PERSPECTIVE

Goodbye to "Rough Fish": Paradigm Shift in the Conservation of Native Fishes

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While sometimes difficult to admit, perspectives of European and white males have overwhelmingly dominated fisheries science and management in the USA. This dynamic is exemplified by bias against "rough fish"—a pejorative ascribing low-to-zero value for countless native fishes. One product of this bias is that biologists have ironically worked against conservation of diverse fishes for over a century, and these problems persist today. Nearly all U.S. states retain bag limits and other policies that are regressive and encourage overfishing and decline of native species. Multiple lines of evidence point towards the need for a paradigm shift. These include: (1) native species deliver critical ecosystem services; (2) little demonstration that native fish removals deliver intended benefits; (3) many native fishes are long-lived and vulnerable to overfishing and decline; and (4) fisher values and demographics shifting towards native fish conservation. Overall, existing native fish policies are unacceptable and run counter to the public trust doctrine where government agencies manage natural resources for public use. We encourage agencies to revisit their policies regarding native fishes and provide suggestions for developing more holistic, protective, and inclusive conservation policy.

INTRODUCTION

European and white males have historically valued only a select group of species (e.g., Salmonidae and *Micropterus* spp.) and have dominated management of freshwater fisheries in North America (Nielsen 1999; Arismendi and Penaluna 2016; Penaluna et al. 2017; Murphy 2020a). And while attitudes and regulations on these species have shifted substantially over the past 100 years (Rypel et al. 2016), policies for many native fishes have not. Less-favored species always sustained fisheries as food fish, but typically for underrepresented groups, such as Black and Indigenous Peoples of Color and immigrants (Floyd et al. 2006; Burger and Gochfeld 2011; Islam and Berkes 2016). The term "rough fish" exemplifies this problem. It is a derogatory term that lumps together diverse fishes and life-history strategies perceived as having low-to-zero value. Sadly, fishers and resource management agencies continue to perpetuate its use (Rose and Moen 1953; Bulow et al. 1988; Love et al. 2019). Related pejoratives include "trash fish," "dirt fish," "other fish," "coarse fish," and "underused fish." However, rough fish remains the most ubiquitous term used today (Figure 1; Table 1).

PEOPLE ISSUES

Carlander (1954) described an apparent origin of the term rough fish. During the mid-late 1800s, commercial fishers netted and processed large quantities of fish while on riverboats. However, during hot summers, slow and heavy boats required weight reductions to ensure the entire catch did not spoil before reaching markets and to allow boats to pass over shallow waters. A common practice was to save fully processed or "dressed" fish, since these commanded higher prices. Less desirable species were "rough-dressed," meaning internal organs were removed but fish were not filleted. To reduce weight, boats discarded rough-dressed fish. Later, biologists began using this term to describe a hypothetical concept that native fishes were limiting preferred gamefish populations, leading to numerous attempts to control and remove native fish populations (Cahn 1929; Tarzwell 1945; Moyle et al. 1950; Carroll et al. 1963). Most removal operations involved intensive netting or whole ecosystem rotenone (poisoning) treatments (Weier and Starr 1950; Meyer 1963; Hughes and Lee 1973). Yet evidence on the efficacy of these treatments is notably scant. Perhaps the most notorious was the 1962 attempt to

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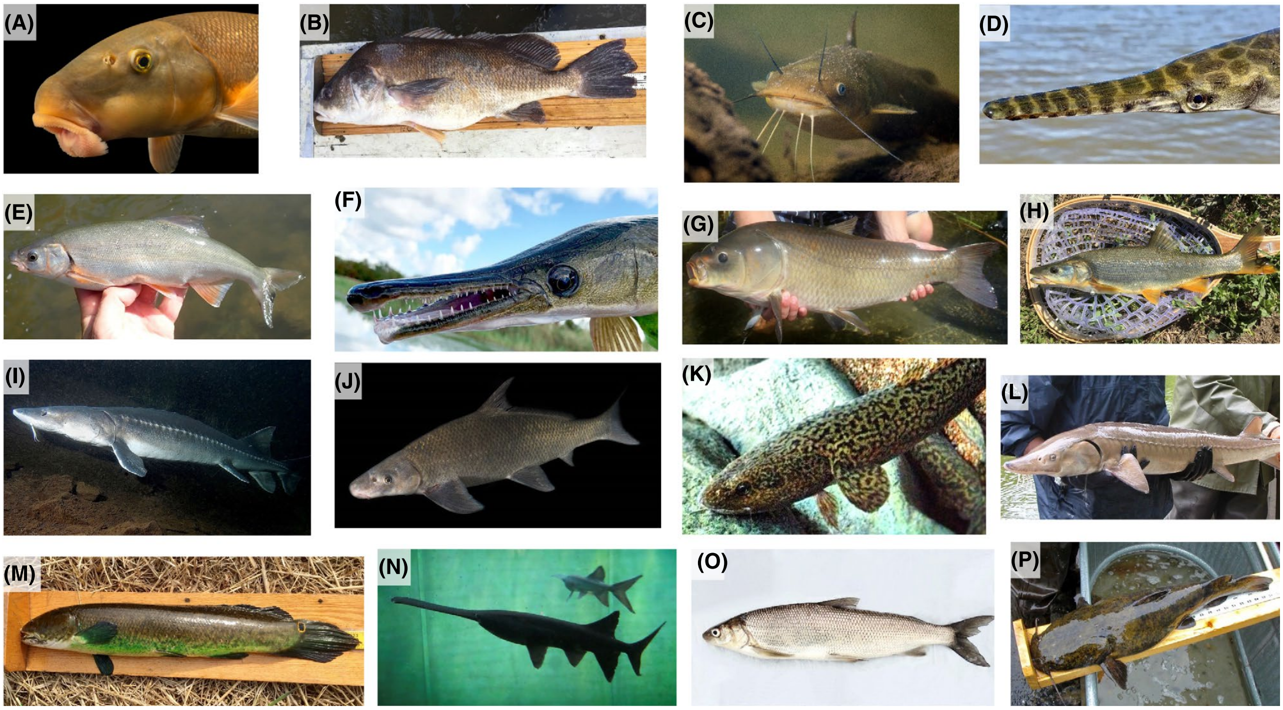

