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Management of Commercial Paddlefish Fisheries in the United States

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Abstract.—As commercial paddlefish *Polyodon spathula* fisheries shifted from primarily flesh to almost exclusively roe harvest, agencies had to change their management strategies. Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee were the only states within the Mississippi River basin that were open to commercial paddlefish harvest in 2006. These seven states were surveyed in 2006 to summarize commercial paddlefish fisheries management in North America. Although commercial fishing license sales declined in most states since the mid-1980s, the number of commercial fishers targeting paddlefish steadily increased since the late 1990s. Total license fees for a resident commercial fisher to set 10 gill nets for paddlefish ranged from US$70.35 to $1,200, and those fees ranged from $242.35 to $2,500 for nonresidents (in the five states that allowed nonresidents). Management strategies employed in these seven states varied greatly in 2006. Arkansas, Mississippi, and Tennessee managed their fisheries with statewide seasons, and Kentucky had seasons for two of three major fisheries. Arkansas, Missouri, Kentucky, and Tennessee had minimum eye-to-fork length limits on all or some of their fisheries. There were numerous gear restrictions in the seven states, including minimum mesh size restrictions, net length limits, and net attendance requirements. Most states had a mandatory harvest report, but the information collected on these reports differed among states. The vastly different management strategies that were employed in the commercial fisheries throughout the Mississippi River basin have resulted in new problems as roe values increase. Future management will likely focus on development of management plans for biologically relevant areas. These management plans should include measures to prevent recruitment overfishing and minimize bycatch mortality. Interjurisdictional management and continued information sharing are necessary to effectively manage paddlefish fisheries in the future.

Introduction

Paddlefish *Polyodon spathula* were historically harvested primarily for their flesh, but in the early 1900s, markets for paddlefish roe began to emerge as other sources for caviar (e.g., lake sturgeon *Acipenser fulvescens*) diminished (Carlson and Bonislowsky 1981). For most of the century, demand, and consequently commercial fishing pressure, fluctuated greatly (Jennings and Zigler 2000; Quinn 2009, this volume). During periods of high demand, many populations were overfished to the point of depletion (Stockard

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1907; Alexander 1914; Pasch and Alexander 1986). Although some populations were able to recover during periods of low demand, biologists became concerned that overfishing, coupled with habitat alterations, could result in extirpation of many populations (Jennings and Zigler 2000; Quinn 2009). These concerns prompted states throughout the Mississippi River basin to close commercial paddlefish harvest (Table 1). In the early 2000s, demand increased dramatically (Figure 1) as Eurasian sturgeon stocks (e.g., beluga *Huso huso*, *Acipenser* spp.) collapsed and Caspian Sea export quotas were limited and then banned (Colombo et al. 2007).

Three states (South Dakota, Texas, and Wisconsin) closed their commercial paddlefish fisheries in the 1970s, but in 1983, there were still commercial fisheries in 12 states within the Mississippi River basin (Gengerke 1986). Alabama, Iowa, Louisiana, North Dakota, and West Virginia closed their commercial fisheries shortly after the survey conducted in 1983 (Pasch and Alexander 1986), and Oklahoma was the last state to close in 1992 (Graham 1997). Graham (1997) reported that Indiana was closed to commercial paddlefish harvest when he conducted his survey; however, commercial fishing was actually allowed in the Indiana waters of the Ohio River at that time. These waters were opened to commercial fishing in 1985 (first license sold in 1987) when the U.S. Supreme Court granted Indiana partial ownership of the Ohio River (T. Stefanavage, Indiana Department of Natural Resources, personal communication). This left seven states open to commercial paddlefish harvest in 2006: Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee (Bettoli et al. 2009, this volume).

Table 1. States within the historic paddlefish range that were closed to commercial paddlefish harvest in 2006 and the year their last fishery was closed.

State	Year closed
Kansas	Never allowed
Montana	Never allowed
New York	Never allowed
North Carolina	Never allowed
Ohio	Never allowed
Pennsylvania	Never allowed
Virginia	Never allowed
Minnesota	1925
Nebraska	1955
Wisconsin	1975
Texas	1977
South Dakota	1978
North Dakota	1982
Iowa	1985
Louisiana	1986
Alabama	1989
West Virginia	1989
Oklahoma	1992

Since the early 1900s (when roe first became marketable), biologists throughout the basin have struggled with management of commercial paddlefish roe fisheries and inadequate regulations frequently resulted in severe overfishing (Stockard 1907; Alexander 1914; Coker 1930; Carroll et al. 1963; Alexander and McDonough 1983; Hoxmeier and DeVries 1996; Scholten and Bettoli 2005). When markets shifted from flesh to roe, commercial fishers began targeting larger, older fish and their effort was confined to a shorter time period (i.e., October through April, when female paddlefish normally have black eggs). Most flesh markets desired a smaller fish that could be easily processed and shipped, and they needed fish all year. In contrast, roe fishers target large, gravid females during staging and spawning periods (October to May in most areas). As fishing habitats changed, management strategies by the agencies needed to change. Paddlefish fisheries management became especially difficult when high roe prices lead to legal and political intervention on behalf of the commercial fishers that were opposed to regulations that may limit, even if only temporarily, their ability to harvest roe (Bettoli et al. 2007).

