identified the shark as a new species and named it after Tolleson: *Strigilodus tollesonae,* or Tolleson's Scraper Tooth. "The whole paleo team kept it a secret from me while the draft of this report was being written," Tolleson said of the species' name. "They emailed it to me with the full draft to look over and I definitely shed a tear. I have to admit, I cried a little bit when they told me that, so it's just such an honor and a great surprise." The species was announced in 2023.

But wait! There are more! *Troglocladodus trimblei* and *Glikmanius careforum* differ greatly from *Strigilodus tollesonae*, and were announced in 2024. Though they lived around the same period, roughly 340 million years ago, the two most recent discoveries are described as fierce predators of their time. Reaching upwards of 10 feet in length, they were built for speed and equipped with sharp, cutting teeth. *T. trimblei* is named for Mammoth Cave's superintendent, Barclay Trimble, who first spotted the tooth sticking out from the rock of the cave wall.

Trimble said of his role in the discovery and of the specific epithet, "It's humbling. When you really think about just being in the right place at the right time, being able to be in the cave and being on some surveys and finding something on the ceiling, it's humbling having that name when I just got lucky enough to be in the right place at the right time."

Several more sets of remains are being reviewed and may also be new to science, and it is expected that even more new species will be found as exploration continues. Unfortunately for those with a taste for spelunking *and* fish, the parts of the cave system where these remains have been found are not accessible to the public.

If you want to know even more about the Mammoth Cave sharks, Hodnett and his colleagues wrote an excellent and detailed account titled "Sharks in the dark: Paleontological resource inventory reveals multiple successive Mississippian Subperiod cartilaginous fish (Chondrichthyes) assemblages within Mammoth Cave National Park, Kentucky."

See https://escholarship.org/uc/item/9rz2v701. This National Park Service page shows species found in the cave, graphics clarifying what lived when, and images of researchers at work: https://www.nps.gov/articles/000/fossils-of-the-2023-national-fossil-day-artwork.htm

News reports about the recent species are at https://www.wbko.com/2023/10/11/new-ancient-shark-species-discovered-mammoth-cave-named-cave-guide/ and https://www.wbko.com/2024/02/01/two-additional-ancient-shark-species-discovered-mammoth-cave/

Park guide Kelli Tolleson descending by rope through a drill borehole to access a passage in the St. Louis Formation. (Photo from the "Sharks in the dark" article)

WELCOME, NEW MEMBERS!

Tricia Beaver, NC
Michael Callahan, CA
Curtis Carman, KY
Chris Cravens, FL
Colton Creason, IL
Adam Davidson, OK
Thomas Dohl, IN
Samantha Fanjoy, MN
Emily FitzGerald, WI
Meredith Jedlicka, GA
Jason Mercer, TX
Jason Miller, TN
Tessa Morris, VA
Damon Mullis, GA
Monte Ramstad, MN
Karen Shrawder, WV
David Smith, MD
Wyatt Tabor, SC
Russell Warr, AL

