Environ Biol Fish (2024) 107:1305–1326
https://doi.org/10.1007/s10641-024-01655-7

From neglect toward enlightenment: the conservation of native fishes in the twenty-first century

Alec R. Lackmann · Douglas A. Watkinson · Solomon R. David · Dennis L. Scarnecchia · Margaret F. Docker

Published online: 17 December 2024

Abstract For decades, many freshwater fishes native to North America have been written off as "rough fish" and neglected as inconsequential or even scorned if perceived as inimical to traditional game-fish. Across the continent, the exact species included in this category vary but often include members of the families Lepisosteidae, Amiidae, Hiodontidae, Catostomidae, Ictaluridae, and Sciaenidae. The casual or callous treatment of these fishes, although occasionally questioned by diversity-minded scientists and the public for at least a century, has recently come under more widespread scientific scrutiny, as more holistic views of ecosystems and ecosystem-based management are increasingly embraced and implemented. Paradoxically, we are also in an era where increasing technological capabilities have exacerbated the casual disposal of native fishes via bowfishing and other methods, often followed by widespread publicity through social media. Amid this rapid technological evolution, recent scientific studies have identified and highlighted the long lifespans, erratic recruitment, and surprisingly complex stock composition and life histories of many of these neglected fishes. Conservation of these distinctive and fragile taxa has been initiated under the recognition of this life history diversity. As exemplified by the 23 articles in this Special Issue on "Underappreciated Native Fishes of North America and their Management" and highlighted in this introductory article, research on many of these taxa has surged, as has their need for management. Scientific discoveries during this timeframe have redefined our understanding of several of the species and have led to an enlightened appreciation of these fishes and their valuable roles in freshwater ecosystems.

A. R. Lackmann (✉)
Department of Mathematics and Statistics, University of Minnesota Duluth, 140 Solon Campus Center, 1117 University Drive, Duluth, MN 55812, USA
e-mail: alackman@d.umn.edu

A. R. Lackmann
Department of Biology, University of Minnesota Duluth, 1035 Kirby Drive, SSB 207, Duluth, MN 55812, USA

D. A. Watkinson
Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, MB, Canada
e-mail: doug.watkinson@dfo-mpo.gc.ca

S. R. David
Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota, 135 Skok Hall, 2003 Upper Buford Cr, Saint Paul, MN 55108, USA
e-mail: srdavid@umn.edu

D. L. Scarnecchia
Department of Fish and Wildlife Sciences, University of Idaho, Moscow, ID 83844-1136, USA

M. F. Docker
Department of Biological Sciences, University of Manitoba, Winnipeg, MB, Canada
e-mail: Margaret.Docker@umanitoba.ca

Keywords Nongame fish · Bowfin · Gar · Suckers · Redhorse · Drum · Lampreys

Introduction: the origins of this Special Issue

This Special Issue of *Environmental Biology of Fishes*, entitled "Underappreciated Native Fishes of North America and their Management," has its origins at the confluence of advances in at least three areas of scientific inquiry and understanding over the last quarter century: in fisheries science, in fisheries harvest management, and in human societal perceptions and values. The first advance has been a number of important research papers in fisheries science on the life history of these species, many of which demonstrated that native fish species live much longer than previously thought (Fig. 1; Lackmann et al. 2019, 2023a; Daugherty et al. 2020; Andrews et al. 2024), have less regular recruitment in many localities than had been assumed (Love et al. 2019; Radford et al. 2021; Lackmann et al. 2021, 2022a,b, 2024a; Montague et al. 2023; Woodling et al. 2024; Maxson et al. 2024), may have previously unrecognized distinct stocks and even subspecies or species (Brownstein et al. 2022; Wright et al. 2022), and play important roles in ecosystem stability (Scarnecchia 1992; Bennett et al. 2015; David et al. 2018; Scarnecchia and Schooley 2020). Studies have also revealed that many of these species are periodic (bet-hedging) strategists (Winemiller and Rose 1992), which has redefined our understanding of the ecological role of several of the taxa and has caused range-wide shifts in the way they are studied and valued (Kopf et al. 2024).

The second major advance has been the increased pursuit and recognition of bowfishing of many native species as an area in need of sustainable harvest management (Quinn 2010; Bennett and Bonds 2012; Bennett et al 2015; Scarnecchia and Schooley 2020; Lackmann et al. 2024b). Species once viewed as nongame are now providing widespread recreational opportunities and therefore warrant more direct harvest management attention routinely afforded game species. They are now, in effect, new game fish (Scarnecchia et al. 2021). Other novel fishing approaches besides traditional angling that target native fishes also require conscientious management. This recognition has resulted in a significant increase in research interest in the topic of bowfishing for native species. Research output and research relevance have both surged since 2019 as it pertains to bowfishing native freshwater fishes of North America (Table 1). Approximately 74% of the peer-reviewed studies in relation to the topic have been published in the past 5 years, a near tripling of the output from the previous 27 years (Fig. 2a). Moreover, these studies of the past half-decade have amassed 376 citations as of late 2024, more than half of all citations in the field ($n=750$) since a seminal paper on gar and bowfin management was published by Scarnecchia (1992) (Fig. 2b). Furthermore, the average citation rate per paper has increased significantly since 2010 ($F_{1,11}=16.4$, df = 1, $p=0.0019$, $R^2=0.60$), from an average of about 1 citation per study per year for studies published in 2010, to an average of 6 citations per study per year for studies published in 2023 (Fig. 2c). Bowfishing has not only increased in popularity among participants; it has also recently

Fig. 1 A closeup of a centenarian bigmouth buffalo *Ictiobus cyprinellus* from Minnesota. Prior to 2019, the maximum known lifespan of bigmouth buffalo was more than 100 years younger than what is now known. Photo credit: Alec Lackmann

Table 1 Peer-reviewed studies since 1990 regarding (or with mention of) bowfishing freshwater fishes native to North America and its management implications, according to Google Scholar. Data as of 03 November 2024