Roe fisheries are difficult to manage because commercial fishers target the same fish

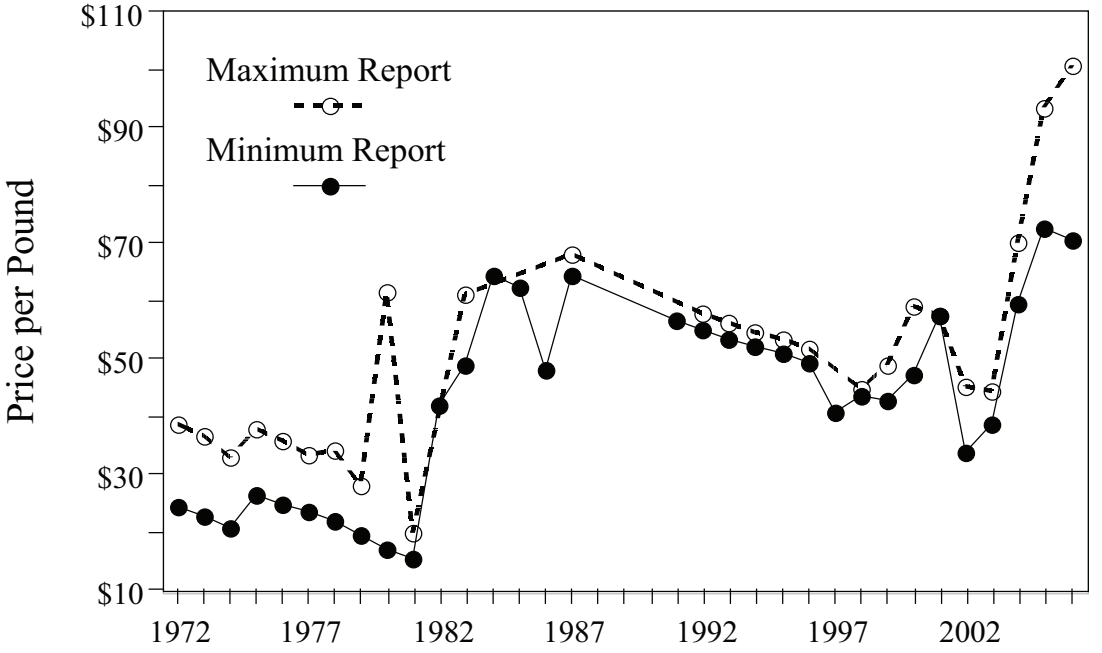

Figure 1. Prices (adjusted for inflation; reported in 2006 U.S. dollars) paid to Tennessee commercial fishers for unprocessed (unsalted) paddlefish roe from 1972 to 2006. Data compiled from various market survey reports, memos, phone transcripts, and other anecdotal reports on file with the Tennessee Wildlife Resources Agency. Maximum and minimum reports reflect the range of records that existed for many years.

(i.e., large, old, gravid females) that are crucial for successful spawning (Francis et al. 2007); however, paddlefish are particularly difficult to manage for a sustainability because of several behavioral and life history characteristics. Paddlefish exhibit several characteristics that make them exceptionally vulnerable to entanglement gears: (1) they are filter feeders that swim with their mouth open and head moving from left to right when they feed (Forbes and Richardson 1920), (2) they frequently migrate long distances (Zigler et al. 1999; Paukert and Fisher 2001a), and (3) they congregate during spawning (Pasch and Alexander 1986). Paddlefish also grow relatively quickly and often recruit into an entanglement fishery before they become sexually mature (e.g., paddlefish as young as age 2 are frequently caught in commercial gill nets; Scholten and Bettoli 2005). Therefore young fish are often exposed to netting mortality before they are able to contribute to the population (Bettoli and Scholten 2006). Relative to other species, paddlefish have a limited recruitment potential due to late maturation (Hoyt 1984; Reed et al. 1992; Timmons and Hughbanks 2000), specific spawning requirements (e.g., silt free-gravel [Purkett 1961; Russell 1986)], water temperatures of 10–18°C [Purkett 1961; Pasch et al. 1980; Wallus 1986], suitable photoperiod [Lein and DeVries 1998)], and sufficient flow [Wallus 1986; Paukert and Fisher 2001b]), and in some systems, they may not spawn annually (Meyer 1960; Hoyt 1984; Russell 1986). Additionally, management of many commercial paddlefish fisheries is further complicated by hampered recruitment resulting from impoundment and alteration of many river systems (Southall and Hubert 1984; Unkenholz 1986; Runstrom

et al. 2001; Gerken and Paukert 2009, this volume).

The objective of this chapter was to describe commercial paddlefish fisheries management strategies in North America during 2006. Summary statistics for commercial paddlefish harvest in each state or system were not reported in this chapter, but see Quinn (2009) for a summary and in depth analysis of this information.