Figure 1. Select examples of native fishes currently and previously classified as rough fish. (A) Largescale Sucker *Catostomus macrocheilus*[1], (B) Freshwater Drum *Aplodinotus grunniens*[2], (C) Yellow Bullhead *Ameiurus natalis*[3], (D) Spotted Gar *Lepisosteus oculatus*[2], (E) Chiselmouth *Acrocheilus alutaceus*[4], (F) Alligator Gar *Atractosteus spatula*[2], G) Bigmouth Buffalo *Ictiobus cyprinellus*[3], (H) Northern Pikeminnow *Ptychocheilus oregonensis*[4], (I) White Sturgeon *Acipenser transmontanus*[3], (J) Blue Sucker *Cycleptus elongatus*[3], (K) Burbot *Lota lota*[2], (L) Lake Sturgeon *Acipenser fulvescens*[2], (M) Bowfin *Amia calva*[2], (N) American Paddlefish *Polyodon spathula*[2], O) Lake Whitefish *Coregonus clupeaformis*[2], (P) Flathead Catfish *Pylodictis olivaris*[2]. A longer species compilation is in Figure 5. Photo Credits: [1]Joel Sartore, used with permission, [2]Solomon R. David, [3]Wikimedia Commons, [4]Matthew L. Miller.

poison 715 km of the Green River flowing through Wyoming, Colorado, and Utah (Holden 1991). The "treatment" targeted Common Carp *Cyprinus carpio* and a number of native fishes. The result was never formally evaluated, but no evidence exists that it was successful. It did kill millions of fish, and put Colorado Pikeminnow *Ptychocheilus lucius*, Razorback Sucker *Xyrauchen texanus*, and other native fishes on the road to listing as endangered species (Holden 1991). Similar

Table 1. Ecosystem service classes, ecosystem services provided by native fishes, and the benefits delivered to humans. Modeled after Vaughn (2018).

Ecosystem service class	Ecosystem service	Benefits to humans
Regulating	Host fishes	Freshwater mussel populations/water quality
	Uptake and processing of contaminants	Water quality
	Carbon sequestration and storage	Climate control
Supporting	Nutrient cycling, transport and storage	Water quality
	Habitat modification	Fish habitat
	Environmental monitoring	Water quality
	Food webs	Biodiversity
	Invasive species control	Biodiversity/Fisheries
	Predation on overabundant prey	Fisheries
Provisioning	Food for other species	Biodiversity/Fisheries
	Food for humans	Food provisioning
	Products from rough fish	Jewelry/art/cosmetics/pet food
	Fishing opportunities	Economic
Cultural	Recreational value	Unique Fisheries/Solitude/Relaxation
	Engaging children in the outdoors	Fisheries
	Cultural value	Spiritual benefits/festivals/derbies/recipes
	Existence value	Conservation value

poisoning events occurred in speciose streams in the southeastern USA, such as in Great Smoky Mountains National Park (Lennon and Parker 1959).

Experiences of sovereign tribes in North America provide damning evidence on the efficacy of prevailing fish management paradigms. For example, the Ojibwe people in Wisconsin have lived with whites for 3 centuries and have been subject to their fish management regimes for about half that time. Litigation over treaty-stipulated hunting and fishing rights in the 1970s and 80s between mostly the state government and the six bands of Ojibwe resulted in joint management of species of most interest to both non-Indigenous sports fishers and native peoples (Nesper 2002). So-called rough fish have not been subject of negotiations because they are devalued by many. However, they have always been esteemed in the Ojibwe communities. Indeed, Namebini-giizis names the month of February the "Sucker Moon" because the noble suckerfish sacrificed their lives to feed the Ojibwe people. Yet during negotiations with the state, members of one of the Ojibwe communities were teased about their alleged preference for suckers (N. Kmiecik, Great Lakes Fish and Wildlife Commission, personal communication).

Now in his late 70s, Tom Maulson, member and former chairman of the Lac du Flambeau Band of Lake Superior Chippewa Indians, recalled his blind grandmother's love of sucker head soup. In the spring, she would exhort her grandsons to go out and get her suckers. Ernie St. Germaine, former chief judge in the same community, also had memories, saying:

> I think I probably told you about the naming ceremony where Pipe and Bineshi attended. We were naming my son Pete. It was spring so I got some suckers from Jr. LaBarge. My mom made sucker head chowder in a small kettle thinking not many would be interested. I had the food on a blanket on the ground on a warm day. Those two old men wanted to make their own plates, so they got up and started dishing up. Old Bineshi had a big spoon he was using to scoop food onto his plate. Then he came around and spotted the kettle of sucker head soup. He started spooning it onto his plate, stopped, picked up the kettle, looked around, asked, "anyone want any of this?" Didn't wait for an answer, sat down with the kettle and his spoon and ate the whole thing.

Some accounts suggest suckers, or so-called rough fish, once had a central place in the traditional Ojibwe diet, but that place may have been usurped, though perhaps incorrectly. Brooks BigJohn, who is also from Lac du Flambeau, a generation younger than these men, recently communicated to one of the authors that smelts, tullibees (Cisco *Coregonus artedi*), sucker, and redhorse remain important in the community. He estimated that 2 dozen or more people in the community smoke fish, including these species. Last winter, fishers went out on frozen lakes and fished for tullibees through the ice, using both suckers and a swimming decoy for bait. When they would get a hundred or so, they would take them home and smoke them, give them away to relatives or friends or sell them for "$5 a pop," Brooks reported. Yet these fishes have received little management focus even though many are immediately threatened by invasive species, climate change, and land use modifications (Sharma et al. 2011; Magee et al. 2019).