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
1	Scarnecchia 1992	A reappraisal of gars and bowfins in fishery management	114	Longnose gar, shortnose gar, spotted gar, Florida gar, alligator gar, bowfin		North America	Exposing questionable fisheries management in North America; recognition of the value gars, bowfins, and other native species bring to native ecosystems
2	Quinn 2010	A survey of bowfishing tournaments in Arkansas	18	Spotted gar, longnose gar, shortnose gar, gizzard shad, river carpsucker, quillback, northern hog sucker, smallmouth buffalo, bigmouth buffalo, black buffalo, spotted sucker, black redhorse, golden redhorse, shorthead redhorse, channel catfish, freshwater drum	1999–2000	AR	Bowfishing tournament take high compared to other sport fisheries; native species make up the majority of take
3	Kelley 2012	Age and growth of spawning longnose gar (*Lepisosteus osseus*) in a north central Texas reservoir	14	Longnose gar	2010	TX	Sexual size dimorphism, asymptotic growth, male longevity 14 years, female longevity 22 years
4	Bennett & Bonds 2012	Description of bowfishing tournaments in the Trinity River, Texas, with emphasis on harvest of alligator gar	12	Alligator gar	2009–2011	TX	Bowfishing tournament take of alligator gar; size ranged from 229 to 2210 mm TL indicates wide vulnerability to bowfishing
5	Walker et al. 2013	Differences in diet and feeding ecology of similar-sized spotted (*Lepisosteus oculatus*) and shortnose (*Lepisosteus platostomus*) gars during flooding of a south-eastern US river	40	Spotted gar, shortnose gar	2007	AR	Diet partitioning between sympatric spotted and shortnose gars, most gars in the study were collected by night bowfishing; average fish size in the study was 620 mm and 580 mm TL, for spotted and shortnose gars, respectively

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
6	Schooley et al. 2014	Harvest management regulation options for Oklahoma's Grand Lake stock of paddlefish	20	North American paddlefish	2008–2012	OK	Population decline, overexploitation evident, recommendations for restricted harvest; paddlefish open to restricted bowfishing harvest as of 2014
7	Bennett et al. 2015	Surveys of Texas bow anglers, with implications for managing alligator gar	18	Alligator gar	2011–2012	TX	Bowfishing alligator gar, a species of concern in TX that is considered "at risk" by the American Fisheries Society, results in immediate management attention
8	Binion et al. 2015	Population dynamics of alligator gar in Choke Canyon Reservoir, Texas: implications for management	39	Alligator gar	2008–2013	TX	Sexual size dimorphism, asymptotic growth, longevity of 27 years
9	Buckmeier et al. 2016	Characteristics and conservation of a trophy alligator gar population in the Middle Trinity River, Texas	29	Alligator gar	2007–2014	TX	Asymptotic growth, longevity of 53 years
10	Buckmeier et al. 2017	Reproductive ecology of alligator gar: identification of environmental drivers of recruitment success	34	Alligator gar	2007–2014	TX	Highly variable recruitment, recruitment success during rare extended high-flow years; stocks must be managed cautiously to avert overexploitation
11	Smith et al. 2018	Modeling the responses of alligator gar populations to harvest under various length-based regulations: implications for conservation and management	23	Alligator gar	2007–2014	TX	Alligator gar, a long-lived periodic life history strategist, is vulnerable to levels of exploitation considered low for other recreational fisheries; they are highly sensitive to exploitation and length-based regulations recommended to sustain and improve fishery

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
12	King et al. 2018	Relative bias and precision of age estimates among calcified structures of spotted gar, shortnose gar, and longnose gar	13	Spotted gar, shortnose gar, longnose gar	2015–2016	IL	Need for age validation in gars amidst increases in recreational exploitation including bowfishing
13	Lackmann et al. 2019	Bigmouth buffalo *Ictiobus cyprinellus* sets freshwater teleost record as improved age analysis reveals centenarian longevity	58	Bigmouth buffalo, black buffalo	2011–2018	MN	Bigmouth buffalo oldest age-validated freshwater fish (112 years), more than 4×older than the previous reported max age for species, slow asymptotic growth, delayed maturity, extreme episodic recruitment, unregulated bowfishing and ecological neglect of "rough fish," management overdue; black buffalo 56 years old (MI), more than 2×older than previously reported max age
14	Snow & Porta 2019	Examination of three state records for spotted gar in Oklahoma	0	Spotted gar	2002–2018	OK	State record spotted gars taken by bowfishing estimated to be 32–43 years old
15	Adams et al. 2019	# GARWEEK: insights from a social media outreach campaign about alligator gar in Oklahoma	3	Alligator gar	2018	OK	Overall positive sentiment for alligator gar across social media; species of special concern in OK; bowfishing alligator gar a "hot topic" issue that generates negativity and sparks vulgar language
16	Smith et al. 2020	Advances in conservation and management of the alligator gar: a synthesis of current knowledge and introduction to a special section	26	Alligator gar		North America	Increases in angling and bowfishing pressure prompted active fisheries management of alligator gar

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
17	Snow & Porta 2020	Seasonal food habits and prey selectivity of alligator gar from Texoma Reservoir, Oklahoma	1	Alligator gar	2017–2019	OK	Assessing diets of alligator gar prior to reintroduction into extirpated waterbodies in OK
18	Scarnecchia & Schooley 2020	Bowfishing in the United States: history, status, ecological impact, and a need for management	31	All	1984–2020	North America	Zero management plans evident for bowfishing across all 50 USA states despite exponential increases in bowfishing participation over the past decade; 83% of fish shot at high-profile 2018 bowfishing tournament in OK native to OK waters
19	Schlechte et al. 2021	Angler practices and preferences for managing alligator gar in Texas	1	Alligator gar	2018	TX	Evaluating the statewide one fish daily bag limit on most TX waterbodies for alligator gar, and the 2019 implementation of a 112 cm TL max length limit and quota on the Trinity River reveals most anglers (including bowfishers) support length limits to reduce harvest
20	Radford et al. 2021	Comparison of four hard structures including otoliths for estimating age in blue suckers	20	Blue sucker	2018–2019	IL, IN	Blue sucker lifespan of 42 years in Wabash River, IL; recreational harvest of blue sucker by anglers or by bowfishing is legal, but not studied in this system; one of the last remaining strongholds of blue sucker in North America

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
21	Lackmann et al. 2021	Long-lived population demographics in a declining, vulnerable fishery—bigmouth buffalo (*Ictiobus cyprinellus*) of Jamestown Reservoir, North Dakota	23	Bigmouth buffalo	2019–2020	ND	A long-lived periodic strategist, bigmouth buffalo lifespans approach 60 years in ND reservoir, slow asymptotic growth, delayed maturity, decadal episodic recruitment, and population decline—most significantly during the bowfishing era of the past decade
22	Sauer et al. 2021	No evidence of physiological declines with age in an extremely long-lived fish	33	Bigmouth buffalo	2017–2018	MN	Bigmouth buffalo continue to improve in their physiological condition in their upper 80 s and 90 s relative to younger individuals, another dimension of the long-lived life history of this periodic strategist
23	Rypel et al. 2021	Goodbye to "rough fish": paradigm shift in the conservation of native fishes	75	All		North America	"Native fishes play instrumental roles in ecosystems and provisioning of ecosystem services. It is the duty of fisheries professionals to protect each species and to bear witness to their ecological, economic, and innate relevance. An effective and progressive field is willing to shed harmful ideas toward a more sustainable future for biodiversity, ecosystems, and all peoples."

