FEATURE

Trophies, Technology, and Timescape in Fisheries Management, as Exemplified through Oklahoma's World Record Paddlefish *Polyodon spathula*

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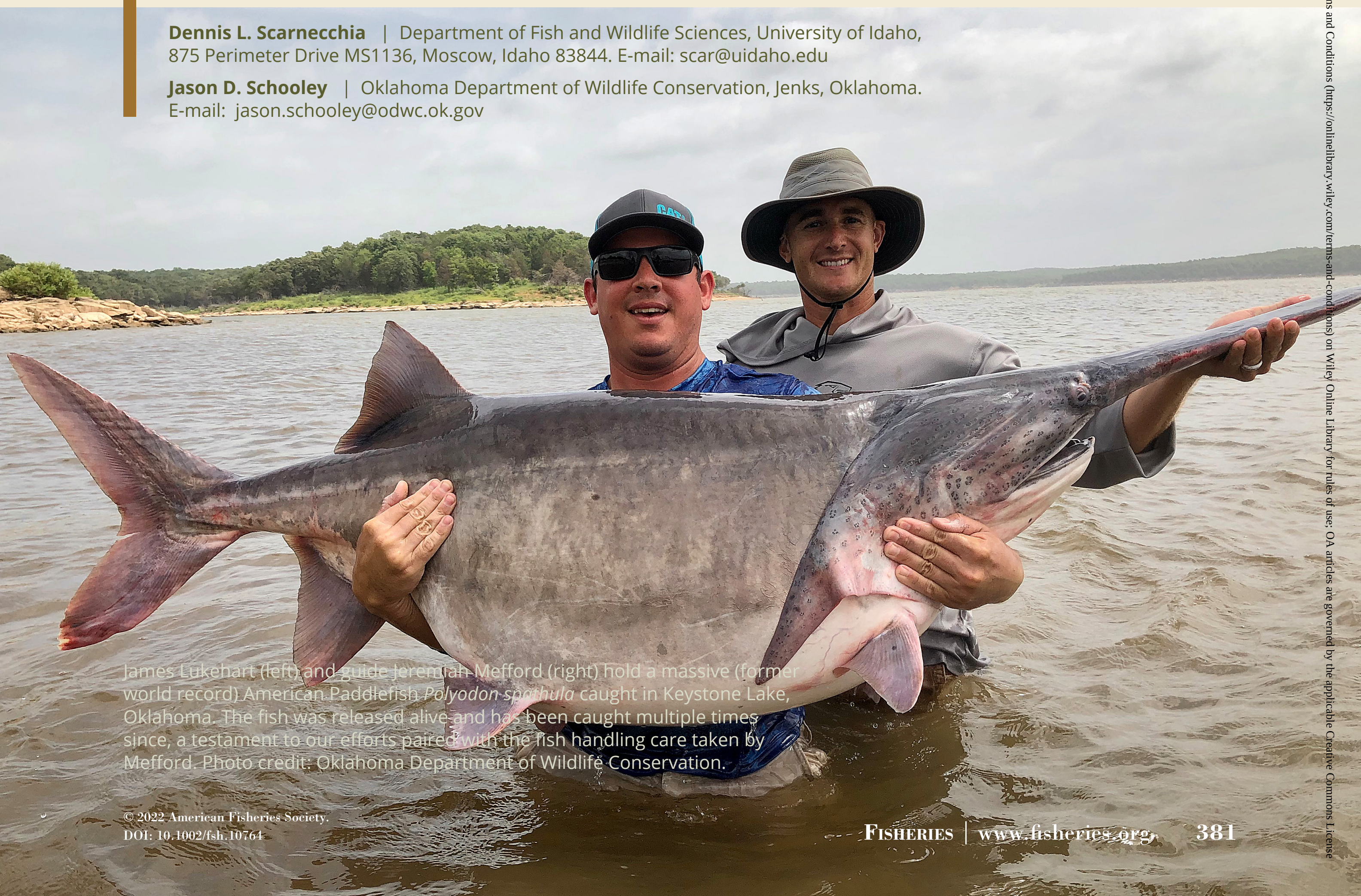

James Lukehart (left) and guide Jeremiah Mefford (right) hold a massive (former world record) American Paddlefish *Polyodon spathula* caught in Keystone Lake, Oklahoma. The fish was released alive and has been caught multiple times since, a testament to our efforts paired with the fish handling care taken by Mefford. Photo credit: Oklahoma Department of Wildlife Conservation.

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In this paper, we use world record Paddlefish *Polyodon spathula* catches to exemplify the origins and management of trophy fisheries and the human motivations involved within a continually compressing timescape of advancing fish finding, harvest capability, and communication and information technologies. 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 capable of responding to such challenges in a meaningful and timely way. Our paper may be useful for other fisheries professionals involved in management of long-lived, trophy fishes and fisheries.

TIMESCAPE

World record fish catches have always garnered a high level of interest by a distinct and sometimes obsessive segment of outdoor enthusiasts: trophy seekers. From June 28, 2020 to June 22, 2021, a span of 12 months, the world weight record for Paddlefish *Polyodon spathula,* an ancient, zooplanktivorous, Acipenseriform fish (MacAlpin 1947; Grande 1984; Grande and Bemis 1991; Murray et al. 2020) and the last surviving species of Polyodontidae (Zhang et al. 2020), was broken three times. Each world record fish was snagged (the most common recreational fishing method for the species) from Keystone Lake, a 9,550-ha flood control/hydropower reservoir on the Arkansas River, Oklahoma, completed in 1968 by the U. S. Army Corps of Engineers. Each catch generated marketable news coverage by the press and excitement by Paddlefish snaggers. Snaggers, like other anglers, have shown enthusiasm for catching large Paddlefish (Scarnecchia et al. 1996, 2000; Hupfeld et al. 2018). Record and trophy catches often engender positive responses among recreational fishers and chambers of commerce (Hupfeld et al. 2018), generate kudos for agency fisheries managers, and stimulate interest among the general public (Thomas 2021).

What constitutes a trophy fish is, in practice, angler-defined. Paddlefish are unusual among fish in that most of them caught by snagging are large fish (often 10 kg or heavier) when compared to fish of most other species. In indices commonly used in freshwater fisheries, trophy has often defined as fish 75–80% of the world record length (Gabelhouse 1984), an inefficient approach for Paddlefish since the largest fish grow much more in girth and weight than in length (Scarnecchia et al. 2007). In terms of weight, we see a trophy Paddlefish as one at or near state and world record weights, perhaps the heaviest 3% of fish weighed for the species or stock.

