American Fisheries Society Symposium 88:239–265, 2019

Chapter 12

Paddlefish Recreational Fisheries: State Management of a Migratory Fish with a Complex Identity

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Abstract.—The Paddlefish *Polyodon spathula* has been identified and characterized disparately by commercial harvesters, anglers, managers, and the public, from a rough fish, to a food fish, to a trophy sport fish, to one of North America's most economically valuable and evolutionarily irreplaceable fish species. It is most commonly harvested with recreational fishing methods often used only for low-valued

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species, including snagging (the most common method) and archery since adults are primarily filter feeders and thus not susceptible to more traditional angling methods used for sport or game fishes. The prevalence of recreational snagging throughout the Mississippi and Missouri basins increased greatly over the period 1950–1975, associated with impoundment of upper Mississippi and Missouri mainstem and tributary reaches. More Paddlefish became accessible to snaggers below dams as spawning and feeding migrations were impeded and fish aggregated in tailwaters. The variability of legal and administrative classifications of Paddlefish and differing perceptions of the species by harvesters, managers, and the public have resulted in a fish with a complex identity. While Paddlefish in the past have been petitioned for federal listing under the Endangered Species Act, to date they have not been listed. Recreational fisheries management strategies, goals, and objectives have varied widely, perhaps understandably, since the species is managed at the state level. To assess the current situation, we administered an electronic survey to state Paddlefish managers from each of the 25 current and former range states, requesting information on Paddlefish status, regulations, perceptions, and management strategies. The legal and administrative classification of Paddlefish by each state remains the primary factor in how they are managed, and we identified several regional management strategies. Paddlefish regulations continue to evolve based on new research findings and stock assessments. The most impactful regulatory changes have been the development of limited entry Paddlefish fisheries requiring the purchase of a special Paddlefish permit and three instances where recreational fisheries and stock assessments are supported in part by voluntary roe-donation programs. Management of Paddlefish across the Mississippi Basin at biologically relevant or regional scales remains the most rational and desirable long-term goal.

Introduction

The Paddlefish *Polyodon spathula* is an ancient Acipenseriform fish of large rivers and reservoirs in 26 states within the Mississippi, Missouri, Ohio, Tennessee, Arkansas, and selected Gulf Coast drainages of the Central United States (Grande and Bemis 1991; Gengerke 1986; Jennings and Zigler 2009). It has also been introduced into waters of Europe (Jarić et al. 2018), Russia (Kharin and Cheblukov 2009), and China (Ji and Li 2019, Chapter 11 this volume). This large bodied, distinctive, highly migratory species (Russell 1986; Pracheil et al. 2012, 2015) supports numerous fisheries throughout its range and is a source of high-quality meat (Decker et al. 1991) and expensive caviar (Harris and Shiraishi 2018).

Recreational, Commercial, or Protected?

For more than a century, the merits of the Paddlefish have been identified and charac-

terized disparately by commercial harvesters, anglers, managers, and the public, from a rough fish (Rider et al. 2019), to a food fish, to a trophy sport fish, to one of North America's most economically valuable and evolutionarily irreplaceable fish species (Grande and Bemis 1991; Scarnecchia et al. 2008; Southwick and Loftus 2017; Fain 2019, Chapter 8 this volume). Unlike most other high-valued inland species in the United States where human harvest and habitat pressures have transitioned species from commercial to recreational (e.g., Centrarchidae, Percidae, Esocidae, Salmonidae; Percichthyidae) or even protected (Smith 1986), the Paddlefish has made an incomplete transition to a recreationally harvested or protected species (Smith 1986). Perhaps uniquely among our inland species, it is managed as a trophy sport fish in some states (e.g., Nebraska and South Dakota; Mestl and Sorensen 2009; Montana and North Dakota; Scarnecchia et al. 2008; Oklahoma; Schooley et al. 2014; Kansas; Neely et al. 2015a, 2015b) as a valuable commercial fish in other states (Rider et al. 2019, Chapter 13 this volume), and as a completely protected species in still other states (e.g., Wisconsin and Minnesota; Runstrom et al. 2001; Hansen and Paukert 2009). The Paddlefish is also distinctive in that adults, being primarily filter feeders, are harvested with recreational fishing methods often used only for species of lower perceived value, primarily snagging. Several less common methods include archery in Fort Peck Dredge Cuts in Montana (Scarnecchia et al. 2008) and Gavins Point Dam tailwater in Nebraska and South Dakota (Mestl and Sorensen 2009), spearing in Oklahoma (Scarnecchia et al. 2013), and throw, trot, bank, and set lines in Missouri (MDC 2018) and Oklahoma (ODWC 2018). These harvest methods, as well as some historical management actions such as removal (Rider et al. 2019, Chapter 13 this volume), are typically applied to species historically and pejoratively classified as rough fishes (e.g., Lepisosteidae, some Catostomidae, Cyprinidae) even though early 20th century accounts of Paddlefish almost invariably describe the species as valuable, especially for the roe, but also for the meat (Stockard 1908; Hussakof 1910; Alexander 1914; Coker 1930).

Native American accounts of Paddlefish harvest are few in number (Rostlund 1951; Scarnecchia et al. 2008), and possibly reflect the difficulty of capturing the fish in its large river habitats compared to other species. Prior to World War II, accounts of Paddlefish harvest mostly described commercial activities (Stockard 1908; Alexander 1914; Coker 1930) with traditional commercial gears such as gillnets, trammel nets, and seines. Consistent with Smith's (1986) "life cycle of fisheries" framework hypothesis, commercial fisheries continue to exist primarily within the core areas of its distribution where fish abundance is often higher and the tradition of commercial fishing is stronger. In some locations, anglers historically described Paddlefish in neutral or pejorative terms (e.g., "rough" fish), probably because of their perceived low value as a sport fish. Such states have historically allowed harvest of Paddlefish with diverse fishing gears, liberal bag or size limits, and no special licenses or reporting requirements.

Recreational fisheries for this largely zooplanktivorous species (Michaletz et al. 1982; Fredericks 1994), primarily involving snagging with treble hooks and spinning or casting rods or archery, have developed where fish congregate and where large numbers of anglers have easy access to the fish (e.g., below dams). In states where the Paddlefish is regarded as a trophy sport fish, managers typically sponsor a fishery of limited seasonal and spatial availability (Hansen and Paukert 2009). These fisheries often have some form of limited entry, requiring special permits or lotteries, and are paired with conservative harvest restrictions. The species is typically afforded conservation status in places where

relatively few fish are present, recruitment is poor, and the stock is depleted due to habitat loss or overfishing. Recreational angling and other harvest may be severely limited or prohibited on some stocks (Runstrom et al. 2001). Some of these stocks may also be artificially enhanced by hatchery-reared fish (Graham 1986; Argent and Kimmel 2006; Grady and Elkington 2009; Hupfeld et al. 2018). With the Paddlefish's diverse, broadly defined identity, and variable legal and administrative status as a commercial, recreational, and protected species, management goals, objectives, and actions for the species have been equally diverse among or across jurisdictions.

