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Paddlefish Restoration to the Upper Ohio and Allegheny River Systems

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Abstract.—Paddlefish *Polyodon spathula* historically occurred in the Ohio and Allegheny River systems, extending into the headwater sections of the Allegheny River in New York and Pennsylvania. At the turn of the 19th century, paddlefish were reported in the Allegheny River near the cities of Salamanca and Olean, New York. The last published historical account of paddlefish in Pennsylvania occurred in 1919 at the mouth of the Kiskiminetas River, a major Allegheny River tributary. The demise of paddlefish in Pennsylvania and New York has been attributed to channelization, dams, gravel dredging, and water quality degradation. The closure of Kinzua Dam in 1968 prohibited access for paddlefish to the upper Allegheny River system from farther downstream. As late as 1986, paddlefish in Pennsylvania were listed as extirpated, and they continue to be classified as such in New York. In order to reestablish self-sustaining populations, Pennsylvania initiated a stocking program in 1991 in the upper Ohio and lower Allegheny rivers. In 1998, New York initiated a complimentary stocking program approximately 160 km upstream in the Allegheny Reservoir (above Kinzua Dam). A second stocking location, Conewango Creek, was added in 2006 in a relatively unaltered section of the historic range. Free ranging adult paddlefish were captured by gill nets and "reliable source" reports were documented in Pennsylvania and New York. No evidence of natural reproduction or year-class structure has been documented in either state. Pennsylvania plans to increase the size of

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stocked fish and New York plans to increase stocking densities as hatchery space permits. Both states will continue to monitor and assess the reintroduction of paddlefish to the upper Ohio River basin.

Introduction

Paddlefish *Polyodon spathula* historically occurred within the Ohio and Allegheny rivers and their larger tributaries (Cooper 1983; Smith 1985). These rivers mark the extreme northeastern extent of the paddlefish range (Figure 1) and likely never supported large numbers due to a lack of optimal habitat (Barry 2004). Paddlefish habitat has been further reduced in Pennsylvania by the segregation of these rivers into a series of navigational pools by lock and dam structures. Eight lock and dam structures on the Allegheny River extend from the 10.8-km marker in the city of Pittsburgh to the 100.1-km marker near the village of East Brady. The demise of paddlefish in Pennsylvania and New York has been attributed to river channelization, gravel dredging, dam building, and water quality degradation (Cooper 1983).

Unfortunately, information on paddlefish distribution in the Allegheny River is lacking. Fowler (1919) provided the last historical account of this species in Pennsylvania at the mouth of the Kiskiminetas River, a major Allegheny River tributary. The decline of paddlefish from the headwaters of the Allegheny River, although poorly documented (Smith 1985), likely mirrored that observed downstream. The construction of Kinzua Dam in 1968 presented a barrier to upstream movement into the headwaters of the Allegheny River.

Since 1986, paddlefish in Pennsylvania and New York have been recognized as extirpated (Eaton et al. 1982; Smith 1985; Gengerke 1986; Argent et al. 1998). Implementation of the Federal Clean Water Act and Amendments of 1972 has markedly improved water quality in the major rivers of New York and Pennsylvania (Anderson et al. 2000). Additionally, the development of Allegheny Reservoir (4,453 ha full pool) following construction of Kinzua Dam created fertile nursery habitat for juvenile paddlefish with unimpeded access for adults to the remainder of the upper Allegheny River system.

By 1990, conditions were deemed acceptable to initiate paddlefish reintroduction to Pennsylvania (Lorson 1991). In 1991, The Pennsylvania Fish and Boat Commission (PFBC) began stocking fingerling paddlefish in the upper Ohio and lower Allegheny rivers and in 1995 initiated a coded wire tagging (CWT) program to identify stocked cohorts (Oven 1995). Fish were obtained from the Missouri and Ohio rivers (Table 1). This tagging program was administered and partially funded by the Mississippi Interstate Cooperative Resource Association (MICRA). Tag retention greater than 90% was achieved 30 d after insertion. Since the inception of this program, nearly 130,000 fingerlings (mean eye-to-fork length [EFL] = 143 mm), half possessing CWTs, have been released in the Ohio River basin within Pennsylvania (Table 1; Figure 1).