In recent decades, the quest for trophy fish has been aided by a range of greatly improving fish finding and information technologies (summarized by Cooke et al. 2021). In Paddlefish recreational snagging, the advent of the Garmin Panoptix LiveScope sonar (www.Garmin.com; hereafter, LiveScope) allows an angler to identify through high-definition sonar a Paddlefish of choice (e.g., trophy fish, which are female; Figure 1). The high resolution of the technology and the unique profile (long rostrum) of the Paddlefish result in a high snagging success rate with less uncertainty than snagging blindly in turbid waters. The large, size-dimorphic female Paddlefish (Scarnecchia et al. 2007) have become easier to detect than ever as snaggers can target trophy fish. A widening array of social media opportunities exist before, during, and after the fish are caught. Internet websites can be used by knowledgeable guides to more effectively identify and recruit trophy seekers. Successful anglers can instantaneously exhibit their catches in live-streamed or recorded videos to a global audience in a synergistic cycle, making trophy seeking less costly and more profitable. High cost (time, money, expertise, or all three) has been a primary deterrent to widespread trophy seeking of all types in the past (Darimont et al. 2017).

Figure 1. Garmin Panoptix LiveScope sonar technology allows Paddlefish anglers to identify, pursue, and target large fish with precision, as pictured here when the Oklahoma Department of Wildlife Conservation monitored the release condition of Lukehart's since-broken world record fish (June 2020). Image courtesy of the Oklahoma Department of Wildlife Conservation.

Accelerating changes in technology create additional challenges for fisheries managers. The compressing *timescape* of fishing and information technology in trophy fishing accelerates harvest pressure on species such as Paddlefish with long, slowly developing life histories (Scarnecchia et al. 2007; Hingley 2020). Many managers now recognize the need to maintain some older age and larger sized fish in harvested stocks, avoiding genetic and environmental truncation of life histories (Birkeland and Dayton 2005; Francis et al. 2007; Kuparinen and Merilä 2007; Hixon et al. 2014). In the past two decades, many native species have been found to have much longer life spans than formerly realized (Scoppettone 1988; Scarnecchia et al. 2007; Lackmann et al. 2019). And unlike trophies of most terrestrial wildlife (Peterson 2000), most of the largest fish are females (Bell 1980; Hixon et al. 2014; Scarnecchia and Schooley 2020). More efficient targeting of trophy specimens has resulted in declines of trophy specimens of many species (He et al. 2019), a trend even depicted in the size of trophy fish in photographs through decades (McClenachan 2009). Trophy fishing also has the immediate potential to create social problems through higher likelihood of interactions among avid trophy seekers.

Effective management of such species requires a plan with a time frame consistent with those longer life spans. Instead, management is occurring in a compressing timescape where human impacts to landscapes, river systems, and aquatic communities are occurring more rapidly than ever (Paddlefish: Sparrowe 1986; Gerken and Paukert 2009). State agencies such as the Oklahoma Department of Wildlife Conservation must sustainably manage Paddlefish amid increasing interest in Paddlefish snagging, improved fish-finding technology, greater and more rapid social media coverage of prime fishing sites and catches, and the prospect of still another world record catch (Gordon 2009; Scarnecchia et al. 2013; Schooley et al. 2014). An understanding of the origins, causes, and management implications of the record catches will better enable managers to sustain healthy Paddlefish stocks and fisheries as part of their public trust responsibilities.

In this paper, we use world record Paddlefish to exemplify the nearly ubiquitous management issues of trophy fisheries and its human motivations within a continually compressing timescape of fish finding, harvest capability, and communication and information technologies. We also briefly summarize available information on the historical, genetic, and environmental aspects of world record Paddlefish. Although our paper exemplifies Paddlefish, it is designed to be relevant to other freshwater and marine fish species and useful for managers of long-lived trophy fishes and fisheries.

TROPHIES IN A HUMAN CULTURAL CONTEXT

> If everyone is special, then no one is. If everyone gets a trophy, trophies become meaningless.
>
> –David McCullough, American historian/writer

A trophy (Greek *tropaion*; Latin *tropaeum*) includes objects or honors given to celebrate a victory or as an award for achievement, or something taken in battle or conquest, especially as a memorial (https://www.merriam-webster.com/dictionary/trophy). Long before trophy fishing, the concept of trophies and the desire for them was well established among *Homo sapiens*. Trophies were widely given and taken, principally though not exclusively by males, as rewards and commemorations for victories in battle against conspecifics since before the Christian era (Dayalan 1985; Camp et al. 1992). Through the centuries, trophies took many forms, from fashioned stone monuments to war booty such as precious metals and artwork, to weapons and ordnance (Vance 1995), to worldwide taking of humans and human body parts of the vanquished, including actions by and toward both Indigenous and non-Indigenous peoples of the western hemisphere (Harrison 2006; Chacon and Dye 2007; Cashin 2011; Dye 2016). In modern culture, sport of myriad types is a major source of trophy production and consumption. Taylor (2014) discusses the important role of sports in replacing modern warfare, from early assertions of psychologist William James onward, asserting that "sport satisfies most of the same psychological needs as warfare, and has similar psychological and social effects." It is not surprising that both activities are seen as requiring skill, courage, character, and fortitude commonly symbolized and rewarded by trophies.

TROPHY FISHING IN A MANAGEMENT CONTEXT

> On those rare occasions during deep-sea fishing when you get a monster on board, your first thought is to perpetuate your triumph…The first step to evidence is to have him weighed by the wharfkeeper and get a written certificate….The second step is to have him stuffed.
>
> – Herbert Hoover on stuffing fish for household ornaments…for proof of prowess, *Fishing for Fun and to Wash Your Soul*

> My big fish must be somewhere.
>
> – Ernest Hemingway, *The Old Man and the Sea*

Amid the decline in market hunting and more gradual but inexorable decline in market (commercial) fishing in North America, a pronounced transition to more trophy hunting and fishing has occurred. Trophy fishing interest can be viewed as a natural response to the rise in recreational fishing in general, in many cases with a larger individual fish being substituted as "mnemonic totems" (Peterson 2000) for large quantities of fish under subsistence and commercial fishing. Reiger (1973) effectively depicted the origins and rise in marine saltwater angling in North America and identified Charles Frederick Holder (1851–1915), also an avid conservationist, as the father of big-game angling. With the development of sport fishing nurtured by Holder's many writings (e.g., Holder 1903) and those of other contemporaries and successors (Turner-Turner 1902; Mitchell-Hedges 1923), trophy taking made a ready transition into North American sport fisheries. Many of the most avid trophy sport anglers were rich, famous, accomplished, and powerful Americans, typically highly successful in a competitive society and at the same time conservation-minded (Holder 1908) in principle, if not always in practice. Trophy fishing, as with other types of trophy seeking throughout history, became another way of gaining peer acceptance and of keeping score against competitors.

The taking of the largest organism, whether fish or terrestrial wildlife, satisfies a portion of the human psyche far transcending ancestral demands for subsistence and rooted in a complex conglomeration of human self-image, social standing, and status

(Shiffman et al. 2014; Child and Darimont 2015; Darimont et al. 2017). Many aspects of trophy hunting and fishing remain poorly investigated (Beattie 2020). Some analyses and interpretations are clouded by imprecisely defined terms (e.g., what a trophy is for different species and which metrics are used; Mitchell et al. 2021). Arguments are also clouded by strong emotional biases for or against trophy seeking (Nelson et al. 2016).