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
24	Scarnecchia et al. 2021	The sport fish restoration program as a funding source to manage and monitor bowfishing and monitor inland commercial fisheries	22	All		North America	"The expanding sport of bowfishing in the past 2 decades, and research over a comparable time period showing very long lifespans of underappreciated native fish species, opens the door to some new ways to classify, manage, and fund monitoring of these natives under the SFR program, while encouraging sport and commercial take of invasives. Evidence from bowfishing and from changes in angling patterns for some nongame species indicates that the time has come to consider reclassifying underappreciated native species into some form of sport status…"
25	Bartnicki & Snow 2021	Examination of the current state record River Carpsucker in Oklahoma	1	River carpsucker	2021	OK	Lifespan of 14 years for OK state record river carpsucker taken via bowfishing; back-calculated growth rate suggests longevity likely exceeds 14 years in OK

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
26	Scarnecchia & Schooley 2022	Trophies, technology, and timescape in fisheries management, as exemplified through Oklahoma's world record paddlefish *Polyodon spathula*	13	All		North America	"Conservation of long-lived species such as Paddlefish, sturgeons (Acipenseridae), or other large species currently challenged by ecological change or habitat losses may be further challenged by the expansion of harvest power through advances in fishing technology in pursuit of trophy fish. Technological evolution may outpace the adaptive abilities of managers to safeguard these fisheries with sensible harvest regulations—often a multi-year, bureaucratic process. Managers must maintain focus on understanding the ecological nuances of these species while proactively developing resilient harvest management frameworks…"
27	York et al. 2022	Oklahoma bowfishing values and perspectives toward nongame fishes and their management	6	All	2021	OK	Survey reveals bowfishing participation more than doubled from 2018 to 2019; most bowfishers (86%) and nonbowfishers (94%) trust state agency to appropriately manage native fishes; information will be used to develop sustainable bowfisheries and conserve native fishes

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
28	Lackmann et al. 2022a	Otolith allometry informs age and growth of long-lived Quillback *Carpiodes cyprinus*	10	Quillback, river carpsucker	2018–2021	MN	Otolith analysis reveals 44-year and 47-year lifespans for quillback and river carpsucker in MN, 3–4 × older than generally reported for their maximum age; quillback exhibit variable recruitment, delayed maturity, and asymptotic growth; *Carpiodes* classified as "rough fish" in MN and subject to unregulated, unmanaged and wasteful bowfishing
29	Lackmann et al. 2022b	Otoliths suggest lifespans more than 30 years for free-living bowfin *Amia calva*: implications for fisheries management in the bowfishing era	7	Bowfin	2017–2021	MN	First successful use of otoliths to age bowfin reveals a 33-year lifespan for bowfin in MN, approximately 3 × older than generally reported for their maximum age in the wild; bowfin in MN exhibit variable recruitment and asymptotic growth; bowfin classified as "rough fish" in MN and subject to unregulated, unmanaged, and wasteful bowfishing
30	Snow et al. 2022	Modeling the population response of alligator gar in Texoma Reservoir to harvest and discard mortality	1	Alligator gar		OK	Alligator gar, a long-lived periodic strategist, is highly sensitive to exploitation; proactive management is needed and length-based restrictions are recommended on an already limited harvest

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
31	Lackman et al. 2023a	Bet-hedging bigmouth buffalo (*Ictiobus cyprinellus*) recruit episodically over a 127-year timeframe in Saskatchewan	19	Bigmouth buffalo	2010–2021	SK	Bigmouth buffalo lifespan of 127 years, quintessential periodic life history strategist, delayed maturity, skip spawning, slow asymptotic growth, episodic recruitment, fragile reproductive ecology with larval bigmouth buffalo prone to stranding if water level recession rate is too rapid; at risk, declining populations in Canada—contiguous waters include MN and ND
32	Radigan et al. 2023	Factors affecting the catch and harvest rates of paddlefish downstream of Gavins Point Dam, South Dakota, 2000–2020	1	North American paddlefish	2000–2020	SD	Bowfishing rates of paddlefish increased during 2000–2020 in SD and significantly since a 2016 regulation change that shifted the bowfishing season from July to June
33	Zentner et al. 2023	Environment affects sucker catch rate, size structure, species composition, and precision in boat electrofishing samples	1	Black redhorse, golden redhorse, northern hogsucker, white sucker, spotted sucker	2019–2020	OK	Higher catostomid catch rates at night—implications for management of night bowfishing when catostomids are more vulnerable, as well as evaluating sampling effectiveness of catostomids for fisheries professionals
34	Long et al. 2023	Validation and comparison of age estimates for smallmouth buffalo in Oklahoma based on otoliths, pectoral fin rays, and opercula	6	Smallmouth buffalo	2017–2019	OK	Age validation of smallmouth buffalo in OK as unregulated bowfisheries increase; smallmouth buffalo otoliths are age validated with the longevity of 61 years in the sample

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
35	Montague et al. 2023	Bowfishing shoot and release: high short-term mortality of nongame fishes and its management implications	6	Black buffalo, smallmouth buffalo, freshwater drum, flathead catfish, longnose gar, shortnose gar, spotted gar, river carpsucker	2021–2022	OK	Fish die after being shot with a bow and arrow (bowfishing); the "shoot and release" of native freshwater fishes, which is only legal in 4 of 50 USA states (1 being OK), should be prohibited like it is in 92% of other states; sport killing and wanton waste of native fishes
36	Lackmann et al. 2023b	Centenarian lifespans of three freshwater fish species in Arizona reveal the exceptional longevity of the buffalofishes (*Ictiobus*)	3	Bigmouth buffalo, smallmouth buffalo, black buffalo	2018–2023	AZ	All three species of USA buffalofishes can live more than 100 years; the rise of catch-and-release buffalofish angling; visible age markings on all three buffalofish species inform dozens of recaptures; numerous stakeholders exist, sustainability key