Methods

The information reported in this chapter was collected via a questionnaire that was emailed during early 2006 to resource agencies in all states known to be within the historic range of paddlefish. This questionnaire was part of a survey designed to determine the current status, distribution, and management of paddlefish within the United States. A complete list of questions and more details on this survey can be found in Bettoli et al. (2009). Additional information was gathered from the states with commercial paddlefish fisheries through follow-up interviews with commercial fisheries managers from those states. Regulations and fees are continually adjusted for commercial fisheries; the fees and regulations reported in this chapter were effective in 2006. All monetary values reported in this chapter were adjusted for inflation and reported in 2006 (U.S.) dollars.

Commercial Fisheries Descriptions by State

Arkansas.—Commercial fishing for paddlefish was allowed in all waters that were open to commercial fishing except the White River above Newport (known paddlefish spawning area), the Red River, the Ouachita River below Felsenthal Lock and Dam, and several bayous located along the Arkansas–Louisiana border. Numerous tailwater areas were closed on the Arkansas River as well as the section from Ozark Dam to the Oklahoma State line (except during special seasons determined by the director of the Arkansas Game and Fish Commission). Six significant commercial paddlefish fisheries (5-year mean roe harvest > 90 kg per year) existed in waters open to commercial paddlefish harvest. On average, roe harvest from the Arkansas River represented 39% of the total harvest each year followed by the White (22%), Mississippi (22%), Ouachita (7%), Farm (6%), and Black (3%) rivers (B. Posey, Arkansas Game and Fish Commission, personal communication).

Illinois.—Paddlefish harvest was allowed in the Ohio, Illinois (below Route 89), and Mississippi (below Lock and Dam 19) rivers, including adjacent backwaters, but not above the mouth of any stream, ditch, or tributary connected to these waters. Paddlefish harvest from these systems was highly dependent on water levels. During most seasons, harvest from the Mississippi River accounted for most (i.e., 75–90%) of Illinois' paddlefish harvest. Harvest from the Illinois River was normally negligible (i.e., 2–4%); however, during springs with high water, harvest from the Illinois River became more significant (i.e., ~20%). Very little (i.e., ≤2–4% of statewide total) paddlefish harvest was reported to the state of Illinois from the Ohio River. Most Illinois commercial fishers who fish the Ohio River do so under a nonresident Kentucky license because this license allows them to fish both and the Illinois and Indiana sections of the Ohio River. These fishers must report their harvest to the state of Kentucky since that is where they are licensed (R. Maher, Illinois Department of Natural Resources, personal communication).

Indiana.—Commercial paddlefish harvest was limited to the Ohio River in Indiana. Paddlefish were normally harvested from each of the five pools created by the John T. Myers, Newburg, Cannelton, McAlpine, and Markland dams along the Indiana–Kentucky border. Indiana com-

mercial fishers also harvested paddlefish from the upper section of the pool created by Smithland Dam on the Illinois–Kentucky border (below John T. Myers Dam). Harvest in each pool varied annually and was generally dependent on water conditions (T. Stefanavage, Indiana Department of Natural Resources, personal communication).

Kentucky.—Commercial paddlefish harvest with entanglement gear (gill nets and trammel nets) was allowed from the Ohio and Mississippi rivers and Kentucky (lower Tennessee River) and Barkley (lower Cumberland River) reservoirs. Additionally, most rivers and Lake Cumberland (upper Cumberland River) were open to paddlefish harvest with snag lines and hoop nets. The Ohio River was the largest commercial paddlefish fishery, contributing 85% of Kentucky's total harvest during a typical year. Significant paddlefish harvest also occurred in Barkley Reservoir (7%), Kentucky Reservoir (5%), the Mississippi River (2%), and Lake Cumberland (<2%). Other paddlefish fisheries comprised less than 1% of the annual paddlefish harvest (D. Henley, Kentucky Department of Fish and Wildlife, personal communication).

Mississippi.—Except for a few waters that were closed to all commercial fishing, commercial paddlefish harvest was allowed from most of Mississippi's rivers and associated backwater lakes. Major commercial paddlefish fisheries were found in rivers and oxbow lakes in the Delta region (i.e., area between the Mississippi and Yazoo rivers in northwest Mississippi) and in the Mississippi River. Harvest from these fisheries was thought to be minimal for local flesh markets. An influx of nonresident fishers in 2005 and 2006 suggested that harvest was increasing. Managers believe that these nonresidents were targeting paddlefish for their roe in September and October when seasons were closed in nearby Arkansas and Tennessee (D. Riecke, Mississippi Department of Wildlife, Fisheries, and Parks, personal communication).

Missouri.—Since the Missouri and St. Frances rivers were closed in 1989, the Mississippi River was the only system open to commercial paddlefish harvest in Missouri (D. Herzog, Missouri Department of Conservation, personal communication). Most paddlefish harvest (~86% each year) originated from the unpooled section (below Lock and Dam 26) of this river. Pools 24 and 26 were the only other fisheries with regular paddlefish harvest (3% and 11% of reported harvest each year, respectively; V. Travnichek, Missouri Department of Conservation, personal communication).