Trophy seeking of fish and wildlife, like most other trophy seeking, has been male-dominated, although not exclusively (e.g., Turner-Turner 1902). Simon (2019) characterized trophy hunting as a fetishized activity projecting the embodiment of skill, courage, and fortitude, attributes associated with statesmanship, even if the skill required for success was often more associated with the hunter's associates than with the hunter. Darimont et al. (2017) identified trophy hunting success with social status and prestige, especially in males. Through evolutionary time, hunting and fishing prowess and success, whether in harvesting more animals or in acquiring trophy animals, "signal underlying qualities to rivals and potential allies"; prowess of the most successful hunters gains them social recognition, standing (Hawkes and Bird 2002) and, ultimately, higher fitness. In hunter–gatherer societies, fishing and hunting prowess would feed their immediate families, but also their extended groups, with the show of largesse, yielding further social and fitness benefits (e.g., Hawkes 1991; Iredale et al. 2008). As described by Hawkes and Bird (2002), "When hunters target large prey, and when others can learn about and compare their successes, hunting reputation becomes a prominent determinant of how desirable a neighbor and ally, and how dangerous a rival, a man might be." Trophy hunting is also associated more so with people of wealth and position, "serving as evidence of one's cultural and economic capital" (Simon 2019).

Brower (2005) characterized the "sportsmanship, virility, and hunting prowess" exhibited in early photographs of hunters with their *large, trophy* prey as emblematic of a new sporting ethic and success symbol as recreational hunting replaced the numerical prowess formerly associated with harvesting *more* fish or wildlife for commercial and subsistence success. Sports such as bowfishing for underregulated native species such as gars (Lepisosteidae) and buffalofishes *Ictiobus* spp. still retain the numerical component of status (Scarnecchia and Schooley 2020), whereas trophies have become important for bowfishers seeking the largest gar species, the Alligator Gar *Atractosteus spatula*, for which harvest has been regulated (Buckmeier et al. 2016).

Immediate motivations identified for trophy hunting have included a sense of achievement (the dominant motivation), followed by appreciation (of the animal and the activity) and affiliation (help from friends in the activity; Beattie 2020). Photographs of the hunter or fisher with their vanquished quarry depict those motivations as well as indicate masculine prowess (Brower 2005), socioeconomic standing, and status. Such signaling associated with successful trophy hunting and fishing has expanded from displays in local newspapers to global displays on the Internet as technology has created a much vaster audience with whom to interact and portray status (Darimont et al. 2017). Positive feedback and validation are immediately and quantifiably manifested as "likes," "follows," or other means of amplification.

Subtle details in photographs may also provide insight into trophy seeking. Child and Darimont (2015) found that the likelihood of true "pleasure" smiles (called "Duchenne smiles"; Ekman et al. 1990) as opposed to "false" or more perfunctory smiles was greater with large as opposed to small prey. Duchenne smile responses to dangerous carnivores versus nonthreatening species, even if both are large, may differ (Mihalik et al. 2019). But whether the trophy sport fisher smiles or not, the pride and perceived status accruing to most possessors of state or world record fish is immediately apparent to those of us working with Paddlefish anglers (and other anglers) at weigh-in sites, where many photographs are taken.

The pursuit, capture, and (often) killing of trophy fish or wildlife costs the trophy seeker in terms of the effort needed to locate and capture the largest individuals (i.e., a higher risk of failure) as opposed to more easily settling for one, or sometimes many, average-sized quarry (Darimont et al. 2017). This high cost may explain why subsistence take of organisms by native Indigenous societies or anyone else is not typically associated with trophy seeking. Exceptions do occasionally exist, however, as in the Rio Madeira of the Amazon River basin, where the harpooning of the Pirarucu *Arapaima gigas*, one of the world's largest freshwater fishes, confers prestige and the right of manhood to future subsistence and commercial fishers (Goulding 1981). More commonly, modern trophy seekers with money are willing to pay more, sometimes much more, to take trophy specimens, especially dangerous carnivores (Mihalik et al. 2019; Simon 2019). They also keep score of the largest fish and wildlife trophies taken. The ascendance of the sport fishing aspect of trophy seeking accounts for the meticulous record keeping by nonrecord holders with socioeconomic interests in trophy fishing (e.g., the International Game Fish Association, http://igfa.org/world-records/).

The cost of trophy seeking in fish and wildlife, including for Oklahoma's Paddlefish, has been greatly reduced by substituting money for time and expertise by hiring an experienced guide, who is often a more important predictor of success than other hunter characteristics, including age or a hunter's physical fitness (Darimont and Child 2014). With an experienced Paddlefish guide, more timely and accurate information, more advanced technologies, or all three, the resulting increased chance of success creates a synergistic incentive for more snaggers of all ages to seek trophy fish.

Oklahoma Paddlefish snagging also exemplifies a transition from commercial to sport and trophy seeking. Commercial Paddlefish harvest has been illegal since 1992 as recreational angling ascended in importance (Gordon 2009). Annual bag limits (two per year) and mandatory online harvest reporting (using the same system as big game terrestrial animals: deer, elk [Cervidae], turkeys *Meleagris* spp.) have been instituted (Schooley et al. 2014). With bag limits and other regulations, size of fish has necessarily replaced number of fish taken as a symbol of success.

Paddlefish snaggers enjoy catching large Paddlefish. An angler survey performed in Oklahoma revealed that approximately 70% of Paddlefish anglers reported that the chance of catching a big fish was "very important" to the success of their trip (Crews 2009). In a study of Montana Paddlefish snaggers in general, on the Fort Peck and Yellowstone–Sakakawea (Montana) stocks, their strongest motivations for Paddlefish snagging were for being outdoors and for the thrill and experience of hooking one. The need to catch a big fish, while important, ranked only in the middle range among 16 motivations (Scarnecchia et al. 1996, 2000). Paddlefish snaggers in both states, however, fully anticipate catching a large fish compared to their catch expectations of nearly all other species. For Oklahoma stocks and the Fort Peck (Montana) stock, where immediate high grading is permitted, trophy snaggers have much flexibility and can sort (i.e., catch-and-release) fish until a sufficiently large specimen is caught. Evidence of sorting is seen in the higher percentage of males (nearly always the smaller fish) with snag hook scars compared to the lower percentage of scars for females (nearly always the larger fish; Figure 2). Trophy Paddlefish snaggers targeting state or world record fish may take further measures worth the extra cost to them. Snaggers strongly seeking trophy Yellowstone–Sakakawea Paddlefish in Montana and North Dakota, under its mandatory retention regulation, a one-fish annual bag limit (Scarnecchia et al. 2021), and an annual harvest cap, may limit their fishing to only those times and locations where trophy fish are most likely to be encountered. LiveScope and similar technologies can enhance selectivity in stocks with or without mandatory retention, increase efficiency, and reduce the cost of seeking these trophy Paddlefish.