Origin of Recreational Fisheries

Although the exact origins of snagging for Paddlefish are not precisely documented, snagging probably occurred in many states before regulations were written that specifically managed it. Early photos (1910) at the Intake Diversion Dam on the lower Yellowstone River, Montana, suggest that some opportunistic snagging of fish below the dam may have occurred early in the last century. Purkett (1963) reported catch statistics from snagging efforts on the Osage River in Missouri from the late 1950s and early 1960s. The prevalence of recreational snagging throughout the Mississippi and Missouri basins increased greatly over the period 1950–1975. One factor associated with development of recreational Paddlefish snagging over this period was the high rate of construction of dams on Upper Mississippi and Missouri mainstem reaches and major tributaries nationwide in the previous decades (Dieffenbach 1948; Hart 1957). More Paddlefish became accessible to snaggers below dams as spawning and feeding migrations were impeded and fish staged in aggregations in tailwaters for long periods (e.g., Missouri River mainstem dams: Park 1962; Friberg 1972; Mestl and Sorensen 2009; upper Mississippi River: Helms 1976; Anderson 1977). Old, long-lived adult fish often grew to large sizes of interest to trophy anglers, even if spawning success in impounded sections was poor (e.g., Big Bend Dam tailwaters, South Dakota; Friberg 1972). The effects of dams on Paddlefish spawning were mostly negative; most stocks decreased and could not sustain initial catch rates (Mestl and Sorensen 2009). Some stocks, however, increased with improved rearing habitat of reservoirs (as a surrogate for eliminated backwaters and side channels of the natural river) provided that spawning habitat above the impoundment was maintained (e.g., Yellowstone River, Montana; Robinson 1966). Stock responses to habitat changes have been mostly negative but have varied widely throughout the species range (Bettoli et al. 2009; Schwemm et al. 2019, Chapter 2 this volume).

As reservoir fisheries increased in area over the period 1950–1975 at the expense of often more difficult free-flowing river fishing, there was also increased societal emphasis on leisure activities associated with water (McFadden 1969). Anglers bought more and larger boats and more fishing equipment. Reservoir and tailwater fisheries proliferated (Jenkins 1970). Increased funding of recreational fishing research, management, information, and education through the Federal Aid to Sportfish Restoration Act (American Fisheries Society 2000) led to state agencies developing and managing more recreational fisheries, including scattered local ones for Paddlefish. By the late 1950s, Paddlefish snagging fisheries, largely viewed as a specialized niche fishing opportunity by agencies, were becoming better defined, and documented, a process that would continue in the ensuing decades. South Dakota legalized snagging in 1957 (Friberg 1972) as fish congregated below mainstem impoundments, including Gavins Point Dam (Stone 1987), Big Bend Dam, and Oahe Dam. Nebraska began to report harvest of Paddle-

fish by snagging below Gavins Point Dam in the late 1950s (Mestl and Sorensen 2009). Montana's snag fisheries below the Intake Diversion Dam expanded greatly in the early 1960s after a Paddlefish population boom in the newly constructed Lake Sakakawea, North Dakota resulted in a strong run of mature fish of the Yellowstone-Sakakawea stock up the lower Yellowstone River (Robinson 1966; Rehwinkel 1978; Scarnecchia et al. 1996). North Dakota, harvesting the same stock, did not open a snag fishery until 1976 (Scarnecchia et al. 2008). Kansas sanctioned its first legal snag fishery below Chetopa Dam on the Neosho River in 1972 (Neely et al. 2015a, 2015b). Illinois legalized snagging in 1973 and Iowa followed in 1974; Paddlefish were commonly caught below locks and dams built in the previous decades (Ackerman 1975; Helms 1976; Anderson 1977; Beck 1978). Recreational Paddlefish snagging in Oklahoma has been pursued for decades and has been actively managed since 1979 (Gordon 2009; Scarnecchia et al. 2013; Schooley et al. 2014). Missouri's recreational Paddlefish fisheries have a long history before and after dam construction on the Osage River and have expanded to other reservoirs in the state (Graham 1986; Schwinghamer et al. 2019, Chapter 10 this volume). Other states have recreational fisheries, including some with coexisting commercial harvest (Quinn 2009).

Other recreational methods besides snagging developed on an ad hoc basis as a result of particular conditions resulting in fish availability. For example, archery fisheries in the Dredge Cuts below Fort Peck Dam, Montana, and below Gavins Point Dam became more feasible because of clear water associated with sediment trapping at upriver impoundments.

History of Fragmented Management

Paddlefish management has never been unified nor strongly coordinated among state management agencies. However, some common themes and approaches have emerged. By the time of the first American Fisheries Society (AFS) Paddlefish symposium in 1983, Elser (1986) identified three primary state management approaches: regulating harvest, protecting habitat, and encouraging public support and involvement in Paddlefish management. He also recommended regional management requiring increased cooperation between and among states to evaluate and manage shared stocks, a logical idea promoted frequently since then (e.g., Pracheil et al. 2012; Hupfeld et al. 2016). Combs (1986) noted that state Paddlefish management strategies were generally based on classification (i.e., legal or administrative) of the species in each state as game, nongame, or protected. He indicated that the use of fishing regulations to manage Paddlefish was a relatively recent development and summarized four types in use at that time: creel limits, seasons, prohibition of high-grading, and sanctuaries/area closures. However, the effectiveness of most of these regulations was unknown, with only 29% of participating state managers reporting success in accomplishing their management objectives (Combs 1986). Despite the regulation strategies in use at the time, Combs (1986) concluded that creel (bag) limits, harvest quotas, and gear restrictions held the greatest promise for effectively managing Paddlefish.

State management of Paddlefish recreational fisheries has become more active since the 1983 Symposium. When Hansen and Paukert (2009) revisited Paddlefish recreational fisheries management in the second AFS Paddlefish symposium in 2006, they noted that for the 14 states with recreational fisheries, the most common regulations in use were seasons, creel limits, length limits, catch and release regulations, and harvest quotas. Four states had adopted Combs' (1986) recommendation to utilize harvest quotas as part of their management strategies. Harvest tag permit systems to track harvested fish had

been developed in several states (Nebraska and South Dakota: Mestl and Sorensen 2009; Montana and North Dakota: Scarnecchia et al. 2008). Although Hansen and Paukert (2009) reiterated the long-standing concern that there was still limited consistency in regulations among states with shared Paddlefish stocks, they noted that agencies were becoming increasingly proactive about implementing regulations and cooperating across jurisdictions. They suggested that managers consider taking steps towards basin-wide management on a biologically relevant scale. The authors also advocated future studies on the effectiveness of regulations and pointed to improvements in genetics (Schwemm et al. 2019, Chapter 2 this volume) and tagging studies (Tripp et al. 2019, Chapter 3 this volume) as potential tools to evaluate management actions.