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
37	Lackmann et al. 2024b*	Harvest trends, growth and longevity, and population dynamics reveal traditional assumptions for redhorse (*Moxostoma* spp.) management in Minnesota are not supported	8	Silver redhorse, greater redhorse, shorthead redhorse, golden redhorse, black bullhead, brown bullhead, yellow bullhead, bowfin, bigmouth buffalo, freshwater drum, white sucker, tullibee, longnose gar, shortnose gar, quillback	2018–2022	MN	Bowfishing tournament take of redhorse is significantly increasing and is more than 200 × the commercial harvest rate in MN; otolith analysis reveals 41-year and 27-year lifespans for silver redhorse and greater redhorse, significantly older than previously reported for their maximum age; redhorse classified as "rough fish" in MN and subject to unregulated, unmanaged, and wasteful bowfishing; fish disposal advertised at single night bowfishing tournaments & tonnes of fish shot and disposed, with the vast majority being native fishes; management of redhorse in MN as a "single stock" not supported by multiple lines of evidence
38	Adams et al. 2024	Spawning ecology and spawning site fidelity of alligator gar, *Atractosteus spatula*, in the Fourche LaFave River: implications for river floodplain management and alligator gar conservation	1	Alligator gar	2007–2013	AR	Alligator gar spawning observations across years reveal site fidelity and the importance of habitat heterogeneity and herbaceous wetland vegetation in river floodplains; implications for conservation of alligator gar and note on how the species is highly vulnerable to bowfishing in these shallow-floodplain habitats and targeted by bowfishers at the study site

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
39	Woodling et al. 2024*	Otolith analysis reveals long-lived population demographics of quillback *Carpiodes cyprinus* and river carpsucker *C. carpio* in Colorado	0	Quillback, river carpsucker	2021–2023	CO	Quillback and river carpsucker lifespans approach 50 years in Colorado, pronounced asymptotic growth, variable recruitment, and management attention needed with range contraction evident and the rise of bowfishing in Colorado
40	Maxson et al. 2024*	Smallmouth buffalo (*Ictiobus bubalus* Rafinesque) population trends and demographics in the Upper Mississippi River System	0	Smallmouth buffalo	1959–2022	MN, WI, IA, IL, MO	Evidence of smallmouth buffalo decline in the Upper Mississippi River System; evidence of recruitment overfishing, lifespans up to 39 years, variable recruitment, delayed sexual maturation; implications for management of unregulated bowfisheries and refined management of commercial fisheries
41	Molinaro et al. 2024*	Population structure and vital rates of shortnose gar *Lepisosteus platostomus* in a large floodplain river	0	Shortnose gar	2015–2018	IL	The need for data on shortnose gar has given rise to exploitation such as bowfishing; fin rays suggest lifespans of 18 years, and the population appears stable, but otolith investigation needed

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
42	Lackmann et al. 2024a	Analysis of bigmouth buffalo *Ictiobus cyprinellus* spawning phenology in Minnesota reveals 50-year recruitment failure and conservation concern	0	Bigmouth buffalo	2021–2023	MN	Despite annual migration and spawning, bigmouth buffalo in Rice Lake National Wildlife Refuge have an average age of 78 years as of 2024, and approximately 100% of the population hatched prior to 1972; extensive seining for YOY post spawn across years revealed YOY in low numbers but conspicuously absent by late summer indicating top-down restriction controlled by predators; bigmouth buffalo, a long-lived periodic strategist, classified as "rough fish" in MN and subject to unregulated, unmanaged bowfishing within National Wildlife Refuge
43	Jackson et al. 2024*	Spawning migration, sex-specific home ranges, and seasonal site fidelity in a lacustrine population of Bowfin (*Amia ocellicauda*)	0	bowfin	2009–2011	NY	Tagging study reveals spawning migration, site fidelity, and sex-specific differences in spawning behavior of bowfin such that individuals congregate in shallow bays during spring; implications for bowfishing management outside of NY as these shallow peripheral regions of lakes are targeted areas in spring; bowfishing not legal for bowfin in NY

Table 1 (continued)

#	Reference	Article title	Citations	Native species	Data collection	Region	Major findings
44	Montague et al. 2024*	Commercial harvest and population characteristics of freshwater drum and buffalo *Ictiobus* spp. in Ohio waters of Lake Erie	0	freshwater drum, smallmouth buffalo, bigmouth buffalo		OH	Commercial fisheries in OH waters of Lake Erie have no regulations for drum or buffalofish despite being economically valuable; longevity of 56 years for freshwater drum and 48 years for buffalofishes in Lake Erie; harvest data suggest overfishing is occurring and longevity overfishing likely as age distributions truncated; more detailed assessment of harvest needed to ensure sustainable management
45	Rider and Janosik 2024*	Using environmental DNA metabarcoding to assess the spatiotemporal occurrence of the imperiled River Redhorse (*Moxostoma carinatum*) in the Escambia-Conecuh River system of Florida and Alabama, USA	0	river redhorse	2020–2021	AL, FL	Environmental DNA reveals the presence of imperiled river redhorse, which has implications for conservation efforts, especially as indiscriminate redhorse bowfishing pressure increases
46	Winter 2024*	Minnesota's Native Fish Bill: a case study in shifting the "rough fish paradigm"	0	all		MN	"In 2024, the Minnesota legislature passed a bill that amends 42 statutes and triggers the adoption of administrative rules to create and regulate the new legal category, "native rough fish." These reforms are an opportunity to examine the role of governance and normative frameworks in a complex socio-ecological system to create a paradigm shift to benefit native fishes.."

*Denotes articles of the topic published in this Special Issue

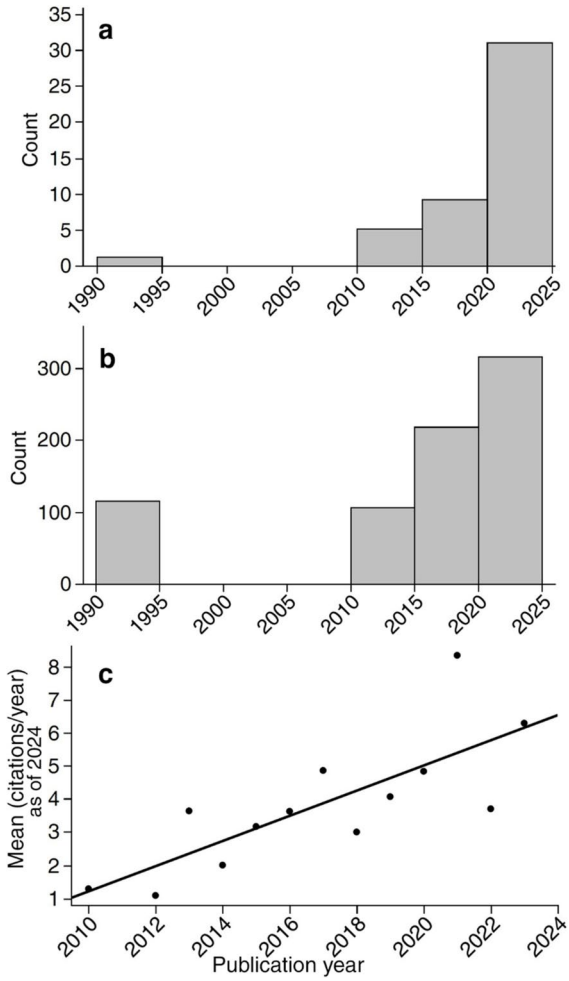

Fig. 2 **a** The number of peer-reviewed publications ($n=46$) across time in relation to bowfishing freshwater fishes native to North America and their management, (**b**) their citations ($n=750$) over the past 35 years, and (**c**) the mean citation rate (average number of citations per study per year, for studies published in year x) since 2010 reveals a significant increase in research relevance over the past 14 years ($F_{1,11}=16.4$, df = 1, $p=0.0019$, $R.^2=0.60$). All data as of 3 November 2024 according to Google Scholar. In conjunction with Table 1

caught the attention of researchers and managers, especially as it pertains to native species (Scarnecchia and Schooley 2020).