Accommodating trophy fishing and its enthusiastic clientele is one of many challenges associated with state fish and wildlife agency missions. For example, the Oklahoma Department of Wildlife Conservation (ODWC)'s mission is to "manage and protect fish and wildlife, along with their habitats, while also growing the community of hunters and anglers, partnering with those who love the outdoors, and fostering stewardship with those who care for the land." Oklahoma's record-breaking Paddlefish came at a time when many other game species, and especially trophy freshwater and marine species worldwide, have suffered a decline in age and size structure associated with overharvest and trophy targeting of the largest specimens (Shiffman et al. 2014). The largest, most fecund fish may be removed from the population if the trophy fish are killed for record verification (Shiffman et al. 2014, 2015). This removal has prompted calls for reducing or eliminating the mortality often associated with trophy fishing (Shiffman et al. 2015). Harvest management strategies

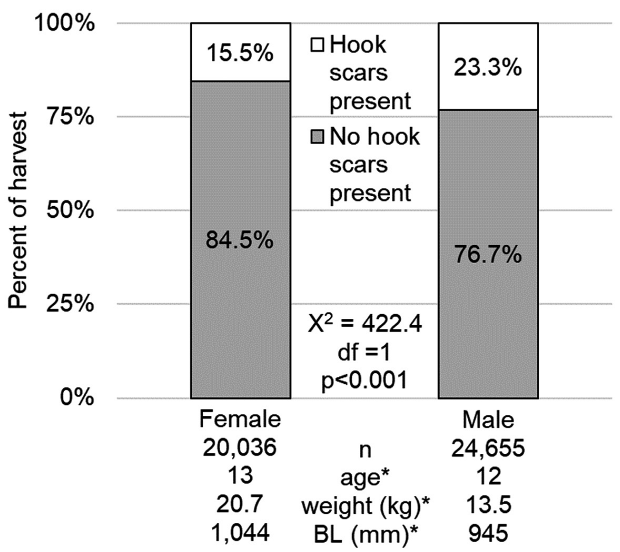

Figure 2. High grading (or trophy seeking) of Paddlefish in Oklahoma is observed in the significantly higher incidence of hook scars (chi-square test), or direct evidence of catch-and-release, on the typically smaller males than on the typically larger females in this sexually size-dimorphic stock. Differences in average age, weight, and body length (BL) by sex were significant ($P < 0.001$, Student's t-test, df = 44,689) and are indicated by an asterisk.

must be found to retain some large female fish in the population (Hixon et al. 2014; Scarnecchia et al. 2014; Scarnecchia and Schooley 2020). In view of increasing fishing pressure, technological advances, and social media outlets in a compressing timescape, managers must more than ever develop an understanding of the motivations of trophy fishers, including traditional anglers, snaggers, and bowfishers, and how to provide the outcomes they seek while maintaining healthy fish stocks. Results from terrestrial studies (Mihalik et al. 2019) suggest that fisher responses may differ somewhat between those targeting large carnivorous species such as sharks (Elasmobranchii) and Alligator Gars compared to those targeting large, more docile, zooplanktivores such as Paddlefish.

PLAUSIBILITY, PREVARICATORS, AND *POLYODON*: EARLY HISTORY OF THE LARGEST PADDLEFISH

> It appears that man cannot escape the snare of exaggeration.
>
> – Mahatma Gandhi

Trophy fishing is well-positioned for deception, exaggeration, controversy, and debate. The evolutionary advantages of deception and exaggeration have been effectively discussed (Otte 1975; Mokkonen and Lindstedt 2016). Otte (1975) noted that "gross lies are less effective than small lies…selection should act to cause judged values to lie on the safe side of reality." Plausible exaggeration may be expedient. McEntire (2009) investigated the art of exaggeration; in her words, "With roots in the Old World and fertile ground in the New World, the tall tale flourished in America, especially within the boasting, expansive atmosphere of the American frontier… Hunting, fishing, weather, domestic life, and agriculture were popular topics, and opportunities for artful exaggeration were numerous." On a broader scale involving more anglers, exaggeration can lead to inaccurate perceptions of fish stock status (Sullivan 2003); such biases must be accounted for in stock assessments, especially those relying on delayed angler responses (Jacobson et al. 1983).

Paddlefish, as one of North America's largest freshwater fishes, has not escaped exaggeration. Who caught, and can claim, the largest Paddlefish has become shrouded in considerable confusion over the decades. The largest Paddlefish reported in the scientific literature is attributed to R. D. Vanderbeck, who took a large specimen by spear in Lake Okoboji, Iowa, in February 1916. The report of the fish was sent by Vanderbeck to John Treadwell Nichols, Harvard-educated ichthyologist and *Ichthyology and Herpetology* (formerly *Copeia*) founder, and reported by him to have a total length of 215.9 cm (85 in) and girth of 116.6 cm (45.5 in; Nichols 1916). However, Nichols saw only a photograph of the fish, along with a note from Vanderbeck. The putative weight of 90 kg (198 lb) was not reported until years later in *Iowa Fish and Fishing*, a book by James Harlan and E. B. Speaker, biologists with the Iowa Conservation Commission (ICC; Harlan and Speaker 1969). This weight was later cited by Thomas Gengerke (1986), another ICC biologist and a Paddlefish expert, who also conducted research and management on Lake Okoboji. The 90-kg weight was thereafter widely accepted as fact. However, later editions of *Iowa Fish and Fishing* (Harlan et al. 1987) had quietly omitted Vanderbeck's fish as the largest, so the validity of this record deserved a closer look.

New evidence and news articles provided by biologists at the Iowa Department of Natural Resources (formerly the ICC) cast doubt on the Vanderbeck record Paddlefish reported to Nichols. A contemporary photograph of unknown origin (and later used as a postcard) states, in its caption, that Vanderbeck's fish weighed 84 kg (185 lb; Figure 3). The date, length, and location listed in the caption all match the details in Nichols (1916). Further, the *Spirit Lake (Iowa) Beacon* newspaper issue from March 2, 1916 recounts Vanderbeck's catch, listing its length as 205.7 cm and girth as 110.5 cm (Figure 4A)—a substantial deviation from Nichols (1916). In disagreement with Nichols (1916) but in agreement with the postcard (Figure 3), the newspaper reports the fish to have weighed 84 kg.

More confusion ensued. Another issue of the *Spirit Lake Beacon* from a week later, March 9, 1916 (Figure 4B) recounted "A Still Bigger Fish Caught in West Okoboji." This piece topped Vanderbeck's 84-kg Paddlefish in the postcard by describing a 95.5-kg (210-lb) fish, also taken by spear, by Ben Wiese (Figure 4B). The specimen is described as 5 cm shorter than Vanderbeck's but with a larger girth at 119.3 cm (47 in). Wiese reportedly and not only heroically speared the fish through a hole in the ice, but through 4.6 m of water with one shot (Figure 4B), which may suggest that the details are slightly exaggerated. It remains unclear why Nichols would publish a note in a scientific journal in August 1916 about a large Paddlefish speared in February when a much larger fish was speared a mere 2 weeks later from the same lake. Perhaps Nichols knew when to quit when dealing with second-hand evidence. The true details of Vanderbeck's or Wiese's Paddlefish catch claims will probably never be known. A more likely explanation is that the fishers, with a well-established reputation as prevaricators, were early on practicing it effectively, something of an art form (McEntire 2009; Figure 5).