The Identity of Paddlefish Today

In view of the historically complex identity and inconsistent management of the species, the authors decided that an effective way of accessing and categorizing the dispersed agency information and diverse perceptions about the species would be with an electronic questionnaire distributed to the state agencies charged with managing Paddlefish. Such questionnaires have been widely used in assembling and synthesizing information on fish and wildlife agency philosophies and priorities (e.g., Mather et al. 1995; Ross and Loomis 1999) as well as more specific management approaches and activities (e.g., Epifanio 2000; LaBonte and Kilpatrick 2017), although there has admittedly been limited evaluation of the reliability of such methods. In this paper we report the results of a questionnaire in examining the status and perception of Paddlefish among state agency managers (biologists and supervisors) across their range. We also describe the current recreational fishery management strategies and regulations being used to manage Paddlefish, document recent changes in Paddlefish status and fishing regulations, and identify common grounds for fine-tuning future inter-jurisdictional management frameworks.

Methods

Questionnaire

In January of 2017, Paddlefish managers (biologists or supervisors) from the 25 Paddlefish native range states (Figure 1) were invited to complete a survey distributed through Google® Forms. The survey consisted of 36 questions related to Paddlefish sport fishing regulations, management, and their opinions on perceptions of Paddlefish and Paddlefish management in their state (Appendix A). Questions were developed to assess and characterize the complexities of classification, status, and management issues historically observed in the species. Questions were broadly classified into five topic areas: 1) Legal classification and status 2) Recreational fishing regulations 3) Social perceptions 4) Recreational fishery management strategies and 5) Paddlefish biology. Respondents were first asked how Paddlefish were classified (sport, commercial, protected, etc.) and if protected, their conservation status (threatened, endangered, etc.). If sport fishing was allowed, this was followed with a series of questions related to recreational fishing regulations. All respondents were asked how popular Paddlefish sport fishing was in their state and how they felt that different groups (anglers, commercial fishers, public, state fish and game agency administrators and state biologists) perceived Paddlefish in their state. All respondents were asked a series of questions related to Paddlefish management (plans, stocking, relevancy, etc.) in their state. Finally, there were several general questions on Paddlefish reproduction and

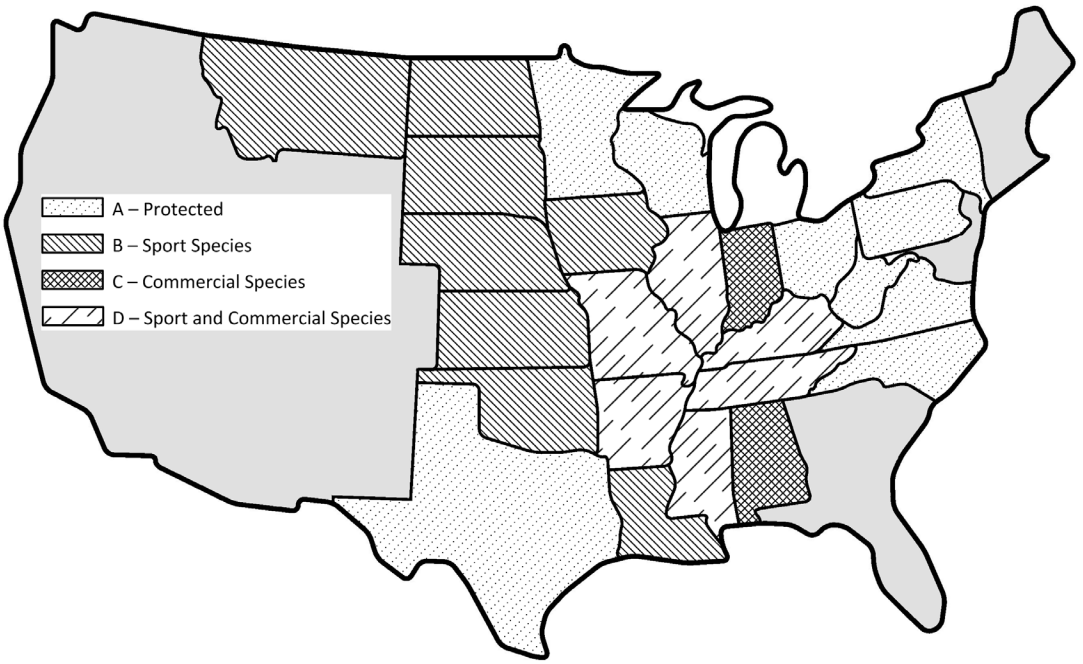

Figure 1. The historical range of Paddlefish in the United States encompassing 25 states. States with similarities in classification of Paddlefish (sport, commercial, sport and commercial, or protected as of 2017) are depicted.

sustainability. Completed survey responses were returned from 24 of 25 Paddlefish range states, one response per state (96% response rate). No response was received from Illinois; therefore, information on Paddlefish fishing regulations for Illinois was obtained from their published fishing guide (IDNR 2018).

Analysis

To classify responses, assess patterns of complexity, and identify states with similar perceptions and management strategies for Paddlefish, the answers from each question (Appendix A) were categorized using hierarchical cluster analyses and reported as dendrograms with PC-Ord 6.0 (McCune and Mefford 1999). Cluster analysis is a multivariate data analysis tool which sorts a set of measured variables into a number of different groups such that similar subjects are placed in the same group (McGarigal et al. 2000). While cluster analysis is not a statistical test, it is used to describe relationships or clusters within a multivariate data set. We used hierarchical cluster analyses with the Euclidian distance measure and Ward's linkage method considered by Shaw (2003) as being the default clustering algorithm used by ecologists. Because there are no objective rules for interpreting dendrograms (McGarigal et al. 2000), the dendrograms were clipped and the number of clusters determined with the intention of describing groups of states sharing common perceptions or management strategies. Clusters were described using common perceptions or management strategies. Correlations were tested using Pearson's r (PROC CORR, SAS 9.4). In all tests, $p < 0.05$ was required for significance.

Results

Legal Classification and Social Perceptions of Paddlefish

As of 2017 Paddlefish continue to be legally classified and socio-economically identified broadly in various states as commercial, recreational, or protected, or combinations thereof. Paddlefish are protected in 9 of 24 states (38%) responding to the survey, with the remaining states split evenly between states that only allow recreational fishing (7; 29%) and states that allow commercial fishing with or without recreational fishing (8; 33%, Table 1). Geographic trends in legal classification of Paddlefish emerged, with commercial states located in the core of the species range and protected status afforded in the northern, eastern, and southern periphery (Figure 1). States with recreational fisheries were primarily located in the western, as opposed to eastern, portion of the species range. In 8 of the 9 states where Paddlefish are protected, they are listed as extirpated, endangered, threatened, or of special concern. Paddlefish are also listed as a species of special concern in more than one third of the states where they are concurrently fished and harvested.