The North American Model of Wildlife Conservation may play an undergirding role in the structure and function of extant fisheries conservation policies across the USA. The North American Model is a set of principles that have collectively been applied to shape the field of wildlife conservation in the United States and Canada (Geist et al. 2001; Organ et al. 2012). As a whole, the model encourages the management of wildlife resources as a public trust. The framework specifically emphasizes that markets for wildlife should be eliminated, that wildlife are allocated by law, allowing killing of wildlife only for legitimate purposes, that wildlife is an international resource, that science is the proper basis for managing wildlife, and that allocation of wildlife for harvest is democratic. While the model has not been explicitly adopted in fisheries and is not included in the traditional definition of "wildlife" in the model, it nonetheless has strongly influenced the field of fisheries (McMullin and Pert 2010; Sass et al. 2017). For example, some fish species have been labeled as "sportfish" in part because they were prioritized for management because of fishing license sales and revenue generated for state agencies. However, this history clearly highlights some of the problems with such an approach; namely that species not preferred by white majorities were largely ignored by managers. The system also encouraged a potentially dangerous dichotomy (i.e., sportfishes versus non-game fishes) depending on angler preference that persists and continues to drive key fisheries policies.

ECOSYSTEM SERVICES

Diverse native fishes present conservation management challenges for humans, but they also provide highly valuable ecosystem services that remain underappreciated (Table 1). Ecosystem services are defined as benefits that humans derive from ecosystems (Daily 1997). Services can be direct such as provisioning water or food. Alternatively, regulating services include processes such as water purification, climate mitigation and control, carbon sequestration, and pollination (Daily 1997; Vaughn 2018). Supporting ecosystem services include nutrient processing and storage, habitat for species, food web support, and environmental monitoring. Finally, cultural services provide human benefits through recreation, tourism, and aesthetic or spiritual experiences (Daily 1997; Vaughn 2018).

Native fishes provide regulating ecosystem services through their support of native freshwater mussels (Figure 2). Freshwater mussel larvae (glochidia) are obligate ectoparasites on fishes; thus fish are essential to reproduction and dispersal of mussels (Barnhart et al. 2008; Haag 2012). Few studies have focused on threats to fish–mussel host relationships (Modesto et al. 2018); however it has long been known that factors affecting distribution of host fishes have negative consequences for mussels (Watters 1996; Schwalb et al. 2013). Loss or mismanagement of native fishes threatens freshwater mussel populations and vice versa. Because freshwater mussels are filter feeders, mussel declines often precede erosion in water quality (Sietman et al. 2001; Zipper et al. 2016). Thus, mismanagement of fish hosts produces negative ecological consequences that cascade to the ecosystem level. Over 70% of North America's freshwater mussels are imperiled (Williams et al. 1993) and mussels are increasingly listed under state and federal endangered species acts (Ferreira-Rodríguez et al. 2019).

An underappreciated but important supporting ecosystem service of native fishes is their role in nutrient storage, processing, and transport, classically with salmon (Naiman et al.

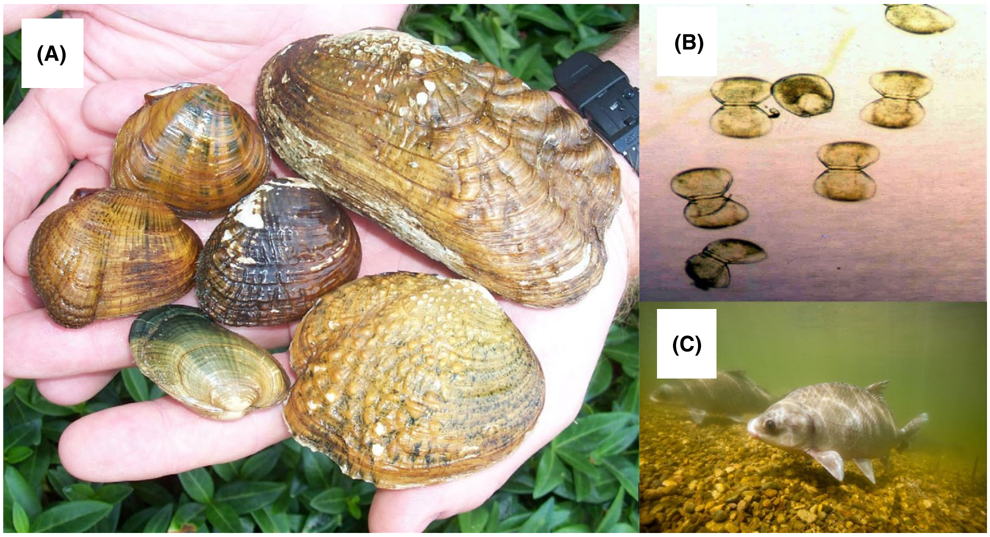

Figure 2. (A) Endangered freshwater mussels in the Clinch River and Powell River watersheds in Virginia. Freshwater mussels live in benthic habitats where they filter feed water to acquire food, and then return clean water to the ecosystem. Freshwater mussels depend on specific fish hosts to successfully reproduce and have evolved complex strategies to attract fish hosts to transmit parasitic glochidia *Lampsilis higginsi* (B) to fishes. Many fish hosts, like (C) Smallmouth Buffalo are considered rough fish in U.S. States and lack protection. All photos from U.S. Fish and Wildlife Service.