NANFA News, continued from page 3

- **Paul Greenberg,** ***Four Fish: The Future of the Last Wild Food*** (2010)
  An examination of the four fishes (salmon, sea bass, cod, and tuna) that dominate restaurant menus, the global forces that get these fish to our dining tables, and how this reflects our damaged relationship with the ocean and its inhabitants. Two more books by this author are also on the longer list: *American Catch: The Fight for Our Local Seafood* (2015) and *The Omega Principle: Seafood and the Quest for a Long Life and a Healthier Planet* (2018).
- **Anders Halverson,** ***An Entirely Synthetic Fish: How Rainbow Trout Beguiled America and Overran the World*** (2010)
  An exhaustively researched and entertainingly rendered account of the Rainbow Trout and why it has become the most commonly stocked and controversial freshwater fish in the United States and many other places.
- **Mark Kurlansky,** ***Cod, a Biography of the Fish that Changed the World*** (1997)
  The fascinating natural history of the Atlantic Cod and its surprisingly important effects on the development of Europe and the settlement and rise to power of North America. The full list also includes Kurlansky's *The Big Oyster: History on the Half-Shell* (2006), *The Last Fish Tale: The Fate of the Atlantic and Survival in Gloucester, America's Oldest Fishing Port and Most Original Town* (2008), and *Salmon: A Fish, the Earth, and the History of Their Common Fate* (2020).
- **Edward Marriott,** ***Savage Shore: Life and Death with Nicaragua's Last Shark Hunters*** (2000)
  The author travels among the last surviving subsistence shark fishermen of Central America to chart the life of the Bull Shark and those who hunt it.
- **Morten Strøksnes,** ***Shark Drunk: The Art of Catching a Large Shark from a Tiny Rubber Dinghy in a Big Ocean*** (2017)
  An entertaining story of how two artists learn about and then spend a year attempting to catch a Greenland Shark, one of the largest and longest-lived fishes on Earth, from a small boat in a frigid Norwegian fjord.
- **Emily Voight,** ***The Dragon Behind the Glass: A True Story of Power, Obsession, and the World's Most Coveted Fish*** (2016)
  A riveting narrative of the high-stakes intrigue behind the raising and marketing of Arowana fishes in the international pet trade.
- **Samantha Weinberg,** ***A Fish Caught in Time: The Search for the Coelacanth*** (2000)
  A highly enjoyable story of the initial discovery of the Coelacanth, the many challenging years of follow-up to learn more about it, and the current state of Coelacanth science.

FISHES OF WISCONSIN POSTERS

The University of Wisconsin Zoological Museum has some amazing fish posters for sale. The 13-foot canvas poster shows all 183 species found in the state, at life size, and costs $150. Nine smaller posters, each depicting a subset (eight show families: the sunfishes, the pikes, the perches, the gars, the suckers, the salmonids, the catfishes, and the minnows; "The Little Fishes of Wisconsin" includes 16 families) are also available. The excellent art is by Kandis Elliot, UW-Senior Artist Emerita, and reference photos were provided by NANFA member John Lyons. See https://charge.wisc.edu/zoology/items.aspx for more info.

THE NORTH AMERICAN NATIVE FISHES ASSOCIATION

DEDICATED TO THE APPRECIATION, STUDY AND CONSERVATION OF THE CONTINENT'S NATIVE FISHES

AN INVITATION TO JOIN OR RENEW

The North American Native Fishes Association is a 501(c)(3) not-for-profit, tax-exempt corporation that serves to bring together professional and amateur aquarists, anglers, fisheries biologists, ichthyologists, fish and wildlife officials, educators, and naturalists who share an interest in the conservation, study, and captive husbandry of North America's native fishes. A portion of each member's dues helps support three important initiatives: NANFA's Conservation Research Grant Program, which funds research on the biology and conservation of North America's most neglected and imperiled fishes; the Gerald C. Corcoran Education Grant, which funds educational outreach programs aimed at children and the general public; and the John Bondhus Conservation Grant, which supports organizations and groups working to conserve native fish populations.

MEMBER BENEFITS

- ***AMERICAN CURRENTS,*** a quarterly publication featuring articles and news items on collecting, keeping, observing, conserving, and breeding North American fishes.
- **REGIONAL NANFA CHAPTERS.** State and regional aquarium groups where members may get together to collect and discuss native fishes, remove exotics, and perform conservation and stream restoration work.
- **NEW MEMBER PACKET.** An 8-page newsletter that's sent to new NANFA members introducing them to NANFA, and to the fascinating world of collecting, keeping and conserving North America's native fishes.
- **ANNUAL CONVENTION.** Where NANFA members from around the country meet for lectures, collecting trips, auctions, fun and finship. **The 2024 convention will be held June 6–9 at Beavers Bend State Park in Broken Bow, OK.**
- **GRANT FUNDING.** Only NANFA members can apply for NANFA's Conservation Research Grant and Gerald C. Corcoran Education Grant programs. For details, see NANFA's website (www.nanfa.org), or contact Dr. Bruce Lilyea, Conservation Grant Chair, 863-513-7611, bruce.lilyea@gmail.com, or Scott Schlueter, Education Grant Chair, scott_schlueter@hotmail.com.

DUES: USA, $30/year ◆ CANADA and MÉXICO, $40/year ◆ ALL OTHER COUNTRIES, $60/year (All amounts in US$)

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