Tennessee.—Approximately 67% of the state's 243,380 surface hectares of major reservoirs and rivers were open to commercial paddlefish harvest. Only 6 of 15 open fisheries had significant paddlefish harvest (5-year mean harvest > 50 fish per year), but these six fisheries represented 80% of the total surface area that was open to commercial paddlefish harvest. On average Kentucky Lake's (lower Tennessee River) paddlefish harvest represented 69% of the total harvest each year followed by the Mississippi River (22%), Chickamauga Reservoir (upper Tennessee River; 5%), Barkley Reservoir (lower Cumberland River; 2%), Old Hickory Reservoir (middle Cumberland River; 1%), and Watts Bar Reservoir (upper Tennessee River; 1%).

Participation

In most states, participation in commercial paddlefish fisheries started to increase rapidly during the late 1990s, and this trend continued through 2006 (Table 2). For example, in 1999, the Tennessee Wildlife Resources Agency (TWRA) began requiring commercial fishers to obtain a free supplemental permit to harvest paddlefish so managers could more closely monitor these fisheries (the permit was accompanied by

Table 2. Number of commercial fishers who targeted paddlefish in each state during 2002–2006 (note: these data were not available from Missouri).

State	2002	2003	2004	2005	2006
Arkansas	33	34	26	42	68
Illinois	19	34	14	34	31
Indiana	–	6	6	7	8
Kentucky	102	104	92	107	97
Mississippi[a]	–	2	12	14	23
Tennessee	86	78	62	62	80

[a] Estimated from number of nonresident commercial fishing licenses that were sold to Tennesee and Arkansas residents during paddlefish season.

a monthly paddlefish harvest reporting requirement). That year, 34 permits were issued, and each succeeding year, the number of permits increased. In 2005, a $1,000 fee was instituted for the permit to increase revenue for this program, and during the first month that they went on sale (March 2006), TWRA sold more permits (68) than they had given away during most preceding seasons. In September 2006, Tennessee limited the number of resident supplemental permits that would be issued each year to 80 in an effort to slow further increases in participation, and by December 2006, all available permits were sold.

Arkansas saw a similar increase in participation despite efforts to limit the number of fishers targeting paddlefish. Prior to 2001, any of the 2,500 commercial fishing license holders could legally harvest paddlefish (although most did not). In 2001, the Arkansas Game and Fish Commission required commercial fishers to obtain a supplemental permit to harvest paddlefish. Although the relatively high permit fee (Table 3) reduced the number of commercial fishers who could harvest paddlefish, the number of permit holders steadily increased from 33 in 2002 to 68 in 2006 (Table 2).

In 2006, Kentucky established a limit on special permits that were required to commercially fish Kentucky and Barkley reservoirs. Any fisher that purchased a special permit during 2003–2005 could purchase a permit in 2006, but these 27 commercial fishers were required to renew their permit annually in order to retain their privilege to purchase a permit. The objective of this requirement was to limit the number of permits to 25 through attrition.

License Fees

Resident commercial fishing licenses ranged from $25 to $200 in the seven states that allowed commercial paddlefish harvest (Table 3). Arkansas did not allow nonresidents to commercially harvest fish, nor did Indiana, except that Kentucky residents were allowed to purchase an Indiana resident license. Nonresident license fees ranged from $150 to $1,000 in the other five states that sold these licenses. Arkansas (resident: $500) and Tennessee (resident: $1,000; nonresident: $1,500) also required a supplemental permit to harvest paddlefish. Tennessee was the only state that did not charge a fee for gear tags (i.e., an identification tag that is required to be attached to all commercial fishing equipment to identify the owner of the gear) because gear tags were not provided by their agency (i.e., commercial fishers were required to tag their gear but were not required to purchase these tags from the state). Resident gear tag fees ranged from $15 per 10 tags ($1.50 per tag) to $30 per tag and nonresident gear tag fees ranged from $100 per 10 tags ($10 per tag) to $36.50 per tag. Indiana

Table 3. License, supplemental permit (extra permit required to harvest paddlefish), and gear tag (fisher identification tag required by some states to be attached to all commercial gear) fees (in 2006 U.S. dollars) for resident and nonresident fishers in the seven states that allowed commercial paddlefish harvest in 2006.

	Resident				Nonresident			
State	License	Permit	Gear tag	Total[a]	License	Permit	Gear tag	Total[a]
Arkansas	$25	$500	$15	$675	Nonresidents not allowed			
Illinois	$35	None	$18.50	$220	$150	None	$36.50	$515
Indiana	$125	None	$15 per 10[b]	$125	Nonresidents not allowed			
Kentucky	$150	None	$15 per 10[b]	$150	$600	None	$100 per 10[b]	$600
Mississippi	$31.85	None per 10	$38.50	$70.35	$203.85	None per 10	$38.50	$242.35
Missouri	$25	None	$30	$325	$200	None	$30	$500
Tennessee	$200	$1,000	None	$1,200	$1,000	$1,500	None	$2,500

[a] Total license fees for a fisher to target paddlefish with 10 nets.
[b] 10 gear tags included with commercial fishing license.

and Kentucky provided commercial fishers with 10 gear tags at no additional charge when they purchased a commercial fishing license. Total license fees for a resident commercial fisher to set 10 nets for paddlefish ranged from $70.35 to $1,200 (Table 3). The same license fees for nonresidents fishing in the five states that allowed nonresidents ranged from $242.35 to $2,500.