The complexity of socioeconomic identification of the species was manifested by a wide-ranging level of interest in the species among states, according to responses of the managers. The reported popularity of Paddlefish recreational fishing among states was divided almost evenly among the four levels (no, little, moderate, and high; Table 2). This variation among states was related to the differing legal or administrative classifications of the species in those states. Paddlefish had little popularity in states where they are completely protected, but are very popular in states that managed them as trophy fisheries. States that managed Paddlefish with liberal bag and possession limits reported popularity ranging between these two extremes. Administrators and biologists shared similar views on Paddlefish social perception within their states and commercial fishers viewed them as principally a commercial species even in states with both sport and commercial fishing. Respondents indicated that the broader public had "no interest" or knowledge of Paddlefish (32%) or ambivalently regarded the species as "just another fish" (32%). The respondents believed that anglers had the widest range of perceptions of any of the groups; 45% indicated that anglers regard Paddlefish as a game or trophy species (Table 2). When these perceptions were analyzed using cluster analysis, three distinct groups were identified (Figure

Table 1. Summary of Paddlefish state legal status across the species' range (survey questions 5 and 6, Appendix A; states listed in Appendix B).

Paddlefish Classification		State Status				
		No status	Special concern	State threatened	State endangered	Extirpated
Protected	9	1	1	5	1	1
Game or sport fish	8	4	4			
Commercial	2	1	1			
Game and Commercial	6	5	1			

Table 2. Summary of popularity and social perception of Paddlefish among constituent groups, managers, and administrators across the species range (survey questions 22 and 23, Appendix A). Angler perceptions are summarized by state in Appendix B.

How popular do you consider Paddlefish sport fishing in your state (number of states)?

No interest	Little interest	Moderate interest	High interest
5	4	4	4

How are Paddlefish perceived in your state by the following groups (percent of responses by group)?

	Anglers	Commercial Fishers	Public	Administrators	Biologists
No Interest	15	14	32	0	0
Just Another Fish	25	14	32	16	11
Game Fish	20	7	16	16	26
Trophy Fish	25	7	21	42	42
Commercial Fish	5	50	0	26	21
Rough Fish	10	0	0	0	0
Nuisance Fish	0	7	0	0	0

2). The first group consists of those states from the core of the species range, most with commercial fishing (Alabama, Arkansas, Indiana, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee). The second group includes those states that do not have commercial fishing and actively manage Paddlefish as a sport or trophy species and includes the western states (Iowa, Kansas, Montana, Nebraska, North Dakota, Oklahoma, and South Dakota) and Pennsylvania. The final group are all of the states that protect Paddlefish, with the exception Pennsylvania, and are located around the periphery of the species range in the north (Minnesota and Wisconsin), northeast (New York, North Carolina, Virginia, and West Virginia) and the southwest (Texas).

Paddlefish Recreational Fishery Management Strategies

As of 2017, the wide range of recreational fishery management strategies continues to reflect the complex identity of Paddlefish and the variable level of interest in them. Paddlefish recreational fishing is allowed in 14 states (Figure 1), but two states (Louisiana and Mississippi) allow only harvest of incidentally caught fish (Table 3). Snagging for Paddlefish is allowed in the remaining 12 states; archery is legal in six states (Kentucky, Montana, Nebraska, Oklahoma, South Dakota, and Tennessee), while other methods (including, spears, spear guns, and various forms of throw, trot, bank, and set lines) are allowed in four states (Kansas, Louisiana, Missouri, and Oklahoma). All twelve states permitting Paddlefish snagging have specific gear restrictions. These restrictions include limits on the number of poles, number and size of hooks (with some fisheries requiring barbless hooks), and the use and size of gaffs. More than half of the states that allow recreational harvest have a two-fish-per-day bag limit, two states have a daily bag limit of one fish, and five states issue permits that allow

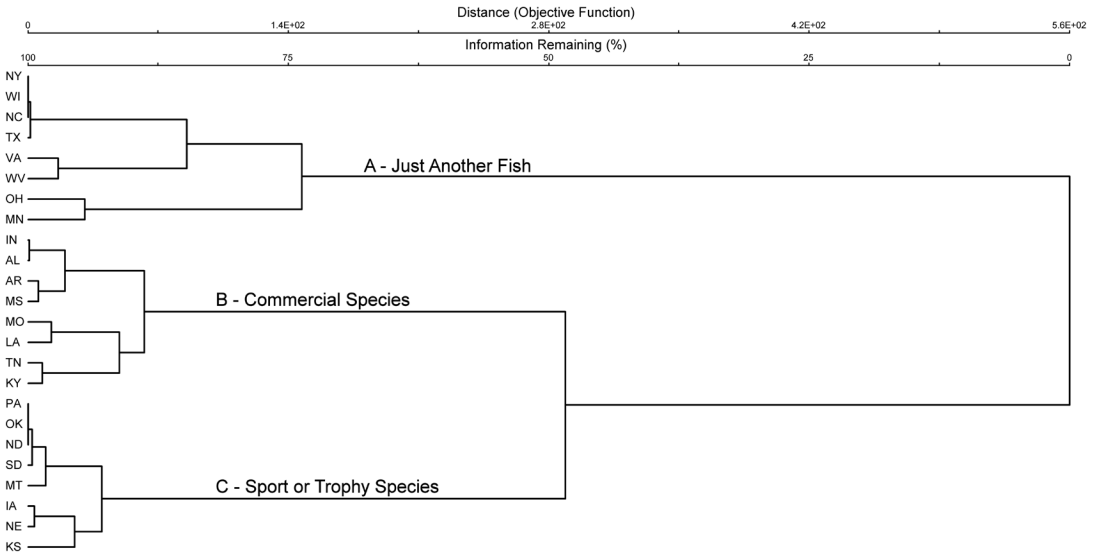

Figure 2. Cluster dendrogram of States with similar perceptions of Paddlefish in 2017.

the harvest of one Paddlefish per permit (and only one or two permits per snagger). Daily bag limits and seasons with hook and gear restrictions, but no length limits, are being used in Arkansas, Kentucky, and Tennessee, which also allow commercial fishing. Daily bag limits and seasons with a minimum length limit or an annual bag limit are being used in Kansas, Missouri, and Oklahoma. Catch-and-release fishing is allowed in 12 states, with three states requiring catch and release on certain days (Montana, North Dakota, and Oklahoma). High grading or culling (e.g., holding and later releasing a fish in favor of a more desirable one) of Paddlefish is now prohibited by all states. About half (54%) of the states that allow recreational fisheries have some sort of Master Angler Program to reward anglers for some type of angling success (e.g., catching a fish larger than a certain size).