In defense of the plausibility of the Lake Okoboji Paddlefish, the 1,540-ha, naturally eutrophic, glacial lake, Iowa's deepest, would seem to be excellent Paddlefish rearing habitat, even though no Paddlefish exist there today as the lake no longer has a river connection. Lake Okoboji does have a well-documented, abundant community of large zooplankton (Stromsten 1920; Lang 1990), including common to abundant *Leptodora kindtii*, the large cladoceran abundant in plankton tows in the past (Stromsten 1920) and in the 1980s (DLS, personal observations, ICC Tucker trawl). *Leptodora* and large cladocerans have been shown to be a preferred food for young Paddlefish (Fredericks 1994; Kozfkay and Scarnecchia 2002). The length of the Paddlefish described to Nichols (215.9 cm) is longer than all subsequent world record fish and plausibly the length that a world record fish would have. But while there is no doubt that Lake Okoboji was inhabited by some very large Paddlefish, and a world record fish from there is plausible, the second-hand report to Nichols (1916) and subsequent contradictions do not support the Lake Okoboji fish as being a reliable official record for the species.

CERTIFIED PADDLEFISH WORLD RECORDS IN THE LATE 20TH AND EARLY 21ST CENTURIES

> I always thought that record would stand until it was broken.
>
> – Yogi Berra

Confusion regarding the Lake Okoboji Paddlefish underscores the need for certifying weights of catches for each species. Most angling world records are maintained by a sanctioning body. For example, the International Game Fish Association (https://igfa.org/) keeps big fish records for many freshwater and marine species. Paddlefish, however, a species with a complex identity (Mestl et al. 2019), is managed disparately as a sport fish in some states, as a commercial fish in others, as a nongame species in others, and as a species of concern in still others (Mestl et al. 2019). Because of those differences and because of the snagging methods typically used to catch it, the species has not always been afforded status

Figure 3. Postcard featuring R. D. Vanderbeck's large Paddlefish speared through the ice on Lake Okoboji, Iowa, in 1916. Note, the weight is listed as 84 kg (185 lb). Image courtesy of the Iowa Department of Natural Resources.

The Spirit Lake Beacon

OFFICIAL COUNTY NEWSPAPER

(A) March 2, 1916

A REAL FISH STORY FROM WEST OKOBOJI

Some fish story is right, but the nice part of the story is that the proof lay in state Wednesday and Thursday in the old Whitney harness shop. This fish story is not only the story of the season, it is claimed to be the biggest catch on record for any body of water in the northwest. The fish is a spoon-bill sturgeon measuring six feet nine inches from tail to end of bill. Measures forty-three and a half inches around the biggest part, seventeen inches across the tail, seventeen inch bill and weighs—now get this—185 pounds. This fish was caught Tuesday by R. Vanderbeek who has for years piloted fishing parties about Okoboji. Mr. Vanderbeek was spearing fish through a hole in the ice from his shanty which is located at the north end of West Okoboji. He said he first noticed the smaller fish race through the water as though they could not get away fast enough, and then this immense shadow came cutting thru the water. He threw two spears both reaching the mark, and after letting out about twenty feet of line, with another man's assitance succeeded in dragging the fighting monster out of the water. He said that he alone would have been unable to land this fresh water whale.

There have been a number of healthy specimens of this variety of the finny tribe caught in Okoboji heretofore, but this one is said to break all records. Mr. Vanderbeek is on his way to Omaha where he will have the big fellow mounted, so that he may forever display it as a proof that he can tell the biggest fish story of any fisherman or would-be fisherman in these parts.

(B) March 9, 1916

A STILL BIGGER FISH CAUGHT IN WEST OKOBOJI

Fishing is growing better as time goes on in West Okoboji. Only two weeks ago R. Vanderbeek speared a Spoonbill Sturgeon near the head of West Okoboji lake weighing 185 pounds which was by far the largest ever taken from those waters, but not to be out done in fishing or with fish stories for the coming generations Ben Wiese on Monday of this week speared a Sturgeon which tipped the scales at 210 pounds. Mr. Wiese's fish is a female wherein the other was a male, and while only measuring 6 feet 7 inches long, 2 inches shorter than the Vanderbeek fish, measures 47 inches or 4 inches larger around with an 18 inch bill.

Mr. Wiese was spearing fish in the bay off Pillsbury Point where the water is about fifty feet deep. The fish was about fifteen feet under water but Mr. Wiese got her strong with the first spear. Realizing he would have a difficult task landing the fish alone he tied it with about twenty feet of rope and went for assistance. The fish was not difficult to manage at first but when he returned from the, about twenty minute trip up to where Charley Wilson was working it had gained considerable life, and it was only with the third attempt with Charleys' assistance that the fish was thrown out upon the ice, where it made things hum for a time.

A deal is on with the Commercial Club of Spirit Lake and Mr. Wiese wherein the club will purchase the monster and have it mounted for exhibition. The Vanderbeek fish was sent to Omaha where it is being mounted for exhibition purpose at the Park.

Figure 4. (A) Excerpt from March 2, 1916 *Spirit Lake Beacon* newspaper describing an 84-kg (185-lb) "spoon-bill sturgeon" speared by R. D. Vanderbeck. (B) Excerpt from March 9, 1916 *Spirit Lake Beacon* newspaper describing a 95.5-kg (210-lb) fish speared by B. Weise. Images courtesy of the Iowa Department of Natural Resources.

as an important fish for which records needed to be kept. As of 2021, the International Game Fish Association does not list Paddlefish as a species for which world records are recorded. However, the world record Paddlefish is recognized by the National Freshwater Fishing Hall of Fame (https://www.freshwater-fishing.org/). Under these circumstances,

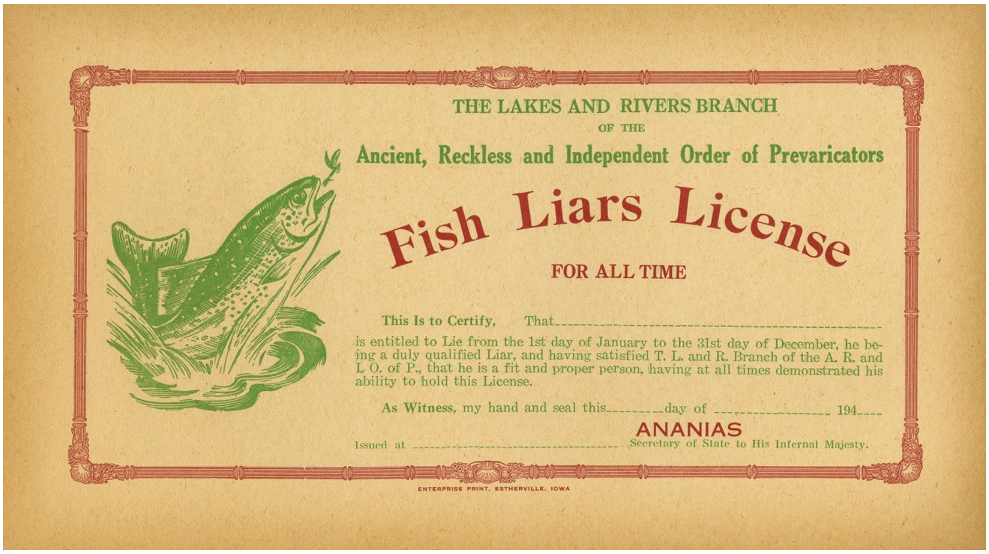

Figure 5. Mid-20th century folk art acknowledgement of the prevalence of exaggeration among inland sport fishers. The biblical Ananias was struck dead after lying (Acts, Chapter 5). The license was printed in Estherville, Iowa, in the 1940s, by coincidence about 32 km from Lake Okoboji.

the more appropriate question is “of the states which allow recreational hook and line snagging for Paddlefish, which one has the largest state record?” In this sense, for this state-managed fish (Mestl et al. 2019), the state agencies that allow snagging for Paddlefish function as a sort of collective sanctioning body. This responsibility also makes it incumbent on the states to have accurate weighing scales certified at regular intervals; such careful certification has not always been uniformly practiced.