Fishing and Harvest Restrictions

Seasons.—Arkansas, Mississippi, and Tennessee managed their fisheries with statewide seasons, and Kentucky had seasons on some of their fisheries (Table 4). Arkansas' season opened November 15 and closed April 15. Kentucky's statewide season was open year-round, but Kentucky and Barkley reservoirs had open seasons from November 1 through March 31 and the last day of February, respectively. Mississippi's season opened May 1 and closed October 15; however, after the 2006 season, paddlefish harvest was prohibited (i.e., season was suspended) while managers explored alternative management strategies. Tennessee's open season ran from November 15 to April 7, except on the Mississippi River where the season remained open 8 d longer (closed April 15 instead of April 7).

Gear restrictions.—Numerous commercial gear restrictions existed in the seven states that allowed commercial paddlefish harvest. Most of these restrictions applied to all commercial fisheries and few were designed specifically for paddlefish fisheries. All seven states required commercial fishers to tag each piece of gear with a gear tag. Tennessee was the only state that did not require commercial fishers to purchase these tags from the agency (Table 3).

None of the states had statewide limitations on the amount of gear that a commercial fisher could deploy; however, several states limited gear in specific fisheries or during special seasons. In 2006, Arkansas limited commercial fishers who participated in their special seasons on the Arkansas River to 457–914 m of entanglement gear. This limit was set for each special season and was based on the number of fishers who participated. On Kentucky and Barkley reservoirs, Kentucky limited commer-

Table 4. Season, minimum eye to fork length (EFL) limit and minimum gill-net mesh size (bar measure) restrictions in the seven states that allowed commercial paddlefish harvest in 2006.

State	Season	Minimum EFL limit	Minimum gill-net mesh size limit
Arkansas	November 15–April 15	864 mm[a]	89 mm—statewide 152 mm—Arkansas River
Illinois	Open year-round	None	102 mm
Indiana	Open year-round	None	102 mm
Kentucky	Open year-round[a]	None[a]	76 mm—Mississippi River 102 mm—Ohio River[a]
Mississippi	May 1–October 31	None	102 mm[a]
Missouri	Open year-round	610 mm	51 mm
Tennessee	November 15–April 7[a]	914 mm[a]	152 mm—statewide 127 mm—Mississippi River

[a] Some exceptions exist.

cial fishers to 304.8 m of entanglement gear with bar mesh sizes between 114 and 152 mm (there was no limit on the amount of entanglement gear with bar mesh sizes between 89 and 114 mm).

Several states had limitations on the length of commercial fishing nets. Illinois restricted fishers to entanglement gear that was longer than 30.5 m, and nets could not extend more than half way across any water body. Mississippi had a similar regulation in that entanglement gear could not extend more than half way across any water body, but they also restricted fishers to nets shorter than 914 m. Tennessee fishers could not extend entanglement gear more than three-fourths of the way across any water body, but there was no minimum or maximum net length restriction. In Arkansas, nets could not extend more than halfway across any stream, and commercial fishers were required to attach a gear tag every 91.4 m. Similarly, Illinois, Indiana, and Kentucky required a gear tag on every 30.5 m of net. All seven states prohibited commercial fishing gear in the area immediately downstream of lock and dam structures.

All seven states had minimum mesh size restrictions on commercial entanglement gear (Table 4). Most minimum mesh size restrictions ranged from 51 to 102 mm bar measure and were implemented to reduce sport fish bycatch. Tennessee and Arkansas had the only minimum mesh size restrictions that were adopted specifically for paddlefish fisheries. Both states enacted 152 mm bar measure minimum mesh size restriction to reduce sublegal paddlefish bycatch (i.e., paddlefish that were considered as bycatch because they were shorter than the minimum size limit and therefore illegal to harvest) in 2002 and 2006, respectively. These restrictions were based on the assumption that prohibiting smaller mesh sizes would reduce the catch of small paddlefish, an assumption supported by preceding research of mesh selectivity (Paukert and Fisher 1999). Subsequent research has suggested that mesh selectivity is not evident in all fisheries and is likely a function of multiple factors, including net construction and hydrologic conditions in the area where nets are deployed. For example, Scholten and Bettoli (2007) suggested that Tennessee's mesh size restriction was probably not having the desired effect in Kentucky Lake as they observed no mesh selectivity in each of six mesh sizes used in their study. Their study used hobbled gill nets that typically have more loose netting than a standard gill net, which they suggested could have contributed to the lack

of mesh selectivity observed. The Arkansas Game and Fish Commission has noted evidence of mesh selectivity in some Arkansas studies but not others, which they contribute partially to differences in hydrologic conditions (J. Quinn, Arkansas Game and Fish Commission, personal communication). When mesh selectivity is detected, it is usually not strong enough to be used as a management strategy to reduce the harvest of a large number of sublegal paddlefish; however, mesh selectivity is a complex issue in paddlefish fisheries that warrants further investigation.