Eleven of the 14 states that allow recreational harvest have established seasons on some or all waters within their state that contain Paddlefish (Table 3). Of the three that allow harvest year-round, two allow only incidental catch and the other allows an angler to harvest only two fish per year (harvested fish must be electronically reported within 24 h). In states with sport fishing seasons, most are one to three months in duration and 75% occur during the spring. Most states (77%) have different Paddlefish fishing regulations for different water bodies. Harvest quotas are managed using special permits and seasons in Iowa, Montana, Nebraska, North Dakota, and South Dakota.

More than half (54%) of states have a management plan for Paddlefish; 60% of the states have a Paddlefish monitoring program (Table 4). Fifteen states reported natural reproduction of Paddlefish and 18 states reported that Paddlefish were self-sustaining. While there were highly significant positive correlations between Paddlefish populations considered self-sustaining and conservation status ($r = 0.63$, $n = 24$, $p = 0.001$) and whether sport fishing is allowed ($r = 0.65$, $n = 24$, $p < 0.001$), there was not a significant correlation between populations considered self-sustaining and stocking ($r = 0.08$, $n = 24$, $p = 0.70$). Nine states reported stocking Paddlefish and nearly all monitored these stockings (89%); however only

Table 3. Summary of Paddlefish sport fishing regulations across the species' range (survey questions 8–20, Appendix A).

What Paddlefish sport fishing methods are permitted?	Snagging only	Snagging and archery	Snagging, archery and other*	Snagging and other**	Incidental
	4	4	2	2	2

*Includes spear, spear gun and trot lines
**Includes pole and line and trot, throw, limb, bank and jug lines

What are the size limits for Paddlefish sport fishing?	None	Minimum length limit	Slot limit	Maximum length limit
	6	3*	3*	4*

*Iowa has a slot limit on the Missouri River, a maximum limit on the Mississippi River and no size limits on tributaries

What are the gears restrictions for Paddlefish sport fishing?	Hook size only	Number of poles only	Hook size and gaff	Hook size and number of poles	Gaff only
	2	2	6	1	1

What are the daily bag limits for Paddlefish sport fishing?	1 daily	2 daily	1 per permit
	2* **	9*	5

*One or two per day in Tennessee depending on water body
**One daily, two per year in Oklahoma

Table 3. Continued.

Is catch and release allowed (not high grading)?	No	Yes	Certain days
	2	10	2

Is there a Paddlefish sport fishing season?	No	Yes
	3	11

Are there different regulations for different water bodies?	No	Yes
	3	10

Do you have a Master Angler program for Paddlefish?	No	Yes
	6	7

Table 4. Summary of Paddlefish life history and state management across the species range states (survey questions 24, 25, 29, 31, 32, and 33, Appendix A).

Does your state have a Paddlefish management plan?		Does your state have a Paddlefish monitoring plan?	
		No	Yes
No	11	8	3
Yes	13	1	12

Has natural reproduction been documented in your state?		Are Paddlefish considered self-sustaining in your state?	
No	6	No	6
Yes	15	Yes	18

Do you feel that current regulations and management strategies are adequately managing Paddlefish in your state?		Do you feel that Paddlefish are being managed on a biologically relevant scale?	
		No	Yes
No	5	4	1
Yes	17	2	15

four states utilized a genetically informed stocking plan (Table 5). Most respondents indicated that they felt that Paddlefish are being managed on a biologically relevant scale in their state (77%) and that the regulations and management strategies are adequate (73%, Table 4).

A cluster analysis using sport fishing management actions (monitoring, stocking, and monitoring with stocking) and fishing regulations (recreational fishing, commercial fishing, allowable fishing methods, size restrictions, gear restrictions, bag limits, catch and release options, seasons, and water body regulations) being employed by the states, identified similar management strategies, often regional, being used to manage Paddlefish. States were immediately separated into two highly related clusters, (A) those where Paddlefish are protected and (B) those where Paddlefish are not protected (Figure 3). We identified seven minor clusters within these two major clusters. These seven minor clusters provided insight into different regional management strategies. Within the nonrecreational fishing states, New York and West Virginia (A2) cluster separately from the remaining states (A1), as both states have stocked Paddlefish and monitor these stockings. Within recreational fishing states, Louisiana and Mississippi form a separate cluster (B1) because they only allow incidental harvest of Paddlefish. Kansas, Missouri, and Oklahoma group together (B2) because in addition to snagging they allow other fishing methods including some combination of spears, spear gun, or trot, limb, bank, set, and jug lines. Montana, North Dakota, and South Dakota form a cluster (B3) because they have harvest quotas and have stocked and monitored these Paddlefish stockings. The final two clusters separate because Arkansas, Kentucky and Tennessee (B5) have no length limits and a two fish per day bag limit whereas Iowa and Nebraska (B4) have slot limits on the Missouri River and a one-fish-per-year limit with a special permit.

Recreational Fishing Regulation and Status Changes

Since 1986, eight states have made major changes to Paddlefish regulations, indicating a new management philosophy concerning Paddlefish management in those states. Oklahoma, which listed Paddlefish as both a sport and commercial species in 1986 with a 3 fish-per-day bag limit, now allows only 1 fish per day and 2 per year, enforces mandatory catch-and-release days, and requires mandatory reporting of harvested fish (Schooley et al. 2014). Iowa, Kansas, Montana, Nebraska, North Dakota, and South Dakota sell Paddlefish permits and, except for Kansas, strictly manage Paddlefish harvest by the number of permits issued, or through harvest quotas and/or seasonal closures. Oklahoma, Montana, and North Dakota currently support

Table 5. Summary of the responses to Questions 26–28 (Appendix A) related to Paddlefish stocking. State responses are listed in Appendix B.