The third major advance involves a reconsideration of these fishes from a broad societal perspective, not just for what they bring to sport or commercial fishing but for the biotic diversity that they provide in our aquatic ecosystems (Scarnecchia 1992; Cooke et al. 2005; Rypel et al. 2021; Scarnecchia et al. 2021; Kopf et al. 2024). Changing societal roles and preferences manifested by a more diverse human demographic in North America is favoring a more diverse reconsideration of all ecosystem benefits of such species. This was highlighted by Solomon David at the 2022 American Fisheries Society Annual Meeting where the phrase was coined: "Diverse fishes, diverse voices" (David 2022). Neglect of these native fishes was not just seen in the comparatively low number of papers once written about their biology (Rypel et al. 2021). Neglect was also seen in the context of a changing human societal context and appreciation for the diversity of these native fishes. The assemblage of papers in this Special Issue is an outcome of the confluence of these three important advances in knowledge and its recognition.

The Special Issue: a synopsis of themes and papers

This Special Issue contains 23 articles: two articles that discuss underappreciated native fishes from a legal or public perspective and 21 that are on a broad ecological and phylogenetic diversity of North American freshwater fishes from lampreys to teleosts. The articles, arranged in the issue in general phylogenetic order, are briefly discussed here and grouped into five general themes.

The first two articles provide interesting and hopeful accounts of changing legislative and public perceptions related to native "rough fish." Winter (2024) provides a case study for native fish conservation based on recent legislation in Minnesota. Previous regulations combined native (e.g., catostomids and holosteans) and invasive (e.g., common carp *Cyprinus carpio* Linnaeus, 1758) species into a single legal category, severely limiting options for managers and confounding conservation efforts. In 2024, Minnesota became the first state to intentionally reform these statutes, creating and regulating a new legal category, "native rough fish." Results and perspectives from Winter (2024) have applicability to other states considering and enacting appropriate legislation. Kelly and David (2024) provide evidence of public interest in nongame native fishes comparable to game fishes using a 10-year analysis of social media. This analysis suggests a willingness of the public to engage

with a wider variety of species-related content than is most often featured. This study also highlights key opportunities for future outreach, which will be critical; greater public appreciation of a wider variety of native freshwater fishes is key to the legislative change described by Winter (2024).

The holosteans—gars and bowfins—are an often-maligned group of freshwater fishes in modern fisheries management. However, their value is slowly being recognized (Fig. 3; David et al. 2018), and seven articles within the Special Issue deal with these fishes. Ellard et al. (2024) identify habitat use trade-offs influencing movement in alligator gar *Atractosteus spatula* (Lacepède, 1803), while Bartnicki et al. (2024) use climate change models to predict future distributions of this largest holostean species. Movement patterns and the influence of ecomorphology in longnose gar *Lepisosteus osseus* (Linnaeus, 1758) are explored by Croft-White et al. (2024) and Doll et al. (2024), respectively, while Molinaro et al. (2024) determine vital rates of shortnose gar *L. platostomus* Rafinesque, 1820 in a floodplain river. The ecology of the emerald bowfin *Amia ocellicauda* (Richardson, 1836) is explored by Moratz et al. (2024), while bowfin spawning migrations and site fidelity are the focus of Jackson et al. (2024).

Catostomids are a rather diverse family of fish, almost exclusively native to North America, and they also figure prominently in this Special Issue. Murchie et al. (2024) used citizen scientists to monitor the migratory behavior of another large-bodied, underappreciated native species, white sucker *Catostomus commersonii* (Lacepède, 1803), and Richter et al. (2024) use acoustic telemetry and environmental data to better understand its seasonal habitat use. The biology, ecology, and management of several species of redhorse (*Moxostoma* spp.), also members of Catostomidae, are also investigated in this issue. Lackmann et al. (2024b) found that single-stock management strategies for the six Minnesota redhorse species are not supported by their life history traits, harvest rates, and population dynamics, and that bowfishing redhorse is significantly increasing with exploitation rates more than 200×that of commercial fishing. Using environmental DNA, Rider and Janosik (2024) were able to identify high spatiotemporal occurrences of the imperiled river redhorse *M. carinatum* (Cope, 1870) in Florida and Alabama. Habitat niche dynamics of another imperiled redhorse, the currently undescribed sicklefin redhorse (*Moxostoma* sp.), were investigated by Favrot and Kwak (2024). Population dynamics of long-lived sucker species including smallmouth buffalo *Ictiobus bubalus* (Rafinesque, 1818), bigmouth buffalo *I. cyprinellus* (Valenciennes, 1844), and *Carpiodes* spp. are explored across a wide geographic range from Colorado to the Laurentian Great Lakes by Woodling et al. (2024), Maxson et al. (2024), and Montague et al. (2024). The late maturation, asymptotic growth, sexual size dimorphism, and variable recruitment exhibited by many catostomids

Fig. 3 A large alligator gar *Atractosteus spatula*, tagged and released at a Mississippi River floodplain lake. Although alligator gars were the focus of eradication efforts by fisheries managers and anglers in the past, perceptions of the species and its value to ecosystems and fisheries have improved over the past 20 years. As charismatic megafauna, gars can also serve as "gateway fish," facilitating public education and interest in other underappreciated native freshwater fishes (e.g., bowfins, buffalofishes). Photo credit: USFWS

across broad geographic regions demonstrate the need for conscientious management of these long-lived taxa.

Population dynamic rates are an integral part of modern fisheries management, but these data were once largely lacking for many native fishes. Stuart et al. (2024) help fill this knowledge gap for freshwater drum *Aplodinotus grunniens* Rafinesque, 1819, a widely distributed freshwater species found from Canada (Fig. 4), through central USA, and into Atlantic drainages of Mexico and Guatemala (Neely et al. 2024). Stuart et al. (2024) found they exhibit variable recruitment related to environmental conditions and considerable longevity for a freshwater fish (62 years). Alongside their broad geographic range and long lifespans, Glowa et al. (2024) found that freshwater drum are remarkably mobile, with mean monthly movement rates among the highest on record for freshwater fishes.