Most states had an entanglement gear attendance requirement (i.e., how often commercial fishers were required to check their gear) to minimize losses to bycatch mortality. Missouri required fishers to constantly attend (fisher must be within sight) their entanglement gear while it was in the water. Illinois had a similar regulation from October 1 through April 30, except that entanglement gear could be left unattended overnight or for 96 h if set under the ice during this period. From May 1 through September 30, Illinois required commercial fishers to check their gear every 24 h. Indiana, Kentucky, and Tennessee required commercial fishers to check their entanglement gear every 24 h. Mississippi; and Arkansas did not have an attendance requirement in 2006.

Minimum length limits.—Three of the seven states had a statewide minimum eye-to-fork length (EFL) limit in place during 2006 (Table 4). The statewide minimum EFL limit in Arkansas was 864 mm; however, there were 914 and 813 mm minimum EFL limits on the Arkansas and White rivers, respectively. Although Kentucky did not have a statewide minimum EFL limit, they did have a 916 mm minimum EFL limit on Kentucky and Barkley reservoirs. Missouri's statewide minimum EFL limit was 610 mm and Tennessee's was 916 mm. Tennessee's one exception to the statewide minimum EFL limit was the Mississippi River, which was managed with an 864 mm EFL limit. Additionally, Tennessee's (statewide, except Mississippi River) and Kentucky's (Kentucky and Barkley reservoir only) minimum EFL limits were scheduled to increase to 940 mm in November 2007 and to 965 mm in November 2008.

Checking for roe prior to harvest.—Many fishers target paddlefish solely for their roe; therefore, nongravid females and males are considered bycatch. These fishers desire a technique to determine if a paddlefish is gravid prior to harvest. Although some rely on external sex characteristics (e.g., tubercles on males; Rosen et al. 1982), most have learned that this method is not always accurate (O'Keefe and Jackson 2009, this volume). Often, fishers will make a small incision in the abdomen to check for presence of roe, but this is discouraged by most fisheries management agencies due to suspected high mortality of this technique. In fact, the cutting or mutilation of paddlefish is specifically prohibited in Arkansas, Indiana, Mississippi, and Tennessee.

It is common practice in most states for commercial fishers to check paddlefish for roe using a syringe equipped with a large (10- or 12-gauge) needle. Commercial fishers insert the needle into the abdomen and "pump" the syringe a few times. If the paddlefish is a gravid female, a few eggs will be sucked into the syringe. In Arkansas, Mississippi, and Tennessee, the only legal way to check for roe prior to harvest is with a 12-gauge needle. Indiana has a similar regulation except that they allow a slightly larger, 10-gauge needle. Although cutting paddlefish was not prohibited in Kentucky, their regulations stated that commercial fishers may use a 10-gauge needle to check for roe. Illinois did not have any regulations that prohibit cutting paddlefish to check for roe, but fisheries managers in that state encouraged

commercial fishers to use either a 10- or 12-gauge needle instead of a knife. Checking for roe by cutting or with a needle was not allowed in Missouri.

Commercial fishers favor regulations that allow the use of a needle to check for roe because they see this as a conservation measure (i.e., they can release nongravid females and males) that they can employ without hindering their ability to harvest gravid females. Although it appears to be a successful technique (e.g., after allowing this technique, Tennessee harvest of nongravid paddlefish decreased from 40% to 15% of the total harvest; Tennessee Wildlife Resources Agency, unpublished data), the survival of fish that are released after being checked is unknown.

On-board processing regulations.—Restrictions on paddlefish processing (e.g., evisceration of entrails, removal of head and tail, roe evisceration) while aboard a fishing vessel are important for sanitary reasons, but they can also be crucial for enforcement of other paddlefish regulations. For example, minimum EFL limits are difficult to enforce if restrictions are not in place to prevent blocking (i.e., removing the head, tail, and fins). Arkansas, Indiana, and Tennessee were the only states that allowed blocking in 2006. Tennessee and Arkansas required that the tail remain on the fish to aid in determining the fish's length after the head was removed. Although TWRA did not support on-board blocking, they developed a minimum block length (i.e., length measured along side of the fish from the fork of the tail to the edge of the skin behind the gill arch) limit as a compromise with their commercial fishers. For every minimum EFL limit, TWRA created a corresponding minimum block length based on a relationship between EFL and block length. This approach was not favored by TWRA because there was high variance in block lengths and industry sources suggested that it was easier to alter a paddlefish's length (i.e., stretch) after the head was removed. Although blocking was allowed, few fish were blocked in Arkansas because they require the blocked carcass to meet the minimum EFL length limit (i.e., when the minimum EFL limit was 914 mm, the block length would have to measure 914 mm). In Indiana, few fish were blocked because most of their paddlefish harvest was processed in facilities that required paddlefish to remain whole and uncut when they arrived at the processing facility.