Does your state stock Paddlefish?		Does your state monitor its Paddlefish stockings?		Does your state have a Paddlefish genetics stocking plan?	
		No	Yes	No	Yes
No	15				
Yes	8	1	7	4	4
Experimentally	1		1	1	

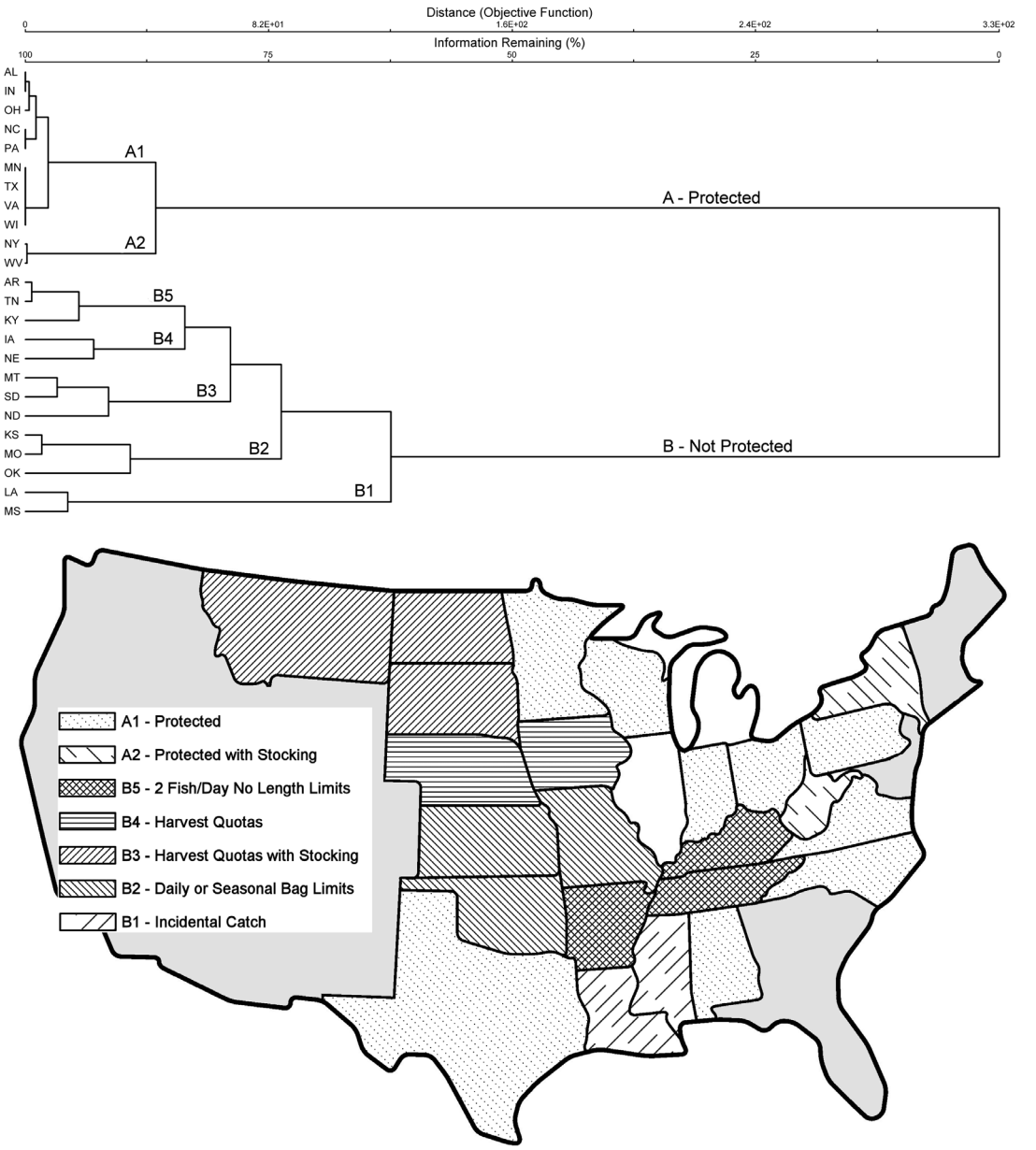

Figure 3. State management strategies for Paddlefish as of 2017 with results of cluster analysis.

their Paddlefish management programs in part through sales of caviar from roe donation programs.

Since 2006, seven states have changed their Paddlefish sport fishing regulations (Table 6). Arkansas opened new snagging seasons on the Black, St. Francis, and White rivers below Beaver Tail Dam. Illinois made changes to standardize border water regulations with neighboring Iowa and Missouri. Iowa changed open season dates and adopted an 84 cm maximum length limit on the upper Mississippi River in addition to opening a new snagging season on the Missouri River with an 89–114 cm protected slot (also requiring the purchase of a Paddlefish permit).

Table 6. Summary of sport fishing regulation changes 2008–2017 for Paddlefish range states with notation on whether the changes were more restrictive, less restrictive, neutral (more restrictive in some areas but less restrictive in others), or equivalent (no changes were made).

State	Regulation Changes	Restriction
Alabama	No changes	Equivalent
Arkansas	A snagging season was opened on the Black and Saint Francis Rivers from January 1–February 15 with a bag limit of 1 per day. A snagging season was opened on the White River below Beaver Tail Dam from April 15–June 15 and snagging must cease after 2 trout are snagged.	Neutral
Illinois	The snagging season on the Mississippi River bordering Illinois and Iowa was reduced to March 1–April 15 with a maximum size limit of 84 cm. A 61 cm minimum length limit with sorting was implemented on the Mississippi River bordering Illinois and Missouri.	More restrictive
Indiana	No changes	Equivalent
Iowa	Season changed on Upper Mississippi River to March 1–April 14 with a 84 cm maximum length limit. Opened a snagging season on the Missouri River from February 4–April 30 with a 89–114 cm protected slot with 1,000 Paddlefish permits available, $22 for residents and $42 for non-residents.	
Kansas	No changes	Equivalent
Kentucky	No changes	Equivalent
Louisiana	No changes	Equivalent
Minnesota	No changes	Equivalent
Mississippi	No changes	Equivalent
Missouri	No changes	Equivalent
Montana	No changes	Equivalent
Nebraska	Moved the Paddlefish archery season below Gavins Point Dam to June 1–June 30. Allow processing of Paddlefish fillets for transportation.	Less restrictive
New York	No changes	Equivalent
North Carolina	No changes	Equivalent
North Dakota	No changes	Equivalent
Ohio	No changes	Equivalent
Oklahoma	Bag limit was reduced from 1 per day and 4 in possession to 1 per day and 2 per year. Monday and Friday are designated catch and release only days. Harvest reporting is mandatory within 24 hours and harvest information filled out immediately. Possession limit for Paddlefish roe was reduced from 22.7 to 1.4 kg. Only one rod and reel is permitted while snagging and snagging is prohibited 10pm–6am.	More restrictive
Pennsylvania	No changes	Equivalent

Table 6. Continued.

State	Regulation Changes	Restriction
South Dakota	Opened a spring snagging season on Lake Francis Case with 350 resident permits, $25.00. Moved the Paddlefish archery season below Gavins Point dam to June 1–June 30.	Less restrictive
Tennessee	Added a snagging season on Watts Bar Reservoir from April 24–May 31 with a bag limit of 1 per day. Removed the 76 cm minimum length limit on Cherokee Reservoir and moved the season to April 1–April 15.	Less restrictive
Texas	No changes	Equivalent
Virginia	No changes	Equivalent
West Virginia	No changes	Equivalent
Wisconsin	No changes	Equivalent

Nebraska rescheduled their Paddlefish archery season below Gavins Point Dam from starting the second Saturday in July for 30 d to June 1–30 and allows anglers to process their Paddlefish before transport. South Dakota also rescheduled their archery season to June 1–30 and has opened a new snagging season on Lake Francis Case, a Missouri River mainstem reservoir. Oklahoma changed bag and possession limits from one per day and four in possession to one per day and two per year, implemented mandatory online reporting of harvested fish, and decreased the amount of Paddlefish roe an angler can possess from 22.7 to 1.4 kg. Tennessee added a new snagging season at Watts Bar Reservoir and removed the 76 cm minimum length limit on Cherokee Reservoir.