Fig. 4 A young angler on the Red River in Manitoba catches her first freshwater drum *Aplodinotus grunniens*, illustrating that "rough" fish are often someone's first fish. Fishing guides are Ken Stewart (front) and Doug Watkinson (back), the authors of *The Freshwater Fishes of Manitoba*. Photo credit: Margaret Docker

The habitat preferences, population dynamics, and even the "personality" of smaller and even more understudied species are also included in this issue. Hartman et al. (2024) model suitable habitat for the five native lamprey species in Illinois. Lampreys, often a maligned group of fishes in North America given the damage caused by their non-native "cousin," the sea lamprey *Petromyzon marinus* Linnaeus, 1758, in the Laurentian Great Lakes, are becoming increasingly appreciated (Maitland et al. 2015; Clemens and Wang 2021). Renner et al. (2024) examine long-term patterns in goldeye *Hiodon alosoides* (Rafinesque, 1819) in South Dakota. Barrett and Cashner (2024) found evidence of a bold-exploratory-active behavioral syndrome in the creek chub *Semotilus atromaculatus* (Mitchill, 1818) and suggested that intraspecific differences such as these can have important influences on stream community dynamics. Although the vast majority of the papers in this Special Issue focus on the larger-bodied holosteans, catostomids, and sciaenids, the increasing recognition of these small, often "out-of-sight, out-of-mind" species is gratifying.

Conclusion

We now realize that many previously neglected, underappreciated native species deserve and require more research and management attention. Mounting evidence from peer-reviewed scientific studies, public discourse on social media, and changing values and perceptions of North Americans suggests a movement away from strictly traditional thinking of these species as "rough fish." We have come to embrace a perspective of understanding and appreciation of the roles these species play not only as newly recognized game fishes, but also as important parts of ecosystem-based management of North American freshwater fisheries. This Special Issue on "Underappreciated Native Fishes of North America and their Management" brings us one step closer to the diversity of native fishes being recognized, respected, and conserved.

Acknowledgements We would like to thank Katie O'Reilly and Jason Schooley for their help in developing this Special Issue and the many reviewers who provided valuable feedback on the manuscripts.

Data availability The data supporting this manuscript are available from the corresponding author following a reasonable request.

References

Adams KM, Taylor AT, Snow RA, Porta MJ (2019) #GARWEEK: insights from a social media outreach campaign about alligator gar in Oklahoma. Proc Okla Acad Sci 99:31–40

Adams SR, Inebnit TE, Lewis LC, Naus CJ, Kluender E, Spooner GG (2024) Spawning ecology and spawning site fidelity of alligator gar, *Atractosteus spatula*, in the Fourche LaFave River: implications for river-floodplain management and alligator gar conservation. Southeast Fish Council Proc 1(64):12–34 (https://trace.tennessee.edu/sfcproceedings/vol1/iss64/3)

Andrews AH, Daugherty DJ, Wertnik M, Welte C, Smith NG, Buckmeier DL, Riecke D (2024) Alligator gar as a centenarian species: extending lifespan estimates using bomb radiocarbon and laser ablation–accelerator mass spectrometry. Mar Freshw Res 75(8):MF24024. https://doi.org/10.1071/MF24024

Barrett JP, Cashner MF (2024) An investigation of personality in the Creek Chub *Semotilus atromaculatus*. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01630-2

Bartnicki J, Snow RA, Taylor AT, Butler CJ (2024) Use of multiple climate change scenarios to predict future distributions of alligator gar (*Atractosteus spatula*) in the United States. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01654-8

Bartnicki J, Snow R (2021) Examination of the current state record River Carpsucker in Oklahoma. Proc Okla Acad Sci 101:67–71

Bennett DL, Bonds CC (2012) Description of bowfishing tournaments in the Trinity River, Texas, with emphasis on harvest of alligator gar. Proc Annu Conf Southeast Assoc Fish Wildl Agencies 66:1–5

Bennett DL, Ott RA, Bonds CC (2015) Surveys of Texas bow anglers, with implications for managing alligator gar. J Southeast Assoc Fish Wildl Agencies 2:8–14

Binion GR, Daugherty DJ, Bodine KA (2015) Population dynamics of alligator gar in Choke Canyon Reservoir, Texas: implications for management. J Southeast Assoc Fish Wildl Agencies 2:57–63

Brownstein CD, Kim D, Orr OD et al (2022) Hidden species diversity in an iconic living fossil vertebrate. Biol Lett 18(11):20220395. https://doi.org/10.1098/rsbl.2022.0395

Buckmeier DL, Smith NG, Schlechte JW, Ferrara AM, Kirkland K (2016) Characteristics and conservation of a trophy alligator gar population in the middle Trinity River, Texas. J Southeast Assoc Fish Wildl Agencies 3:33–38

Buckmeier DL, Smith NG, Daugherty DJ, Bennett DL (2017) Reproductive ecology of alligator gar: identification of environmental drivers of recruitment success. J Southeast Assoc Fish Wildl Agencies 4(1):8–17

Clemens BJ, Wang CJ (2021) Dispelling misperceptions of native lampreys (*Entosphenus* and *Lampetra* spp.) in the Pacific northwest (USA). Conserv Sci Pract 3:e402. https://doi.org/10.1111/csp2.402

Cooke SJ, Bunt CM, Hamilton SJ, Jennings CA, Pearson MP, Cooperman MS, Markle DF (2005) Threats, conservation strategies, and prognosis for suckers (Catostomidae) in North America: insights from regional case studies of a diverse family of non-game fishes. Biol Conserv 121(3):317–331. https://doi.org/10.1016/j.biocon.2004.05.015

Croft-White MV, Larocque SM, Reddick DT, Smith PD, Cooke SJ, Midwood JD (2024) Diversity of movement patterns of longnose gar tracked in coastal waters of western Lake Ontario. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-023-01491-1

Daugherty DJ, Andrews AH, Smith NG (2020) Otolith-based age estimates of alligator gar assessed using bomb radiocarbon dating to greater than 60 years. N Am J Fish Manag 40(3):613–621. https://doi.org/10.1002/nafm.10390

David SR, King SM, Stein JA (2018) Introduction to a special section: angling for dinosaurs—status and future study of the ecology, conservation, and management of ancient fishes. Trans Am Fish Soc 147(4):623–625. https://doi.org/10.1002/tafs.10072

David SR (2022) Modern conservation insights from ancient fishes. Plenary at the 152nd Annual Meeting of the American Fisheries Society. Spokane, Washington. https://www.youtube.com/watch?v=jiGXwcn446w