2002; McIntyre et al. 2008; Alexiades et al. 2017). Childress and McIntyre (2016) studied White Sucker *Catostomus commersonii* and Longnose Sucker *C. catostomus* and spawning migrations into tributary streams of the Laurentian Great Lakes (Figure 3). Similar to ecological role of salmon to stream ecosystems, streams with sucker runs pulsed nitrogen (up to 44% for NH_4-N) relative to streams without suckers. They also showed how ecosystem respiration spiked coincident with sucker egg deposition. Jones and Mackereth (2016) documented how adfluvial White Suckers provided the vast majority of nutrient subsidies (84% N and 78% P) in a stream that also received subsidies from salmon carcasses. In addition, Booth et al. (2020) documented that Sonora Sucker *C. insignis*—a dominant fish species in the desert Southwest—functionally engineer aquatic ecosystems through movement and bioturbation.

Recreational fishing is a cultural ecosystem service. In the USA, recreational fishing supports an economic impact in excess of US$114 billion and 828,133 jobs (Allen et al. 2013). Importantly, a fish classified as rough fish at one time can quickly become recreationally desirable (David et al. 2018). Alligator Gar *Atractosteus spatula* were once persecuted and reduced to the brink of extinction throughout their native range (Buckmeier et al. 2016; Figure 4). However, interest in the species has exploded, especially as a catch-and-release opportunity (Smith et al. 2020). In Texas, Alligator Gar fishing was unregulated, but increasing popularity in locations like the Trinity River led to implementation of a statewide one fish/day bag limit. Television shows promoting catch-and-release fishing for gar drove excitement further and fishing guides switched to catch-and-release trip models. Fishers now spend thousands of dollars to travel to Texas for the possibility of catching giant gar. In early 2021, the state of Minnesota changed their state fish and game statutes to include gar species as "game fish." Similarly, catfishes were long held in low esteem by fishers, but following increased attention in the 1980s, and 1990s, especially from media outlets like *In-Fisherman*, interest in catfish angling spiked. Today, catfishes support one of the most popular recreational fisheries in the USA (Arterburn et al. 2002; Stewart et al. 2012; Hyman et al. 2017).

Figure 3. Spawning aggregation of White Sucker. In the Laurentian Great Lakes, streams with runs of spawning suckers pulse in nitrogen upwards of 44% during runs (Childress and McIntyre 2016).

CONSERVATION ISSUES

Unfortunately, members of the public can confuse native fishes for harmful non-native fishes, resulting in conflated management efforts. Common Carp create disruptions in the ecology of freshwater ecosystems through bioturbation of sediments and near constant resuspension of legacy phosphorus, leading to harmful algal blooms (Miller and Crowl 2006; Bajer et al. 2009; Weber and Brown 2009). Fishers frequently misidentify native suckers as Common Carp, leading to false conclusions that native suckers are similarly harmful. The Santa Ana River, California is a common location for illegal off-roading and other unsanctioned activities, disrupting riverine habitat of the threatened Santa Ana Sucker *C. santaanae*. Although this river is essential habitat for this species, the population is subject to repeated disturbances, in part because users assume the sucker are carp (Richmond et al.

Figure 4. (Left) Alligator Gar captured from Moon Lake, Mississippi, March 1910. Photo credit: D. Franklin. (Right) Earrings made from the ganoid scales of an Alligator Gar. Photo credit: Betty Willis. Photos from wikicommons.org.

2018; Saffarinia et al., in review). Misunderstandings also lead to needless killing of native species, e.g., by throwing them on shore or killing and discarding them in other ways.

Many fishes managed as rough fish are long-lived, often >20 or 30 years (Rypel et al. 2006; Perry and Casselman 2012; Love et al. 2019; Smith et al. 2020). A recent study found Bigmouth Buffalo *Ictiobus cyprinellus* can attain at least 112 years of age, making this the oldest known freshwater teleost (Lackmann et al. 2019). Yet bag limits for the species remain unlimited in almost every U.S. state. Broadly speaking, these species share population characteristics classically associated with the periodic life-history strategy (Winemiller and Rose 1992). Periodic life-histories are adapted to temporally unstable environments such that in many years recruitment is low, but under certain conditions recruitment temporarily and synchronously spikes, functionally buoying populations for long periods (Winemiller 2005; Mims and Olden 2012). Unfortunately, this same strategy renders such species vulnerable to overfishing and collapse (Beamish et al. 2006; de Mitcheson et al. 2020).

Increasingly though, entire segments of the angling community are devoted to native fishes. These trends indicate shifts in public perception towards native fishes that can be recognized and cultivated. MeatEater, the popular media company run by television personality Steven Rinella, recently began a column extolling the virtue of undervalued fish. A growing number of online communities are devoted to native fish conservation and responsible angling. Roughfish.com is a site founded on the principle that all fish deserve respect. For its contests and recognition programs, it only allows native fish caught by hook-and-line (not bowfishing, snagging, etc.) and strictly enforces rules that suckers, gar, and all species be treated with care and respect. Fishers keeping life lists of species caught is a growing trend, with the idea now garnering attention in popular outdoor media. Life lists de-emphasize game species because they make up only a small component of fish diversity. Species like buffalo (*Ictiobus* spp.), carpsuckers (Carpiodes), and rare minnows (Leuciscidae), which can be challenging to catch by angling, are considered trophy catches. Life list fishers almost universally embrace catch-and-release methods. The North American Native Fish Association is devoted to the conservation of native fish species; group members collect fishes together and develop and freely share culture techniques. There are festivals and holidays devoted to native fishes including Sucker Days (Nixa, Missouri), Bullhead Days (Waterville, Minnesota), sucker fishing derbies (e.g., in Wahpeton, North Dakota, Omer, Michigan), and the Eelpout (Burbot *Lota lota*) Festival (Walker, Minnesota).