Reintroduction of paddlefish in New York by the New York Department of Environmental Conservation (NYS-DEC) began in 1998 with the stocking of 48 fish averaging 226 mm EFL in Onoville Bay, Allegheny Reservoir with the ultimate goal of establishing a self-sustaining population. The program was expanded in subsequent years towards achieving an annual stocking of at least 500 fingerlings (0.1 fish/ha). Through 2006, 6,623 fingerlings averaging 200 mm EFL have been stocked in either the Allegheny Reservoir or Conewango Creek (Table 2; Figure 1). All paddlefish rostrums were implanted with CWTs for

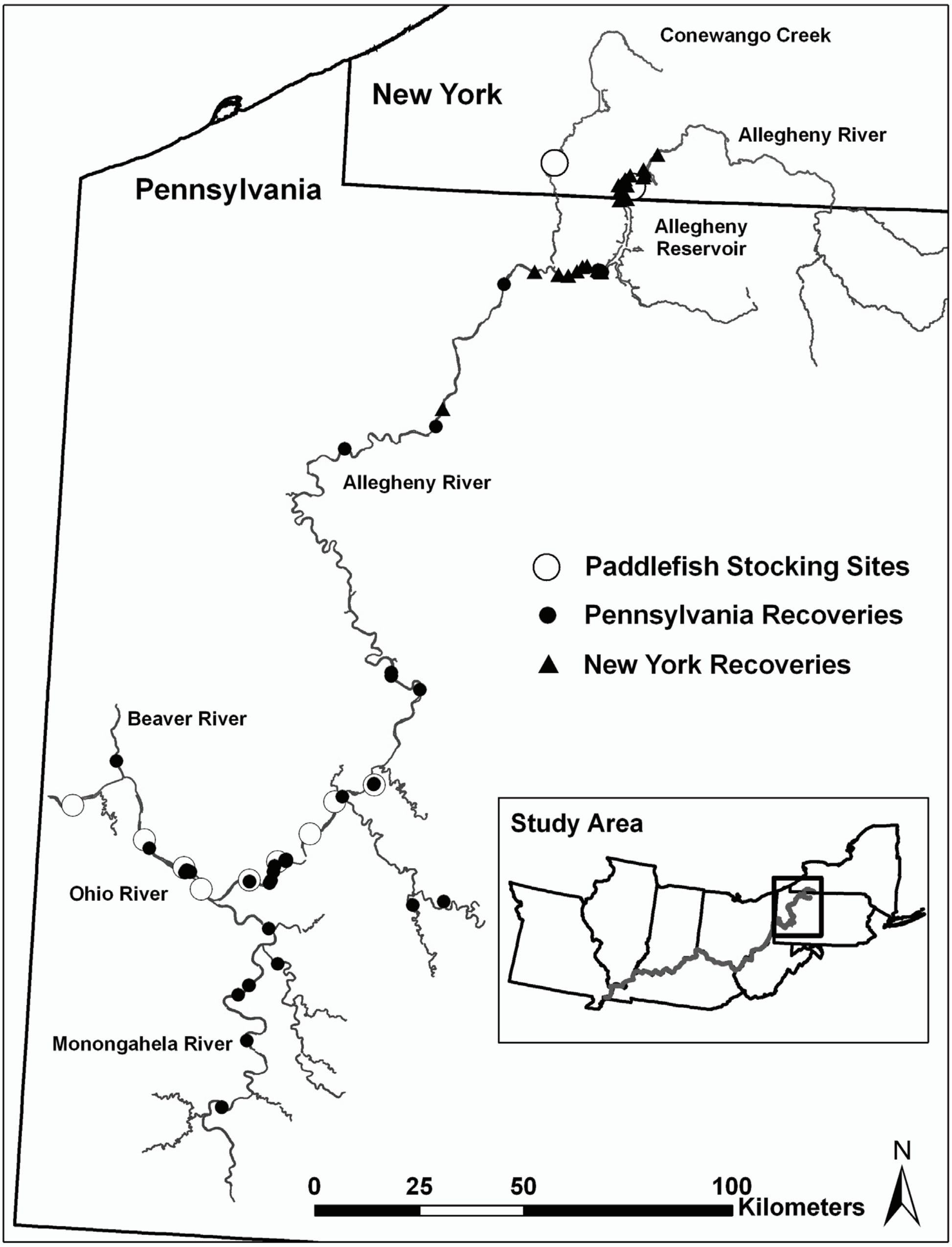

Figure 1. Paddlefish stocking sites and recovery sites in Pennsylvania and New York.

subsequent identification (Oven 1995). In 2008, NYS-DEC initiated an assessment of its reintroduction program, which included attempts to capture juvenile and adult paddlefish and a radio-telemetry project to assess movement patterns.