Under states acting as the aggregate certification body, the claim for the world record Paddlefish has moved among a few states in the past half century. In 1973, Larry Branstetter caught a 64.8-kg (142.5-lb) Paddlefish from Fort Peck Reservoir, Montana (Figure 6A). This fish measured 195.5 cm (77 in) in total length, the same length as the largest fish the authors have seen, although 20 cm shorter than Vanderbecks’s claim for the Lake Okoboji fish. From the filling of this Missouri River main-stem reservoir in the late 1930s and 1940s, trophic upsurge led to many large fish being taken from Fork Peck Reservoir (Scarnecchia et al. 2021). This record was certified by Montana Fish, Wildlife, and Parks and held for 31 years. In 2004, Kansas claimed the world record Paddlefish when Clinton Boldridge of Riley, Kansas, landed a 65.5-kg (144-lb) fish from a

Figure 6. (**A**) Previous world record Paddlefish caught by Branstetter in 1973 (Montana) and (**B**) by Boldridge in 2004 (Kansas). Both records were certified by the respective state agencies. Image (B) courtesy of Kansas Department of Wildlife and Parks.

Table 1. Summary of trophy Paddlefish snagged in Keystone Lake, Oklahoma, in 2020–2021. Length measurements are total length (TL) or body length (BL; measured eye to fork).

Date	Angler	Weight (kg, lb)	Girth (cm)	Length (cm)	Status
Feb 14, 2020	Justin Hamlin	71.2, 157.0	NA	NA	Not certified
May 23, 2020	Jeremiah Mefford	64.9, 143.0	113.0	193.0 TL 140.3 BL	State record
June 28, 2020	James Lukehart	66.5, 146.7	114.3	NA TL 137.9 BL	World record
July 23, 2020	Cory Watters	68.9, 151.9	112.4	181.6 TL 139.1 BL	World record
June 22, 2021	Grant Rader	74.4, 164.0	109.2	207.6 TL 143.5 BL	World record

4.2-ha pond in Atchison, near the Missouri River (Figure 6B). The fish was hooked in the mouth on a doughball. The world record weight of this fish, which was certified by the Kansas Department of Wildlife, Parks, and Tourism, held for 16 years.

During 2020–2021, a string of five trophy Keystone Lake Paddlefish, including a certified state record and three successive certified world record fish, were snagged by anglers (Table 1). This remarkable series of catches began in February 2020 with a putative, but not certified, world record 71.2 kg (157 lb). A 64.9-kg (143-lb) ODWC-certified state record fish was snagged in May 2020, a 66.5-kg (146.7-lb) certified new world record fish was snagged in June 2020, and yet another world record fish (68.9 kg [151.9 lb]) was snagged in July 2020. The last fish was found to have been tagged 23 years earlier (January 4, 1997) with a uniquely identifiable coded jaw band by Craig Paukert (presently a U.S. Geological Survey cooperative professor at the University of Missouri), then a graduate student at Oklahoma State University, and his field assistant, Brandon Brown, now Paddlefish Caviar Program coordinator at the ODWC. At the time of tagging, the fish measured 657 mm body length (BL; front of eye to fork of caudal fin; Ruelle and Hudson 1977), weighed 3.5 kg, and was estimated to be 2 or 3 years old. This record fish was released alive. Nearly a year later, in June 2021, the world record fell again when Grant Rader of Wichita, Kansas, landed a Paddlefish certified by the ODWC at 74.4 kg (164.0 lb; Figure 7). All five catches (Table 1) were made with the aid of one knowledgeable guide who, like a few others, had attained snagging proficiency and precision using LiveScope. Examination of diagnostic characters visible in photographs of Rader's fish identified it as a recapture of the uncertified fish caught and released February 2020 (Figure 7). The fish succumbed to handling stress and was harvested by the snagger, internally examined by the ODWC, fin clip retained for later genetic analyses, and aged via a sectioned dentary bone at 29 years (Figure 7) using the methodologies described in Scarnecchia et al. (2011). The female fish was nonreproductive (no evidence of roe development and with diminutive ovaries), and the combined weight of ovaries and gonadal fat deposits was 12.38 kg (16.6% of body weight). Exceptionally large Oklahoma Paddlefish are often, but not exclusively, reproductively dysfunctional; in these situations, energy resources are invested in continued somatic growth rather than in reproduction, post-age of maturity (Scarnecchia et al. 2007).

Although the specific genetic and environmental conditions leading to world record Paddlefish are of scientific and popular interest, too little is known to ascertain how the record fish have come about. Paddlefish rearing in productive, lentic habitats are typically faster growing and reach larger sizes than those rearing strictly in flowing waters (Paukert and Fisher 2001), although not if the lentic waters are unproductive (e.g., Missouri River dredge cuts below Fort Peck Dam, Montana). Trophic upsurge after filling of Fort Peck Reservoir (initial filling in the late 1930s and early 1940s) has been suggested as a likely cause of the Montana record fish of 1977 (Scarnecchia et al. 2021).

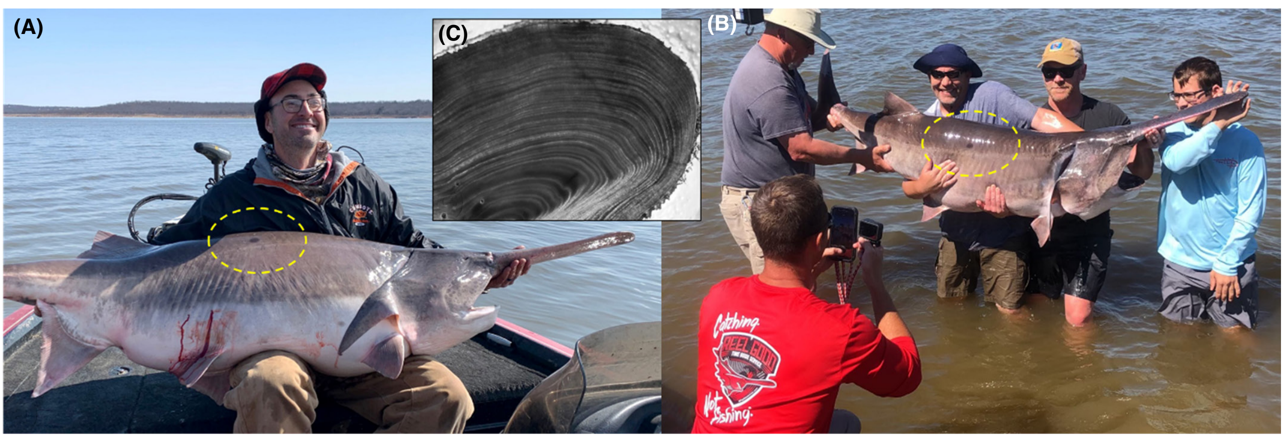

Figure 7. Through examination of photographs of (A) the putative world record fish and (B) Grant Rader's certified world record (Rader is pictured far right), unique pigment on the dorsal area (circled) and other characters indicated that the two anglers caught the same fish. (C) Inset depicts the outer portion of the dentary cross section of this current world record Paddlefish (estimated age = 29). Images courtesy of the Oklahoma Department of Wildlife Conservation.