To understand the scope of fishing regulations allowed on native fishes across the USA, we conducted a survey of extant fishing regulations using publically available information. We downloaded the most recent versions of each U.S. state fishing regulations. Regulatory handbooks are curated by state fish and game agencies and uploaded to both state websites and the regulatory hosting aggregator www.eregulations.com. All regulatory handbooks were then scoured for information on whether there were rough fish bag limits >10 fish/day, and whether there were unlimited bag limits or possession limits. As a contrast to rough fish regulations, we simultaneously collected information on a ubiquitous sportfish (Largemouth Bass *Micropterus salmoides*) as a comparison of interest. There were at times different limits set for different species. In these situations, we report the lowest rough fish bag limit. In some states, regulations for rough fish species are not explicitly mentioned, but an “other” category bag limit exists, and we report on that limit. In other cases, no catch regulations were written for species within the rough fish category, so bag limits were listed as unlimited as implied by the law.

Unfortunately, in our survey of fishing regulations in all 50 U.S. states, problematic policies dominated our landscapes. In all states, there were bag limits >10 fish/day, and in 43 states (86%), there were unlimited bag limits for at least one species (Table 2). In another two states (4%), bag limits are so high that they are functionally unlimited. Similarly, possession limits were rarely specified (again indicating unlimited limits), and when they were, limits were high. No states had bag limits rivaling those for sportfish populations. For example, black basses *Micropterus* spp. are often managed with five fish/day bag limits. Regulations for most native fishes were often simply absent from fishing regulation pamphlets, only appearing for species protected by the *Endangered Species Act*, lumped into an “other” category or mentioned as an aside. However, we recognize that one of the attractions of rough fish angling is that catching fish is possible in almost any waterway, whereas fishing for game fish is increasingly limited (e.g., without a boat or private access to water). It is also important to recognize that in some communities, native and non-native fishes remain an important source of nutrition. In a creel survey of bank fishers along the Black Warrior River in Tuscaloosa, Alabama, 78% of African American and 100% of Hispanic fishers reported consuming their catch, and at least six species listed in this paper as rough fish were regular components of the creel. In contrast, only 22% of white fishers reported consuming their catch (B. Price, unpublished data).

Table 2. Summary of rough fish regulations in the USA. If different bag limits existed by species, we report the lowest limit. Some states had regional- or ecosystem-specific regulations, but present here only statewide regulations.

State	Bag limits of over 10 fish per day	Unlimited bag limits	Possession limit	Term used	Largemouth Bass bag limit
Alabama	Y	Y	N	Nongame fish	10
Alaska	Y	Y	N	Other	-
Arizona	Y	Y	N	Other species	6
Arkansas	Y	Y	N	Rough fish	10
California	Y	Y	N	Other	5
Colorado	Y	Y	N	Game fish	5
Connecticut	Y	Y	N	Other	6
Delaware	Y	Y	N	Other	6
Florida	Y	Y	N	Nongame fish	5
Georgia	Y	Y	N	Other	10
Hawaii	–	–	–	Other	10
Idaho	Y	Y	N	Nongame fish	6
Illinois	Y	Y	N	Other	6
Indiana	Y	Y	N	Other	5
Iowa	Y	Y	N	Rough fish	3
Kansas	Y	Y	N	Other	5
Kentucky	Y	Y	N	Rough fish	6
Louisiana	Y	25	50	Nongame fish	10
Maine	Y	Y	N	Other	2
Maryland	Y	15	30	Other	5
Massachusetts	Y	Y	N	Other	5
Michigan	Y	Y	N	Other	5
Minnesota	Y	Y	N	Rough fish	6
Mississippi	Y	Y	N	Other	10
Missouri	Y	50	100	Nongame fish	6
Montana	Y	Y	N	Nongame fish	5
Nebraska	Y	Y	N	Nongame fish	5
Nevada[1]	Y	Y	N	Other	-
New Hampshire	Y	Y	N	Other	5
New Jersey	Y	25	N	Other	5
New Mexico	Y	Y	N	Other	5
New York	Y	Y	N	Other	5
North Carolina	Y	Y	N	Nongame fish	5
North Dakota	Y	Y	N	Nongame fish	3
Ohio	Y	Y	N	Forage fish	5
Oklahoma	Y	Y	N	Other	6
Oregon	Y	Y	N	Nongame fish	5–6
Pennsylvania	Y	50	N	Other	6
Rhode Island	Y	Y	N	Other	5
South Carolina	Y	Y	N	Other	5
South Dakota	Y	Y	N	Rough fish	5
Tennessee	Y	Y	N	Nongame fish	5
Texas	Y	Y	N	Other	5
Utah	Y	Y	N	Nongame fish	6
Vermont	Y	Y	N	Other	5
Virginia	Y	20	N	Nongame fish	5
Washington	Y	Y	N	Food fish	5
West Virginia	Y	Y	N	Other	6
Wisconsin	Y	Y	N	Rough fish	5
Wyoming	Y	Y	N	Nongame fish	6

[1]Bag limits in Nevada vary exclusively by region, but several rough fish taxa are unregulated, so they were listed as unlimited bag limit.

We recommend the following actions by agencies to improve native fish protection and management:

Recognize that the pejorative rough fish reflects a cultural problem and remove it from official documents. Evidence continues to mount that the value systems in fisheries require a rewrite. Widespread use, acceptance, and normalization of pejoratives signal broader issues surrounding inclusivity (Iwama 2007; Mullen 2020). Management of freshwater fisheries began mostly with white male founders of the American Fisheries Society, who focused on a few favored fishes (Nielsen 1999; Murphy 2020a). These problems persist into modern times. A shift in all corners of the field is needed to recognize needs and places for many more fishes and fishers (Zeller and Pauly 2004; Bennett 2018; Lavoie et al. 2019; Nielsen 2021). Deliberate efforts to change cultural problems would help recruitment and retention of Black and Indigenous People of Color to our field, while also saving fishes in desperate need of conservation. Pejoratives reflect a painful past that many in our field have been implicitly or explicitly encouraged. Furthermore, use of the terms "sportfish" and "gamefish" versus "non-game fish" may also be problematic. These terms reinforce a zero sum game mentality and species-based management practices that are exclusionary and less effective (Sass et al. 2017; Reid et al. 2020).