Roe evisceration (i.e., removal of roe from body cavity) on the water is another on-board processing technique that can make it difficult to enforce minimum EFL limits. If on-board roe evisceration is allowed, it is easier for unscrupulous commercial fishers to take roe from sublegal females. Roe evisceration was allowed on the water in Arkansas, Illinois, Indiana, Missouri, and Tennessee but specifically prohibited in Kentucky. Although they allowed on-board roe evisceration, Arkansas, Illinois, and Missouri required ovaries to remain intact on the water. Commercial fishers were allowed to remove ovaries and place them on ice, but further processing was restricted to facilities away from the water's edge. This allowed officers to check that there were enough legal-sized harvested fish in the boat to account for the number of ovaries in the cooler. Conversely, Tennessee did not require ovaries to remain whole, so many fishers "screened" (i.e., separated eggs from ovary sac by rubbing the ovary over wire mesh) and rinsed their eggs once while on the water. This last step made it even more difficult for officers to prevent the harvest of sublegal fish. There was no way to determine the number of ovaries or if roe from sublegal fish was mixed with roe from legal fish.

Harvest reporting.—Most states require commercial fishers to report their

harvest on a form provided by the state agency that manages commercial fisheries. In 2006, Mississippi was the only state that did not require harvest reports from commercial paddlefish fishers. Some states have found that compliance with commercial harvest reports has improved since the U.S. Fish and Wildlife Service began inspecting harvest reports from fishers who were requesting permission to export their paddlefish products out of the country. Missing or incomplete harvest reports often result in denial or delayed issuance of an export permit. Most of the six states with a harvest report required daily completion and monthly submission of reports by the harvester (Table 5). Harvest gear, harvest location, and roe weight were the only statistics that were required on all harvest reports. Quinn (2009) noted major disparities (e.g., differences in reporting periods, information collected, unstandardized weights reported for flesh and roe) in the harvest reporting requirements in each state. Lack of standardization makes harvest comparisons difficult and this complicates management of interjurisdictional fisheries. For these reasons, at the time of this publication, most states were working through the Mississippi Interstate Cooperative Resource Association (MICRA) to standardize their harvest reporting requirements.

Future Management Considerations

One of the primary focuses of MICRA has been addressing issues related to vastly different management strategies that were employed in the commercial fisheries throughout the Mississippi River basin. For years, managers were concerned with these differences because it was well documented that paddlefish were highly mobile and frequently moved among states (Carlson and Bonislowsky 1981; Combs 1986; Jennings and Zigler 2000). As demand for roe increased, new problems began to arise. At one time, few commercial fishers left their home state to commercially fish other waters. When demand increased and prices were sufficient to support interstate travel, fisheries managers in states that did not have closed seasons began noting an increasing number of nonresidents who were participating in their fisheries (Graham 1997). Most of these nonresidents were from states that had a closed season and fishers shifted their effort to other waters when paddlefish harvest was closed in their home state. High nonresident license

Table 5. Information requested on harvest reports for each of the seven states that allowed commercial paddlefish harvest in 2006. "Reporting period" refers to the time period for which harvest/purchases must be tallied by the reporter; "Fisher" refers to the commercial fisher who harvests the paddlefish; and "buyer" refers to the wholesale fish dealer who purchases the paddlefish products from the commercial fisher.

State	Flesh weight	Roe weight	Number of fish	Number of egg fish	Reporting period	Individual who reports
Arkansas	No	Yes	Yes	Yes	Daily	Buyer
Illinois	Yes	Yes	No	No	Monthly	Fisher
Indiana	Yes	Yes	Yes	No	Daily	Fisher
Kentucky	Yes	Yes	No	No	Daily	Fisher
Mississippi	No reporting required					
Missouri	Yes	Yes	No	No	Daily	Fisher
Tennessee	Yes	Yes	Yes	Yes	Daily	Fisher and buyer

fees and the cost of traveling were no longer a deterrent because these expenses could quickly be recouped through higher egg prices. This activity greatly increased fishing pressure in many states, and it became more apparent that states needed to work together to ensure sustainability of paddlefish stocks in the Mississippi River basin.

In 2006, several states were working with their neighboring states to standardize regulations for large reaches of rivers that they shared. Indiana and Kentucky began standardizing their commercial fishing regulations in 1987. Kentucky and Tennessee standardized many of their commercial paddlefish regulations for Kentucky Lake in 2005. In early 2007, Arkansas, Mississippi, and Tennessee began discussing the standardization of commercial paddlefish regulations for their sections of the lower Mississippi River.

Complete standardization of regulations in every state that allows commercial fishing for paddlefish is not likely due to differing population characteristics in some populations. Commercial fisheries in "tributary" systems (e.g., Arkansas, Cumberland, Tennessee) and the upper Mississippi River will likely require specific management plans; however, management plans for biologically relevant reaches should be pursued. For example, the Mississippi (below Lock and Dam 26, Alton, Illinois) and lower Ohio rivers should probably be managed as one population based information gathered through several MICRA projects. Tagging studies documented significant immigration and emigration between these systems (Conover and Grady 2000; Ohio River Fisheries Management Team, unpublished data) and sampling indicates that paddlefish in these systems exhibit similar population characteristics (Ohio River Fisheries Management Team and Tennessee Wildlife Resources Agency, unpublished data). Patterns in genetic structure also suggest significant mixing between connected systems, such as the Mississippi and Ohio rivers (Heist and Mustapha 2008). Although a basin-wide management plan is probably impracticable, future efforts should focus on developing management plans for specific reaches that likely contain an intermixing paddlefish population.