Doll JC, Fisher I, Selby A, Jacquemin SJ, Sinopoli D, David SR (2024) Ecomorphology of longnose gar (*Lepisosteus osseus*): on the influence of size, sex, and river location. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01619-x

Ellard JK, Roberts HC, Daugherty DJ, Fleming BP, Acre MR, Perkin JS (2024) Scale-dependent tradeoffs between habitat and time in explaining alligator gar (*Atractosteus spatula*) movement. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-023-01473-3

Favrot SD, Kwak TJ (2024) Habitat niche dynamics of the sicklefin redhorse: a southern Appalachian Mountain habitat specialist. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-023-01465-3

Glowa SE, Watkinson DA, Enders EC, Klein GM, Gutowsky LFG (2024) Exploring the extensive movements and home range of one of North America's most mobile fish: the freshwater drum (*Aplodinotus grunniens*). Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01635-x

Hartman JH, Davis MA, Tiemann JS (2024) Species distribution models predict suitable habitat for the overlooked and understudied freshwater lampreys of Illinois. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01593-4

Jackson JR, Jacobs GR, Latzka AW, Landsman T, Young BP, McCune AR (2024) Spawning migration, sex-specific home ranges, and seasonal site fidelity in a lacustrine population of Bowfin (*Amia ocellicauda*). Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01585-4

Kelley SW (2012) Age and growth of spawning longnose gar (*Lepisosteus osseus*) in a north central Texas reservoir. West N Am Nat 72(1):69–77. https://doi.org/10.3398/064.072.0108

Kelly FJ, David SR (2024) Don't judge a nongame fish by its cover-age: an assessment of social media posts featuring Minnesota native fishes. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01644-w

King SM, David SR, Stein JA (2018) Relative bias and precision of age estimates among calcified structures of spotted gar, shortnose gar, and longnose gar. Trans Am Fish Soc 147(4):626–638. https://doi.org/10.1002/tafs.10042

Kopf RK, Banks S, Brent LJN, Humphries P, Jolly CJ, Lee PC, Luiz OJ, Nimmo D, Winemiller KO (2024) Loss of Earth's old, wise, and large animals. Science (in press). https://doi.org/10.1126/science.ado2705

Lackmann AR, Andrews AH, Butler MG, Bielak-Lackmann ES, Clark ME (2019) Bigmouth buffalo *Ictiobus cyprinellus* sets freshwater teleost record as improved age analysis reveals centenarian longevity. Commun Biol 2:197. https://doi.org/10.1038/s42003-019-0452-0

Lackmann AR, Kratz BJ, Bielak-Lackmann ES, Jacobson RI, Sauer DJ, Andrews AH, Butler MG, Clark ME (2021) Long-lived population demographics in a declining, vulnerable fishery - bigmouth buffalo (*Ictiobus cyprinellus*) of Jamestown Reservoir, North Dakota. Can J Fish Aquat Sci 78(10):1486–1496. https://doi.org/10.1139/cjfas-2020-0485

Lackmann AR, Bielak-Lackmann ES, Jacobson RI, Butler MG, Clark ME (2022a) Otolith allometry informs age and growth of long-lived Quillback *Carpiodes cyprinus*. Environ Biol Fish 105(8):1051–1064. https://doi.org/10.1007/s10641-022-01315-8

Lackmann AR, Bielak-Lackmann ES, Butler MG, Clark ME (2022b) Otoliths suggest lifespans more than 30 years for free-living bowfin *Amia calva*: implications for fisheries management in the bowfishing era. J Fish Biol 101(5):1301–1311. https://doi.org/10.1111/jfb.15201

Lackmann AR, Sereda J, Pollock M, Bryshun R, Chupik M, McCallum K, Villeneuve J, Bielak-Lackmann ES, Clark ME (2023a) Bet-hedging bigmouth buffalo (*Ictiobus cyprinellus*) recruit episodically over a 127-year timeframe in Saskatchewan. Can J Fish Aquat Sci 80(2):313–329. https://doi.org/10.1139/cjfas-2022-0122

Lackmann AR, Black SA, Bielak-Lackmann ES, Lackmann JA (2023b) Centenarian lifespans of three freshwater fish species in Arizona reveal the exceptional longevity of the buffalofishes (*Ictiobus*). Sci Rep 13(1):17401. https://doi.org/10.1038/s41598-023-44328-8

Lackmann AR, Seybold S, Bielak-Lackmann ES, Ford W, Butler MG, Clark ME (2024a) Analysis of bigmouth buffalo *Ictiobus cyprinellus* spawning phenology in Minnesota reveals 50-year recruitment failure and conservation concern. Sci Rep 14(1):19444. https://doi.org/10.1038/s41598-024-70237-5

Lackmann AR, Bielak-Lackmann ES, Jacobson RI, Andrews AH, Butler MG, Clark ME (2024b) Harvest trends, growth and longevity, and population dynamics reveal traditional assumptions for redhorse (*Moxostoma* spp.) management in Minnesota are not supported. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-023-01460-8

Long JM, Snow RA, Shoup DE, Bartnicki JB (2023) Validation and comparison of age estimates for smallmouth buffalo in Oklahoma based on otoliths, pectoral fin rays, and opercula. N Am J Fish Manag 43:618–627. https://doi.org/10.1002/nafm.10865

Love SA, Tripp SJ, Phelps QE (2019) Age and growth of middle Mississippi River smallmouth buffalo. Am Midl Nat 182(1):118–123. https://doi.org/10.1674/0003-0031-182.1.118

Maitland PS, Renaud CB, Quintella BR, Close DA, Docker MF (2015) Conservation of native lampreys. In: Docker M (ed) Lampreys: biology, conservation and control. Springer, Dordrecht, pp 375–428. https://doi.org/10.1007/978-94-017-9306-3_8

Maxson KA, Solomon LE, Bookout TA et al (2024) Smallmouth buffalo (*Ictiobus bubalus* Rafinesque) population trends and demographics in the Upper Mississippi River System. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01554-x

Molinaro SA, King SM, Solomon LE, Maxson KA, Stein JA (2024) Population structure and vital rates of shortnose gar *Lepisosteus platostomus* in a large floodplain river. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01583-6

Montague GF, Schooley JD, Scarnecchia DL, Snow RA (2023) Bowfishing shoot-and-release: high short-term mortality of nongame fishes and its management implications. N Am J Fish Manag 43(4):962–983. https://doi.org/10.1002/nafm.10904

Montague GF, Zentner DL, Snow RA, Bartnicki JB, Shoup DE, Schmidt BA (2024) Commercial harvest and population characteristics of freshwater drum and buffalo *Ictiobus* spp. in Ohio waters of Lake Erie. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01598-z