In Oklahoma, studies of Paddlefish genetics and environmental aspects of Paddlefish ecology in reservoirs have provided some indications of factors associated with the Keystone Lake record specimens. Schwemm et al. (2015, 2019) found Keystone Lake Paddlefish to have the highest genetic diversity of seven populations sampled (Figure 8). Keystone Lake was also distinct from the five other Oklahoma reservoir populations in having the higher allelic richness (A_r; mean number of alleles per locus; Petit et al. 1998; Greenbaum et al. 2014) than the others. Of the six Oklahoma reservoirs sampled, Keystone Lake Paddlefish had the highest allelic richness (A_r = 5.36), higher than Kaw Lake upriver of it (A_r = 4.76) and the only reservoir with an A_r>5.0. Allelic richness in Keystone Lake was closer than the other reservoirs to the higher allelic frequencies associated with the more open populations of the large rivers (Mississippi River mainstem, A_r = 6.15; Red River mainstem, A_r = 6.29). A higher allelic richness may lead to greater evolvability and greater potential to respond to environmental changes and opportunities (Greenbaum et al. 2014). Missouri River genetics may also be a factor. Several thousand Paddlefish stocked in Kaw Lake upriver of Keystone Lake were from Missouri River broodstock; gene flow has probably occurred from the smaller numbered, lower-diversity Kaw population downriver to the larger, more diverse Keystone population (Schwemm et al. 2015). Missouri River-origin Paddlefish have historically reached large sizes, including, for example, the Montana and Kansas state record fish (Figure 6).

Ecologically, Keystone Lake likely provides an especially favorable environment for growing large Paddlefish (Paukert and Fisher 2001). Nealis (2013) showed that lengths, weights, and lengths at age of standard gillnetted female Paddlefish in Keystone Lake were significantly longer in BL and significantly longer at age than from Grand Lake, indicating faster growth through age 13. Faster growth of Keystone Lake female Paddlefish was consistent with them putting less effort into spawning (roe weight 18–20% of total fish weight) than Grand Lake fish (roe weight 23–24% of total fish weight (Scarnecchia et al. 2011; Nealis 2013). Keystone Lake Paddlefish also put more weight into gonadal fat (Scarnecchia et al. 2007), a pattern more similar to stocks from more northerly latitudes (Scarnecchia et al. 2011). Keystone Lake fish were significantly plumper than Grand Lake fish (Nealis 2013). Reservoir populations in both Keystone Lake and Kaw Lake have produced larger Paddlefish than Grand Lake. Other environmental factors leading to large Paddlefish in Keystone Lake may be reservoir productivity and habitat quality. Eachus (2021) sampled zooplankton communities in Keystone Lake and six other reservoirs in the eastern half of Oklahoma (Eufaula, Grand, Kaw, Oologah, Tenkiller, and Texoma) and found that median densities of large zooplankton (copepods and cladocerans) in summer 2020 were highest in Kaw and next highest in Keystone and Oologah lakes, and all three were higher than in Grand Lake (Eachus 2021). More research on zooplankton ecology and Paddlefish density is needed for a more definitive answer. Overall, however, available evidence indicates that, as would be expected, a combination of genetic and environmental factors have contributed to world record Paddlefish in Keystone Lake.

RESPONSIVE FISHERIES MANAGEMENT IN A COMPRESSING TIMESCAPE

As with other fisheries, Oklahoma's Paddlefish fisheries have been occurring in a progressively compressing timescape. Since the early 1990s, Oklahoma's Paddlefish snag fisheries on Grand Lake and other localities, including Keystone Lake, have shifted from mainly low-cost, low-tech bank fisheries toward higher-cost, higher-tech boat fisheries guided by increasingly sophisticated fish finders capable of locating larger fish (Gordon 2009). Traditionally, Paddlefish snagging was a spatially and temporally limited springtime season conducted from riverbanks during upstream spawning migrations. Snaggers would typically stand on the bank of a discharge-swollen river and cast across it with a surf rod rigged with a heavy lead sinker and a large treble hook. Blind snagging is a tiring sport, however, and it can be fruitless for days unless fish are highly concentrated, such as below dams or at river confluences. In the past decade, with improved fish finding technology, snaggers have found fish in more places, in deeper waters, and earlier in winter (i.e., prespawn reservoir areas in November–February). Traditional blind snagging from the bank has given way to snagging from a boat and letting the outboard drag the hook through the water in areas preidentified via sonar to hold Paddlefish. Creative use of downriggers on the line has allowed snag anglers to target fish in the deeper waters of reservoirs many months before the spring spawning run. Whereas traditional bank snagging was all about timing and a strong back, and boat trolling with downriggers is about carefully selecting likely spots and depth, fishing with

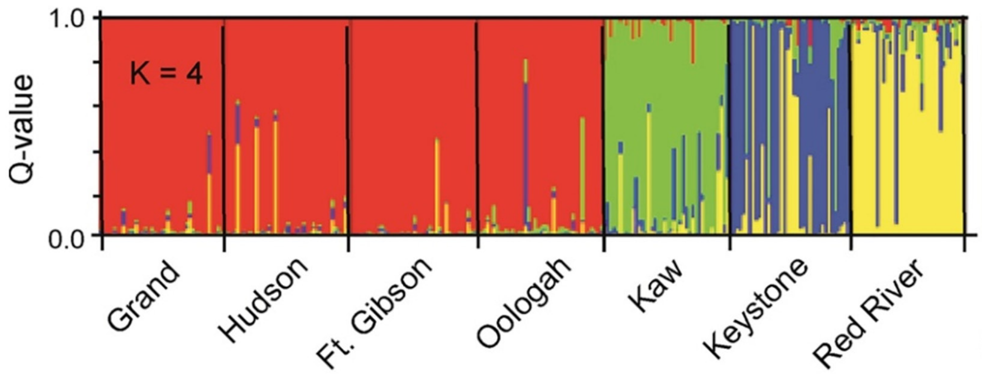

Figure 8. Structure plot from Oklahoma Paddlefish genetics analysis. Higher genetic diversity is symbolized by more colors within a single stock. Missouri River genetic influences on Kaw Lake are generally indicated by green, some of which has been integrated into the makeup of Keystone Lake Paddlefish. Image reproduced from Schwemm et al. (2015, 2019).