Future commercial paddlefish management plans will likely resemble those created for marine commercial fisheries. In general, most management plans for marine commercial fisheries address two major issues that were common in commercial paddlefish fisheries in 2006: (1) preventing recruitment overfishing, and (2) minimizing losses to bycatch mortality. Much research has been conducted in the marine commercial fisheries, and fisheries managers were beginning to turn to this research in 2006 to guide their management of commercial paddlefish fisheries.

Several states were already using spawning potential ratios (SPR; Goodyear 1993), a statistic common in marine fisheries management, to determine if their paddlefish size limits were sufficient to prevent recruitment overfishing (Slipke et al. 2002). The SPR compares the spawning ability of a fished population to the population's spawning ability if it had never been fished. This approach is based on the principle that sufficient numbers of fish must survive to spawn in order to replenish the population. As exploitation increases, the SPR for a population decreases from a maximum value of 100% (i.e., no fishing related mortality) to 0% (Slipke et al. 2002). Goodyear (1993) suggested that SPRs should be maintained above 20–30% to prevent recruitment overfishing in most fish populations. Minimum SPRs necessary to prevent overfishing for nest-building species (e.g., flathead catfish *Pylodictis olivaris*, largemouth bass *Micropterus salmoides*) are likely lower (<20%) because these species offer more protection for their eggs and fry (i.e., egg and fry survival is higher; Slipke

et al. 2002). In contrast, paddlefish broadcast their eggs over gravel and leave them unattended (i.e., egg and fry survival is low). This spawning characteristic and the paddlefish's life history strategy (i.e., long-lived, late-maturing) necessitate a much higher minimum SPR. In fact, target SPRs of 35–40% and higher are used for marine species with similar life history strategies as paddlefish (Mace 1994; Clark 2002). A 30% minimum SPR target is likely a very conservative (from the harvester's standpoint) minimum for paddlefish, and future efforts should focus on determining if this minimum is sufficient for preventing recruitment overfishing at high exploitation rates (e.g., 50–75%).

The use of minimum SPRs will greatly improve the utility of minimum size limits for preventing overfishing; however, these size limits will be ineffective if sublegal paddlefish (i.e., paddlefish bycatch) do not survive netting and release. Initial mortality rates of paddlefish caught in entanglement gear increase with water temperatures (Bettoli and Scholten 2006), and most seasons encompass periods when water temperatures result in excessive mortality. Management plans will have to include strategies to minimize the mortality of paddlefish bycatch in commercial gill nets if length limits are to be effective. One such strategy is to confine paddlefish netting to periods when water temperatures normally remain below 52–57°F (11–14°C), to prevent excessive losses to bycatch mortality. In 2006, Arkansas and Tennessee were applying this strategy to set their season dates based on observed water temperatures, but this approach could be used basin wide to minimize bycatch mortality.

Future management efforts will also have to include efforts to implement regulations necessary to allow enforcement of size limits. High roe prices create incentive for commercial fishers to violate regulations, especially size limits designed to protect gravid females. When size limits are proposed, managers should evaluate fines to ensure they are high enough to deter illegal harvest of sublegal fish. It will also be important to consider other regulations that could indirectly affect the enforcement of length limits. For example, if roe evisceration is allowed on the water, illegal fishers could easily harvest roe from sublegal paddlefish and mix it with the roe of legally harvested fish. Evisceration and on-board processing regulations become increasingly more important as size limits are increased, to the point that fishers will be forced to release gravid females. Fisheries managers should consult with law enforcement personnel during the development of paddlefish management plans to ensure that regulations will be enforceable.

Another necessary step to reduce illegal harvest of paddlefish will be the standardization of harvest reporting and licensing requirements so interstate transfers can be better monitored. The vastly different reporting requirements in place in 2006 made it difficult to track interstate transfers of paddlefish products, and these situations were often exploited by individuals who wanted to sell illegally harvested products. Additionally, not all states required wholesale buyers to be licensed or report their transactions with commercial fishers, and this provided a venue for illegal fishers to "launder" their products. Managers should continue efforts to standardize information reported to each state and require all wholesale buyers to report their transactions. If this information was submitted to a central database, then law enforcement personnel could easily identify illegal fishers by comparing basin-wide harvest and sale reports.

Conclusion

Since the 1983 paddlefish symposium, much has changed in commercial paddlefish fish-

eries management. Demand has increased substantially and commercial fishers have increased their focus on roe harvest. The monetary value and political nature of the commercial fishing industry have made it difficult for managers to implement regulations that are necessary to prevent overharvest in many systems that remain open to commercial harvest. Interjurisdictional management and continued information sharing through groups like MICRA will be important as fisheries managers embark on the next 20 years of paddlefish management. As demand for U.S. paddlefish roe increases, managers will have to continually monitor paddlefish stocks for signs of overfishing. Management plans should be developed for biological significant areas, and these plans will have to focus on preventing recruitment overfishing and minimizing losses to bycatch mortality.

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