We recommend eliminating this term and similar pejoratives from the lexicon of our respective fields. Such terms are not helpful, and linked with harmful ideas and outdated science. Agencies can select new terminology, and at least one state (Minnesota) has made preliminary steps to replace this term with "underused fish." We recommend the following as other potential candidates: "underrepresented native fishes," "under-managed fishes," or simply "native fishes."

Integrate Indigenous perspectives into fisheries management. Eurocentric natural resource management tends to focus on a notion that there is only a single "knowable truth" (Berkes 2003; Reid et al. 2020). Outside of first principles, this idea, when applied to fisheries, has led to controlling views that emphasize dominance over natural ecosystems and peoples (Charles 2001; Gibbs 2010; Moore 2017). Importantly, this paradigm has presided over massive collapses in freshwater diversity, fisheries, and ecosystem function (Post et al. 2002; Villéger et al. 2011; Embke et al. 2019; Börk et al. 2020). It has strained beneficial relationships with Indigenous partners in conservation (Reid et al. 2020; Cook et al. 2021). Fisheries professionals should listen to and use all good ideas, regardless of origin (Reid et al. 2020). Incorporation of Indigenous knowledge and co-production of management strategies will improve conditions for declining species while also helping reconcile inequality and uneven power dynamics (Chapman and Schott 2020; Schott et al. 2020).

Revisit species bag limits. Bag limits for many native fishes are too high. Given the longevity reported for many species and populations (Pereira et al. 1995; Lackmann et al. 2019; Daugherty et al. 2020), biomass replacement rates are likely also low (Rypel and David 2017; Myers et al. 2018). We recommend developing modern bag limits for native fishes that reflect best available science. For example, weight of evidence suggests some bowfishing practices must be practiced more conservatively, and in some cases, not at all (Scarnecchia and Schooley 2020). If key information is missing to make such determinations, agencies can prioritize data collection and literature reviews to improve decision making. This is especially true where native fishes support significant unregulated fisheries. Every U.S. state currently allows bag limits ≥10 fish/day, and most bag limits are unlimited. Only three states have possession limits. Possession limits need to be broadly considered as a native fish conservation tool and might be in line with possession limits applied to other managed species (e.g., often twice the daily bag limit). While a blunt tool, bag and possession limits can be effective at curbing overfishing and improving population structure (Rypel 2015; Oele et al. 2016; Moreau and Matthias 2018). Agencies must simultaneously be careful with such instruments, lest harvest limits restrict access to fisheries and food for disadvantaged communities.

As is often the case, fisheries management is complex and there are potential counterpoints to consider. For example, we acknowledge potential conflicts with bowfishers because of the growing popularity of this activity, and its propensity to target native fishes and non-native carps. Indeed bowfishing is one of the fastest growing segments of the outdoors recreation market. Bowfishers are composed primarily of males, and management concern about the sustainability of these activities has been increasing (Scarnecchia and Schooley 2020). But bowfishing *is* a lethal act of take, similar to hunting and fishers often do not consume the fish they kill. However, bowfishing organizations support tournaments that remove non-native species (Scarnecchia and Schooley 2020) and increasingly recognize that bad actors are hurting their reputation. Nevertheless, is the same level of scientific rigor applied to bowfishing management compared to ungulate or carnivore management? We suggest not. Furthermore, there is wide heterogeneity around bowfishing policies, and how they are enforced. On the one hand, a bill was recently passed and ratified in the State of Illinois (HJR0141) to develop protections for all native gar species to ensure long-term viability of these fishes (David et al. 2018). The measure urged the Illinois Department of Natural Resources to collaborate with stakeholders to identify ways to reintroduce Alligator Gar to create sustainable and regulated trophy fishing opportunities; reintroduction efforts began in 2010. However, gar simultaneously remain unregulated via bag limits in the state, as they remain in most states. *Act 297* in Wisconsin expanded application of requirements relating to taking rough fish by bow and arrow or crossbow, and also sought to re-classify catfish as a rough fish, effectively liberalizing take of myriad species via bowfishing. In addition, the Act prohibited the state agency from promulgating or enforcing any rule that prohibits taking of rough fish or catfish with a bow and arrow, crossbow, or by hand. Such political activities demonstrate just how poorly the value of native fishes has been understood by the public, since they actually promote decreased management of these species, and battles are likely to intensify in coming years. Decision makers will make difficult choices regarding whether current iterations of these activities are sustainable for future generations and supported by the best available science.

Support science on native fishes. Scarnecchia (1992) long ago highlighted that species categorized as "rough fish" should not be managed as nuisances, but rather viewed as central to the function of ecosystems and as a unique resource for anglers. Yet little science has occurred to enable such management. In an effort to understand biases in the peer-reviewed literature, we conducted a survey of the fisheries literature using Google Scholar. In this exercise, we limited our search to journals published by the American Fisheries Society (i.e., *Transactions of the American Fisheries Society*, *North American Journal of Fisheries Management*, *North American Journal of*

Aquaculture, *Journal of Aquatic Animal Health*, and *Marine and Coastal Fisheries* as of 2019). However, we note that we also performed a similar survey using all journals and papers indexed by Google Scholar, but the primary results remained the same; thus here we present only the more direct survey of AFS publications. We also limited the survey to inland fisheries species. "Gamefishes" include species commonly managed by state agencies with special harvest regulations, stockings, and other enhancements. "Rough Fishes" include species commonly listed as such in state agency handbooks. "Rough Fish Escapees" refer to species previously classified as rough fish species, but in general receive some protective status now. We did not consider invasive species originating from outside the USA for this survey. We searched Google Scholar, specifying the species common name and scientific names together in the search (e.g., "Freshwater Drum" AND "*Aplodintous grunniens*") for all five AFS journals and all years, up to and including 2019.