Moratz C, Shroynal JS, McReynolds AT, Houghton C, Forsythe PS (2024) Ecology of eyetail bowfin (*Amia ocellicauda*) in Green Bay Lake Michigan. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01631-1

Murchie KJ, Childress ES, McIntyre PB (2024) For the love of suckers: scientific benefits of engaging volunteers to monitor migrations and advocate for native non-game fishes. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01616-0

Neely BC, Murdock E, Sprenkle EN, Stockebrand P (2024) Examination of freshwater drum populations at the center of their latitudinal range: implications for development of diverse recreational angling opportunities. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01545-y

Quinn JW (2010) A survey of bowfishing tournaments in Arkansas. N Am J Fish Manag 30(6):1376–1384. https://doi.org/10.1577/M10-008.1

Radford DS, Lackmann AR, Moody-Carpenter CJ, Colombo RE (2021) Comparison of four hard structures including otoliths for estimating age in blue suckers *Cycleptus elongatus*. Trans Am Fish Soc 150(4):514–527. https://doi.org/10.1002/tafs.10303

Radigan WJ, Fopma S, Sorensen J, Longhenry CM (2023) Factors affecting the catch and harvest rates of paddlefish downstream of Gavins Point Dam, South Dakota, 2000–2020. Fish Manag Ecol 30(1):11–23. https://doi.org/10.1111/fme.12596

Renner EA, Miller BT, Danda KR (2024) Goldeye (*Hiodon alosoides*) population dynamics in Lake Oahe and Lake Sharpe South Dakota. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01573-8

Richter IA, Smokorowski KE, Blanchfield PJ (2024) Seasonal habitat use of white sucker *Catostomus commersonii* in a small Boreal lake. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01581-8

Rider HJ, Janosik AM (2024) Using environmental DNA metabarcoding to assess the spatiotemporal occurrence of the imperiled River Redhorse (*Moxostoma carinatum*) in the Escambia-Conecuh River system of Florida and Alabama, USA. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01574-7

Rypel AL, Saffarinia P, Vaughn CC et al (2021) Goodbye to "rough fish": paradigm shift in the conservation of native fishes. Fisheries 46(12):605–616. https://doi.org/10.1002/fsh.10660

Scarnecchia DL (1992) A reappraisal of gars and bowfins in fishery management. Fisheries 17(5):6–12. https://doi.org/10.1577/1548-8446(1992)017%3c0006:AROGAB%3e2.0.CO;2

Scarnecchia DL, Schooley JD (2020) Bowfishing in the United States: history, status, ecological impact, and a need for management. Trans Kans Acad 123:285–338. https://doi.org/10.1660/062.123.0301

Scarnecchia DL, Schooley JD (2022) Trophies, technology, and timescape in fisheries management, as exemplified through Oklahoma's world record paddlefish *Polyodon spathula*. Fisheries 47(9):381–394. https://doi.org/10.1002/fsh.10764

Scarnecchia DL, Schooley JD, Lackmann AR et al (2021) The Sport Fish Restoration Program as a funding source to manage and monitor bowfishing and monitor inland commercial fisheries. Fisheries 46(12):595–604. https://doi.org/10.1002/fsh.10679

Schlechte JW, Daugherty DJ, Smith NG, Buckmeier DL (2021) Angler practices and preferences for managing alligator gar in Texas. J Southeast Assoc Fish Wildl Agencies 8:23–31

Schooley JD, Scarnecchia DL, Crews A (2014) Harvest management regulation options for Oklahoma's Grand Lake stock of paddlefish. J Southeast Assoc Fish Wildl Agencies 1:89–97

Smith NG, Daugherty DJ, Schlechte JW, Buckmeier DL (2018) Modeling the responses of alligator gar populations to harvest under various length-based regulations: implications for conservation and management. Trans Am Fish Soc 147(4):665–673. https://doi.org/10.1002/tafs.10040

Smith NG, Daugherty DJ, Brinkman EL, Wegener MG, Kreiser BR, Ferrara AM, Kimmel KD, David SR (2020) Advances in conservation and management of the alligator gar: a synthesis of current knowledge and introduction to a special section. N Am J Fish Manag 40(3):527–543. https://doi.org/10.1002/nafm.10369

Snow RA, Porta MJ (2019) Examination of three state records for spotted gar in Oklahoma. Proc Okla Acad Sci 99:41–46

Snow RA, Porta MJ (2020) Seasonal food habits and prey selectivity of alligator gar from Texoma Reservoir, Oklahoma. J Southeast Assoc Fish Wildl Agencies 8:15–22

Snow RS, Stewart DR, Smith NG, Porta MJ (2022) Modeling the population response of alligator gar in Texoma Reservoir to harvest and discard mortality. N Am J Fish Manag 42(6):1635–1652. https://doi.org/10.1002/nafm.10857

Stuart M, Kludt N, Pegg MA, Montesanto F, Lyon C, Chance-Ossowski CJ (2024) Dynamic rates of freshwater drum near the northern extent of their range: evidence of environment-recruitment relationships. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01589-0

Walker RH, Kluender ER, Inebnit TE, Reid Adams S (2013) Differences in diet and feeding ecology of similar-sized spotted (*Lepisosteus oculatus*) and shortnose (*Lepisosteus platostomus*) gars during flooding of a south-eastern US river. Ecol Freshw Fish 22(4):617–625. https://doi.org/10.1111/eff.12066

Winemiller KO, Rose KA (1992) Patterns of life-history diversification in North American fishes: implications for population regulation. Can J Fish Aquat Sci 49:2196–2218. https://doi.org/10.1139/f92-242

Winter TJ (2024) Minnesota's Native Fish Bill: a case study in shifting the "rough fish paradigm". Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01653-9

Woodling JD, Treble A, Brandt MM, Lackmann AR (2024) Otolith analysis reveals long-lived population demographics of quillback *Carpiodes cyprinus* and river carpsucker *C. carpio* in Colorado. Environ Biol Fish 107(12). https://doi.org/10.1007/s10641-024-01557-8

Wright JJ, Bruce SA, Sinopoli DA, Palumbo JR, Stewart DJ (2022) Phylogenomic analysis of the bowfin (*Amia calva*) reveals unrecognized species diversity in a living fossil lineage. Sci Rep 12(1):16514. https://doi.org/10.1038/s41598-022-20875-4

York B, Schooley JD, Scarnecchia DL (2022) Oklahoma bowfishing values and perspectives toward nongame fishes and their management. N Am J Fish Manag 42(4):1020–1040. https://doi.org/10.1002/nafm.10795

Zentner DL, Brewer SK, Shoup DE (2023) Environment affects sucker catch rate, size structure, species composition, and precision in boat electrofishing samples. J Fish Wildl Manag 14(1):135–152. https://doi.org/10.3996/JFWM-22-052