LiveScope is about absolute precision (Figure 1). Thus far, it is primarily fishing guides utilizing LiveScope. This ability to target a moving fish by "sight" in a deep reservoir any day of the year presents additional management challenges, such as warm water temperatures and possible enhanced catch-and-release mortality. Continually improving fish-finding and fish sizing technologies, as used on Keystone Reservoir (Frazee 2021), along with improved media communications have allowed anglers to become much more efficient in the harvest of larger fish in ways that are just beginning to be effectively studied and interpreted (Sbragaglia et al. 2020).

The rapid succession of world record Paddlefish caught in 2020 and 2021 in Oklahoma (Frazee 2021) exemplifies an important challenge facing 21st century fisheries agency managers. The rapidly shortening timescape of habitat change, including fish community change, fisheries changes, and rapid technological innovation, is challenging fisheries managers to keep pace. Cooke et al. (2021) surveyed a wide range of emerging and developing technologies creating challenges for managers. Effects on management can be obvious, such as the LiveScope examples discussed above, or more subtle and indirect, such as effects on catch time series and stock assessments as new technologies alter catch-per-effort statistics in databases. Many of these changes present particular challenges for longer-lived, late-maturing iteroparous species such as sturgeons and Paddlefish, which recruit slowly or sporadically, require more cautious recreational harvest (Figure 3 in Post 2013). The Paddlefish's protracted, slow-lane life history (Musick 1999) was not fully recognized until the past three decades (Scarnecchia et al. 2007, 2019; Jennings and Zigler 2009); in the prior half century, Paddlefish managers assumed they were managing a fish with a shorter life span. In Russell's (1986) review and synthesis of Paddlefish life history, the oldest fish identified was age 29, from the Fort Peck stock (Berg 1981); fish from the next oldest stocks were aged to a maximum of 20 years (Lake of the Ozarks, Missouri; K. Graham, Missouri Department of Conservation, unpublished data; Yellowstone–Sakakawea stock, Montana; Rehwinkel 1978). By the early 1990s, improvements in aging methodologies with low-speed saws indicated unvalidated ages of 40–60 years in some northern stocks (Scarnecchia et al. 2019). The late-maturing Yellowstone River stock's life history was described as a series of stages, including as prime reproduction phase from 25 to 40 years of age (Scarnecchia et al. 2007). The ages of the oldest fish have not yet been formally validated; fish older than 65 years in northern stocks may exist. The discoveries of longer life spans, lower natural mortality rates, sporadic recruitment, more protracted life histories, and larger female fish than male fish has been widespread among Paddlefish and other riverine fish taxa, including gars (Daugherty et al. 2020) and several sucker species (Catostomidae; Bednarski and Scarnecchia 2006; Lackmann et al. 2019). Compounding these challenges was the lack of recognition of the Paddlefish among many harvesters as an important fish deserving of much conservation attention (Rider et al. 2019), a problem pervasive among many native, nongame species (Scarnecchia et al. 2021). The continuing availability of trophy Paddlefish in Oklahoma and elsewhere, along with the economic and social benefits they provide, will depend on a range of management actions designed to maintain abundance and age and size structure of the stocks (Scarnecchia et al. 2019). Managers should seek to avoid genetic and environmental truncation of life histories (Scarnecchia and Schooley 2020).

The desire to reduce mortality of trophy fish provides a strong incentive to practice catch-and-release (Shiffman et al. 2015; Bettoli et al. 2019). Catch-and-release has been shown to be a viable approach to reducing unnecessary or undesirable mortality in Paddlefish (Scarnecchia and Stewart 1997; Cha and Melstrom 2018). Studies on other species suggest that adherence to catch-and-release guidelines can further improve survival (Arlinghaus et al. 2007; Cooke and Schramm 2007; Brownscombe et al. 2017). These guidelines include avoiding snagging during periods of warm temperatures (e.g., summer), minimizing the time the fish are out of water, avoiding handling the fish by the operculum and gills (instead, handling Paddlefish by the rostrum and caudal peduncle), and avoiding pulling the fish up rapidly from great depths.

If necessary, restrictions or prohibitions on sophisticated fish-finding equipment and other technologies may be called for in some instances and localities, not the first of many efforts at reducing harvest efficiency and fish mortality that have been applied worldwide in managing recreational fisheries. With much more efficient and effective trophy fishing comes greater demands on managers to ensure that the effective targeting of trophy fishes still maintains a sustainable stock. The ODWC utilized LiveScope to verify the disposition and immediate survival of several of these trophy Paddlefish described here. LiveScope also aided the ODWC in making an unfortunate decision to harvest one of the fish based on low probability of survival.

Sustainable Paddlefish management requires more patient, cautious management than heretofore conducted in most localities. Successful management also involves the persistent acquisition of long-term databases for reliable stock assessments. Well managed, a strong year-class may provide more than a decade of harvest; a strong year class in more northerly, long-lived stocks may last three decades if harvest is judiciously conducted. Examples of long-term management approaches for long-lived, iteroparous species include Lake Sturgeon *Acipenser fulvescens* management in Lake Winnebago (Bruch 1999; Bruch et al. 2016), Grand Lake Paddlefish in Oklahoma (Schooley et al. 2014), and Yellowstone–Sakakawea and Fort Peck Paddlefish (Scarnecchia et al. 2008). This long-term management approach will occur, however, in a continually compressing timescape, which will call for more rapidly responsive harvest management on a shorter time frame, even including unpredictable, unforeseeable closures.

Epstein (2013) discussed "the troublesome relationship between technological innovation and government regulation," seeking to identify "some test that allows us to sort regulations into those which should be welcome from those which should be opposed." His suggested solutions were designed for the business world. His title asked, Can technological innovation survive government regulation? But for managing long-lived fish species and their fisheries in the 21st century under the public trust doctrine, a question for dealing with new technologies in fisheries management (Cooke et al. 2021) might be the reverse: can government regulation survive technological innovation? Moving forward, state agencies must develop the necessary administrative capabilities to respond much more rapidly to the needs of long-lived species amid the challenges of a compressing timescape of technological and environmental change. Fisheries policymakers and managers, who in previous generations saw technological advances in the pages of fishing magazines, must now invest more time on industry Web pages and social media pages to keep abreast of the latest changes in technologies (Cooke et al. 2021). They must take the lead to ensure that the new technological innovations are utilized to work to the benefit of, rather than to the detriment of fish populations and aquatic communities (Scarnecchia 1988).

Structural changes in regulatory systems and their pace of implementation may also be needed. Each year, it becomes increasingly unlikely that traditional, sometimes somewhat rigid, multi-year regulation cycles of state fisheries agencies have the flexibility to meet the demands of successful management of Paddlefish and other species. A shortening timescape affecting the Paddlefish and numerous other freshwater and marine species calls for more responsive and timely management and regulatory flexibility. Forward-looking management agencies should now be considering, designing, and implementing those changes where needed.

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