We found that for 27 popular gamefish species in North America, 1,698 studies were published on average per species in the AFS journals. In contrast, for 28 species classified as rough fish, only 149 papers were published on average per species. In a third group with 9 species, termed rough fish escapees (species previously classified as rough fish that have since garnered some research and management attention, e.g., catfishes and sturgeons), there were roughly double the publications (334), but still greatly lagged behind gamefish species (Figure 5). The analyses show gamefish receive ~11x more research and management attention in AFS journals than other native fishes, and 5x more attention than rough fish escapees. These results parallel those of another recent study that found only 3% of research output was on critically endangered fishes; most critically endangered fishes had zero articles (Guy et al. 2021).

Some of these disparities result from funding mechanisms. The *Sport Fish Restoration Act* (SFRA or the *Dingell–Johnson Act*) has been an engine for recreational fisheries funding in the USA. The SFRA generates revenue from a federal excise tax on sportfishing equipment, imports of fishing tackle, yachts and pleasure boats, and a portion of gasoline fuel tax attributable to small engines and motorboats. The U.S. Fish and Wildlife Service redistributes these funds back to states to fund management and research overwhelmingly focused on sportfish. State agencies apply similar logic for in-state revenues generated via fishing license sales. We need novel revenue streams to assist in conservation management of diverse species and habitats (Sass et al. 2017). An alternative is to simply consider *all* fishes as sportfish and focus more studies on species targeted by fishers from disadvantaged communities. A more eclectic mix of management targets could lead to more ecosystem-based management, benefiting a wide array of species.

Conserve and manage locally unique fishery resources. Identifying, developing, and promoting endemic and unique fisheries is important. First, this process necessitates planning that will prevent being surprised by a rapidly emerging fishery. Second, agencies can call attention to truly special resources. Heritage trout challenges exist in many western U.S. states. Parallel programs focused on the small and diverse Redeye Bass *Micropterus coosae* and Spotted Bass *M. punctulatus* complexes are gaining traction in Alabama, Georgia, and South Carolina. The Cherokee National Forest actively manages snorkeling events in the Conasauga River, where a number of federally listed species exist, raising awareness of the beauty and value of these species. Programs that frame other native species as desirable could offer similar results. Arizona established a "Trophy Roundtail Chub" fishery on Fossil Creek, thus defining the species as a pleasing catch. Utah has placed billboards on the Colorado and Green rivers showing native fish that must be caught and released, and invasive fish (often game species in the Mississippi Valley) that should be harvested. Catch-and-release state records do not exist for many native fishes. Often, these species are lumped together (i.e., one category for buffalo or redhorse, regardless of species). Establishing specific categories for catch-and-release helps define these fishes as worthwhile species and fisheries. Finally, wanton waste remains an issue. Behaviors that intentionally waste precious natural resources as represented by native fishes are inappropriate. One potential recommendation for all states to consider is to enact and enforce wanton waste laws in a similar manner as done with ungulates or waterfowl.

Co-manage species and taxa that are interdependent. The availability of suitable fish hosts is vital for freshwater mussels (Haag 2012). Almost uniformly, the distribution of rare federally listed mussels overlaps with fishery resources, but separate agencies usually manage either resource. Thus, even though both taxa are co-evolved, mussel and fish managers rarely connect to discuss actions or policies to protect both taxa. Improved coordination among activities will necessitate improved communication between federal agencies that manage *Endangered Species Act*-listed mussels and state agencies that manage freshwater fish populations. If fish hosts are unknown, agencies can sponsor studies to identify fish hosts of critically endangered mussels. Unexpected loss or harvest of fish hosts will place freshwater mussel populations at further or continued risk of decline or collapse. Similar interdependence is seen in native chubs *Nocomis* spp., whose nests underpin the structure and function of entire ecosystems through nest associates and mutualisms (Peoples et al. 2011; Frimpong 2018).

Enhance science education and communication. Positive experiences with nature influence a person's relationship with the natural world and tendency toward future pro-environmental behavior; yet those experiences are dwindling, especially in children (Miller 2005; Soga and Gaston 2016). Adopt-a-fish educational programs support K–12 students and stakeholders in learning about watersheds, aquatic ecosystems, and fisheries research through a multidisciplinary approach (Schmetterling and Bernd-Cohen 2002; Frank et al. 2009). Youth fishing programs are also effective at promoting positive experiences that encourage higher levels of self-identity, recruitment and retention, and decreased perception of barriers to fisheries (e.g., money, transport, time, skills; Morales et al. 2020).

As trusted sources, state agencies and various conservation groups stand in a leadership position to correct misinformation and shape public attitudes toward native fishes. Social media plays a key role in continuing myths about native fishes, but also fosters new attitudes and behaviors (Shiffman 2012; Shiffman 2018; Lewandowsky et al. 2019; Taylor and Sammons 2019; Klar et al. 2020). Between 2005–2015, adult social networking increased from 5% to 65%; this pattern was consistent across sex and racial/ethnic groups (Perrin et al. 2015). Although there is concern that scientists may just be talking to other scientists on these platforms, an analysis of the use of Twitter by academics, researchers found that, above a following of 1,000, follower type diversified greatly and included educational organizations, journalists, nonscientists, and decision makers (Côté and Darling 2018).