The status of Paddlefish has changed in five states since 1986 (Figure 1). Louisiana removed Paddlefish from the commercial species list and now allows only sport harvest of incidentally caught fish. Paddlefish were commercially harvested in northeast Oklahoma until 1992, after which no commercial permits have been issued. Legal status of Paddlefish in Oklahoma, however, has not changed. Recreational fishing for Paddlefish is no longer allowed in Alabama; it is now classified as strictly a commercial fish. In Virginia, Paddlefish were listed as both a recreational and commercial species in 1986 but are now listed as a threatened species with full protection. West Virginia, which listed Paddlefish as a sport fish in 1986, does not currently allow any harvest. Indiana, which allowed only recreational fishing in 1986, has reclassified Paddlefish as a commercial species and no longer allows recreational fishing. Since 1986, North Dakota changed the classification of Paddlefish from commercial to sport. No states that listed Paddlefish as protected in 1986 have downgraded their classification or altered their status to allow recreational fishing.

Discussion

Responses of agency biologists and administrators in 2017 are consistent with our interpretation that the Paddlefish remains a species with a complex identity. Results from our survey support Combs' (1986) original observation that management strategies for Paddlefish are influenced primarily by the perceptions of Paddlefish in each state and region and how they are legally and administratively classified. His observation remains relevant today and is most clearly evidenced in the states that have enacted status changes

for Paddlefish. For example, Alabama and Indiana, which group with states where Paddlefish are perceived less as a sport species than a commercial species, have both eliminated sport fishing for Paddlefish and now allow only commercial fishing. Virginia and West Virginia, which at one time allowed recreational fishing but where Paddlefish are not strongly viewed as a sport fish, have both given Paddlefish protected status. Louisiana is unique in that although it groups with states that principally view Paddlefish as a commercial fish; they have removed Paddlefish from the commercial list and made it a sport fish but allow only incidental recreational harvest. These changes reflect the existing diversity of agency perceptions of an unconventional fish with an unconventional life history that is not harvested by conventional angling methods.

As of 2018, Paddlefish remain a state-managed fish without a single, unified framework plan or philosophy. There exist complex and differing identification and socio-economic characterizations of the species, and a disparate social status afforded the species by anglers, commercial harvesters, and the public. Its complex identity is reflected in a wide range of management strategies, goals, and objectives applied to it among states across the species range and even within individual rivers (Hansen and Paukert 2009; Scholten 2009). The regional recreational management strategies identified in the survey across their range may be as diverse (from no length limits and two fish per day to protected slot limits and one fish per year; Figure 3) as those of any fish species in the United States.

However, results of our assessment of management strategies and regulations indicate some changing management emphases for this species. Historically, Paddlefish management was defined by seasons and/or daily bag and possession limits, some of which would be considered liberal today, or, at the other extreme, complete protection (Combs 1986). As a result of numerous studies that have evaluated Paddlefish stocks and management actions, additional regulatory strategies have evolved in recent years, including permits, lotteries, harvest tags, time and area restrictions, no high grading, catch-and-release, catch-and-release-only days, mandatory reporting of harvest, minimum and maximum size limits, protected slot limits, limits on the number and size of hooks, mandatory use of barbless hooks, restrictions of gaffs, harvest quotas, season closures, fishery closures, and on-the-water pickup and processing of Paddlefish by roe donation programs. Other management tools include stocking programs, some of them long-term (Missouri: Russell et al. 1975; Schwinghamer et al. 2019, Chapter 10 this volume) and some more recent (Argent and Kimmel 2006), which are being used to reestablish a stock (https://www.fws.gov/refuge/caddo_lake/wildlife/paddlefish.html) or support put-and-take fisheries (Hupfeld et al. 2018).

The challenges of managing recreational Paddlefish snagging fisheries can be complicated by the increasing demand for the species' valuable roe (Harris and Shiraishi 2018). Female Paddlefish are targeted by both legal and illegal commercial fishers for their roe (Williamson 2003), which has potential impacts on recruitment and population viability. Some states permit both recreational and commercial Paddlefish harvest, resulting in user groups competing for the same resource.

Inadequate stock assessment data has also been a major problem. Past reviews (Combs 1986; Elser 1986; Hansen and Paukert 2009) of management have all noted that most states lacked the information needed to evaluate management effectiveness. Historically, few states have had steady, consistent monitoring programs. Three states (Montana, North Dakota, and Oklahoma) have dealt with these two issues, the high value of roe and the high expense of monitor-

ing the fisheries, by offering free, voluntary cleaning of the Paddlefish harvested (both sexes) in controlled recreational fisheries for donation of any roe from the harvested fish. Caviar produced from the programs is sold with a portion of the net proceeds (Montana and North Dakota) or all net proceeds (Oklahoma) returned to the public through state management agencies for public conservation efforts (Scarnecchia et al. 2008; 2013). This approach has led to the development of centralized fish cleaning stations, resulting in more complete, less expensive data collection for stock monitoring and a stable funding source for managing the fisheries. However, this stock assessment strategy is not necessarily appropriate or applicable for all states or all Paddlefish stocks.

The challenges of managing recreational Paddlefish snagging fisheries are further complicated by the species' highly variable life history (Scarnecchia et al. 2019a, Chapter 1 this volume). Life history characteristics vary by stock across a latitudinal gradient (Scarnecchia et al. 2011). Average lifespan, age at maturity, and maximum size are typically reduced among Southern stocks while irregular patterns of recruitment are observed throughout the range (Scarnecchia et al. 2019a, Chapter 1 this volume). Even with trophy fisheries, successful management must proceed so that older aged spawning fish remain present (Scarnecchia et al. 2019b, Chapter 5 this volume). Historically, little was known about Paddlefish spawning locations and movement (Russell 1986) and population demographics. However, since the second AFS Paddlefish Symposium in 2006 (Paukert and Scholten 2009), there have been significant studies conducted to address these needs, including Paddlefish stock assessments (e.g., Sharov et al. 2013; Scarnecchia et al. 2014), investigations into movement (Budnik 2010; Tripp et al. 2019, Chapter 3 this volume; Hoover et al. 2019, Chapter 4 this volume), investigations into recruitment (Scarnecchia et al. 2009; Scarnecchia et al. 2019b, Chapter 5 this volume), and surveys exploring angler success and angler demographics (Hayden 2009; Jager and Schooley 2016). Recreational fisheries managers now have more information to apply to their management programs; as with many fisheries, more effective implementation of that knowledge remains an urgent need.

The migratory life history and interjurisdictional nature of Paddlefish often make managing this species complex and difficult. Hansen and Paukert (2009) noted that while isolated populations could be managed separately, populations that are interjurisdictional may require joint regulations. Regional management plans will present challenges not only due to the complexity of landscape and riverscape-level coordination for this migratory fish, but because of the complex identity of the Paddlefish, which manifests as different perceptions and management strategies, goals, and objectives among biologists, administrators, anglers, and regulatory bodies. While there are currently no basin-wide management strategies in existence for Paddlefish, the fact that 77% of biologists report that Paddlefish are being managed on a biologically relevant scale (compared to 29% three decades ago; Combs 1986) suggests that management is improving. Despite numerous management challenges, state management agencies are refining inter-jurisdictional management programs through increased communication and collaboration. Much of this interjurisdictional communication and collaboration occurs within the Paddlefish and Sturgeon Subcommittee of the Mississippi Interstate Cooperative Resource Association (MICRA, www.micrarivers.org). Biologists, state management agencies, and MICRA should continue to promote biologically relevant management for interjurisdictional Paddlefish stocks across its range.

Acknowledgments

The authors thank each of the agency Paddlefish biologists and managers participating in this survey.

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Appendix A. Paddlefish management survey metric. Survey was digitally distributed and respondents provided multiple choice or free-form* answers which were later grouped into limited answer categories.

Question	Answer Options
1 - What is your name and contact information?	Email and phone number
2 - For which agency do you work?	*
3 - In what state do you manage Paddlefish?	*
4 - In what water bodies are Paddlefish found in your state?	*
5 - How are Paddlefish classified in your state? (e.g., sport fish, commercial fish, big game fish, protected, etc.)	*
6 - What is the conservation status of Paddlefish in your state? (e.g., species of concern, threatened, state endangered, etc.)	*
7 - Is there sport fishing for Paddlefish in your state?	Yes/No
8 - If yes, which sport fishing methods are permitted?	Snagging, archery, other*
9 - Are there size restrictions for Paddlefish sport fishing?	Yes/No
10 - If yes, what are the size restrictions for Paddlefish sport fishing?	*
11 - Are there restrictions on gear used for Paddlefish snagging? (e.g., hook size, number of hooks, use of a gaff hook, etc.)	Yes/No
12 - If yes, please describe the gear restrictions?	*
13 - What is the daily bag and possession limit for Paddlefish?	*
14 - Is catch and release, or high grading of Paddlefish permitted?	Yes/No
15 - Is there a season for Paddlefish sport fishing?	Yes/No
16 - If yes, what are the Paddlefish sport fishing season dates?	*
17 - Are there differing sport fishing regulations for different water bodies?	Yes/No
18 - If yes, please describe the different regulations?	*
19 - Is there a Master Angler or equivalent program for Paddlefish?	Yes/No

Appendix A. Continued.

Question	Answer Options
20 - If so, what are the qualifying length/weight requirements?	*
21 - What is the fine/liquidated or civil damages fee for an illegally harvested Paddlefish in your state?	*
22 - How popular would you consider Paddlefish sport fishing in your state?	No interest, Little interest, Moderate interest, High interest
23 - How do you think Paddlefish are perceived by these different groups (Anglers, Commercial Fishers, Public, State Fish and Game Agency Administrators, State Fisheries Biologists) in your state?	Unaware, Rough Fish, Commercial Fish, Just Another Fish, Game Fish, Big Game/Trophy Fish, Nuisance
24 - Has Paddlefish reproduction been documented in your state?	Yes/No
25 - Are Paddlefish considered self-sustaining in your state?	Yes/No
26 - Does your state stock Paddlefish?	Yes/No
27 - If yes, does your state have a Paddlefish conservation genetics stocking plan?	Yes/No
28 - If yes, does your state monitor the success or effects of the stocking program?	Yes/No
29 - Does your state currently have a Paddlefish management plan?	Yes/No
30 - What is/are the goal(s) of your state Paddlefish management plan? (e.g., maximize harvest, provide a trophy fishery, maintain a self-sustaining population, etc.)	*
31 - Does your state have a Paddlefish monitoring program?	Yes/No
32 - Because Paddlefish are capable of moving long distances and sometimes cross political boundaries, do you feel Paddlefish in your state are managed on a biologically relevant scale?	Yes/No
33 - Do you feel that current regulations/management strategies are adequately managing Paddlefish in your state?	Yes/No
34 - If you could recommend changes to existing regulations or management strategies to manage Paddlefish, what would they be?	*

Appendix A. Continued.

Question	Answer Options
35 - What information for managing Paddlefish in your state do you feel is missing?	*
36 - What do you feel are the greatest threats to Paddlefish populations in your state?	Overharvest, Illegal harvest, Habitat degradation, Habitat fragmentation, Invasive species, Lack of interjurisdictional management plans, Lack of consistent regulations, Other

Appendix B. Summary of Paddlefish range states depicting: legal status as a sport fish (S), commercial fish (C), sport and commercial fish (SC), or protected species (P); states which have stocked Paddlefish and if stocking is monitored; angler perception of Paddlefish as just another fish (J), trophy (T), rough (R), unknown (U), sport (S), or commercial (C); whether or not reproduction has been documented within the state; whether or not Paddlefish stocks are considered sustainable; and which states have had a Paddlefish regulation or status change since 1986 (noted by an asterisk *). A dash (-) indicates no answer or not applicable.

States	Legal status	Stocked, monitored	Perception (anglers)	Reproduction documented	Population sustainable	Reg. Change	Status Change
AL	C	N	R	Y	Y		*
AR	SC	N	U	Y	Y	*	
IA	S	N	S	Y	Y	*	
IL	SC	-	-	-	-	*	-
IN	C	N	J	-	Y		*
KS	S	Y,N	J	Y	Y		
KY	SC	N	C	-	Y		
LA	S	N	R	Y	Y	*	
MN	P	N	U	-	Y		
MO	SC	Y,Y	S	Y	Y		
MS	SC	Y,Y	J	Y	Y		
MT	S	Y,Y	S	Y	Y		
NC	P	N	-	N	N		
ND	S	Y,Y	T	Y	Y		
NE	S	N	T	Y	Y	*	
NY	P	Y,Y	-	N	N		
OH	P	N	J	Y	Y		
OK	S	Y,Y	T	Y	Y	*	
PA	P	N	T	N	N		
SD	S	Y,Y	T	Y	Y		
TN	SC	N	S	Y	Y	*	
TX	P	N	-	N	N		
VA	P	N	U	N	N		*
WI	P	N	-	Y	Y		
WV	P	Y,Y	J	N	N		*