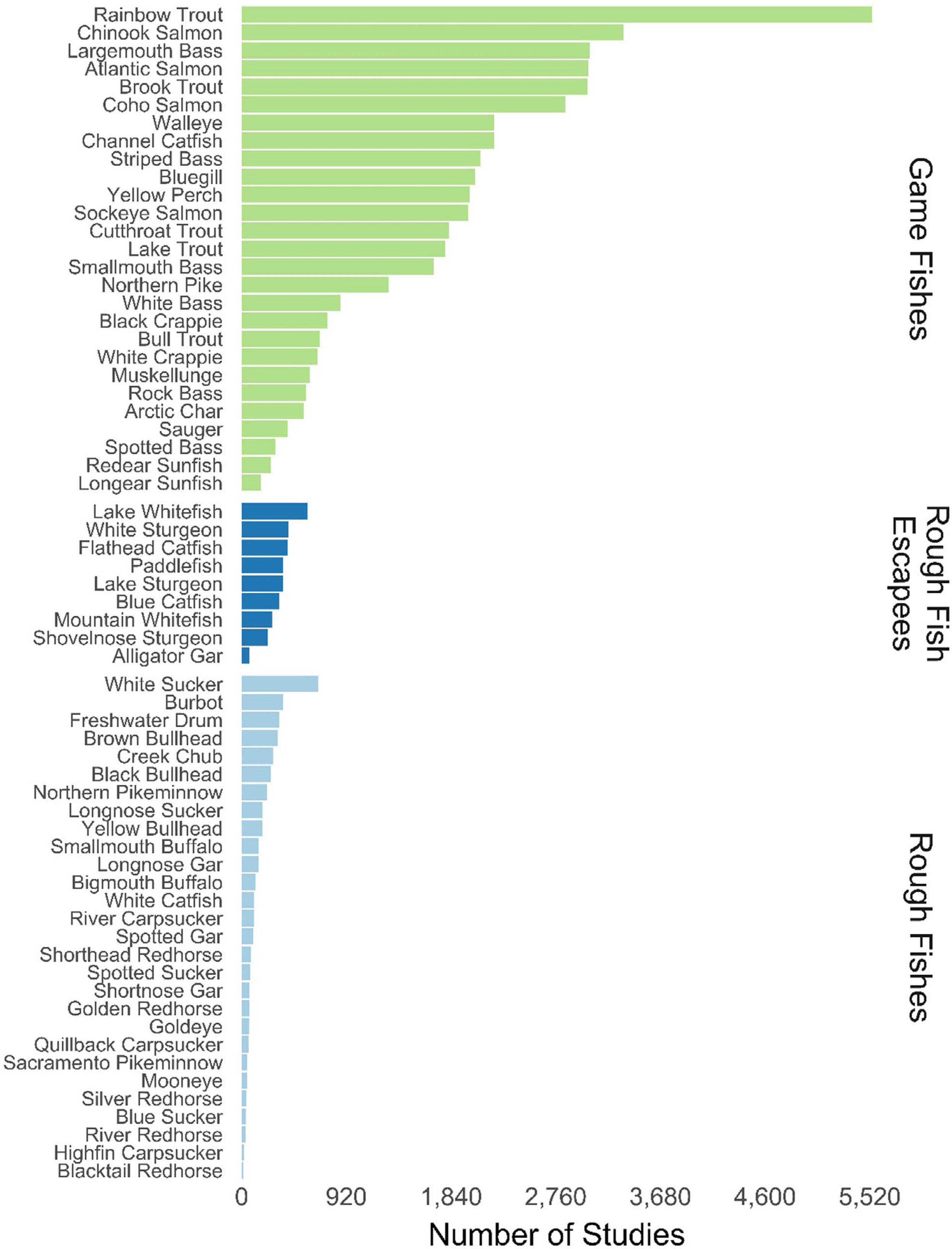

Figure 5. Cumulative number of scientific studies in American Fisheries Society (AFS) journals as indexed by Google Scholar (i.e., *Transactions of the American Fisheries Society*, *North American Journal of Fisheries Management*, *North American Journal of Aquaculture*, *Journal of Aquatic Animal Health*, and *Marine and Coastal Fisheries* as of 2019). We searched species by common and scientific name together. "Gamefishes" include species commonly managed by state agencies with special harvest regulations, stockings, and other enhancements. "Rough Fishes" include species commonly listed as such in state agency handbooks. "Rough Fish Escapees" refer to species previously classified as rough fish species, but in general receive some protective status now.

One-on-one interactions by individual scientists through various media outlets is not an efficient or effective strategy to uproot a pervasive problem (Thaler and Shiffman 2015). Promotional campaigns could be helpful to dispel myths about native versus nonnative fish, communicate accurate science, and engage the public. In a social media campaign that highlights a fish species each day during the month of December (#25DaysofFishmas), diverse native fishes are featured alongside more well-known fishes. In the first 3 years of the #25DaysofFishmas campaign on Twitter, species with the greatest number of impressions (i.e., views) were Bowfin *Amia calva* (46,000 views), Paddlefish *Polyodon spathula* (42,000 views), and Spotted Gar *Lepisosteus oculatus* (41,000 views).

CONCLUSIONS

There are grand challenges facing freshwater resources and native fishes at all scales (Ficke et al. 2007; Katz et al. 2013; He et al. 2019; Reid et al. 2019). Increasingly, broad public interest is emerging to preserve all species and the ecosystems in which this diversity resides (Walker-Springett et al. 2016; Venturelli et al. 2017; Arlinghaus et al. 2020). The fields of fisheries and ecology play fundamental roles in addressing the problems wrought by human domination of the world's ecosystems (Vitousek et al. 1997; Pinsky and Mantua 2014; Carpenter et al. 2017). Fisheries management can be effective at solving complex issues, provided public support, funding, and prioritization of science-based decision making (Rypel et al. 2016; Sass et al. 2017). However, we must all realize that fishes judged "rough" or "trash" by some, could concurrently be considered "amazing," "attractive," or "important" by others. Fisheries can move away from divisions into sportfish, non-game fish, etc., and towards a more holistic and protective approach. As people increasingly observe the pervasiveness of unconscious bias (Murphy 2020b), problems associated with past philosophies and paradigms are more obvious. 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 towards a more sustainable future for biodiversity, ecosystems, and all peoples.

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