The objectives of this paper are to summarize recent efforts by both states to (1) document the presence of paddlefish in the Ohio and Allegheny rivers, (2) assess reproductive condition of captured paddlefish, and (3) document natural reproduction.

Table 1. Paddlefish stockings in the Allegheny River (AR) and Ohio River (OR) in Pennsylvania from 1991 to 2006. EFL = eye-to-fork length.

Year	Broodstock source	Locations stocked	Total stocked	No. stocked/year/ha	EFL (mm)
1991	Missouri River	AR	995	2.6	NA
		OR	1,200	1.3	
1992	Missouri River	AR	5,500	17.3	NA
		OR	450	0.9	
1993	Missouri River	AR	1,300	3.8	NA
		OR	1,060	1.1	
1994	Missouri River	AR	2,090	2.8	NA
		OR	2,850	3.1	
1995	Missouri River	AR	2,819	11.3	140
		OR	5,987	6.2	
1996	Missouri River	AR	3,533	4.8	122
		OR	3,144	3.4	
1997	Missouri River	AR	13,116	44.1	104
		OR	13,120	13.1	
1998	Missouri River	AR	2,387	3.2	110
		OR	2,276	2.4	
1999	Missouri River	OR	760	1.8	177
2000	Missouri River	AR	5,887	8.0	142
		OR	5,018	5.4	
2001	Missouri River	AR	3,550	10.6	145
		OR	4,747	5.0	
2002	Ohio River	AR	3,550	10.6	145
		OR	2,138	2.5	
2003	Ohio River	AR	1,058	1.0	166
		OR	544	0.6	
2004	Ohio River	AR	1,967	5.2	154
		OR	3,750	7.4	
2005	Ohio River	AR	18,569	31.5	157
		OR	13,866	27.4	
2006	Ohio River	OR	2,706	15.5	154
		Total stocked:	129,937		Mean EFL: 143

Methods

In Pennsylvania, gill-net sampling stations were located directly below lock and dam structures on the Ohio and Allegheny rivers and at the mouth of the Kiskiminetas and Beaver rivers (Figure 1; Table 1). Sample sites were selected within each pool to maximize the capture of paddlefish by focusing on those areas most heavily stocked by the PFBC (Barry 2004; Table 1) and an area of the Dashields Lock and Dam pool identified by side-scan sonar as containing optimal paddlefish habitat (Nieman et al. 1999). Gill nets containing either multi or single-mesh monofilament panels were fished overnight at selected locations from April to June in 2005 and 2006. Gill nets were fastened to onshore structures or set in mid-channel areas with marked anchors and floats. Multimesh nets contained 7.6-m-long panels of 10.1, 12.7, 15.2, 17.8, and 20.3 cm bar mesh hobbled from 6 to 4.5 m deep or 2.4-m-deep panels of 2.5, 5.0, 7.6, 10.1, and 12.7 cm bar mesh (the latter were fished in 2006). Single-mesh nets (38.1 or 91.4 m in length) contained 7.6, 10.1, or 12.7 cm bar mesh. Nets were constructed to the specifications utilized by commercial paddlefish fishers in Tennessee (Scholten and Bettoli 2005) and by fisheries

Table 2. Paddlefish stockings in New York from 1998 to 2006. EFL = eye-to-fork length.

Year	Broodstock source	Location stocked	Total stocked	No. stocked/year/ha	EFL (mm)
1998	Missouri River	Allegheny Reservoir	48	0.01	258
1999	Ohio River	Allegheny Reservoir	535	0.12	211
2000	Ohio River	Allegheny Reservoir	132	0.03	226
2001	Ohio River	Allegheny Reservoir	1,878	0.42	163
2002	Ohio River	Allegheny Reservoir	762	0.17	195
2003	Ohio River	Allegheny Reservoir	778	0.18	182
2004	Ohio River	Allegheny Reservoir	803	0.18	161
2005	Ohio River	Allegheny Reservoir	1,433	0.32	206
2006	Ohio River	Conewango Creek	367	0.08	194
		Total stocked:	6,369	Mean EFL:	199.6

biologists in West Virginia (C. O'Bara, West Virginia Department of Natural Resources, personal communication) and Pennsylvania (Kimmel and Argent 2006).

In 2008, NYS-DEC deployed monofilament single-mesh gill nets 30 m in length and 3 m deep (20.3, 25.4, or 30.5 cm bar mesh). Nets were fished during the day and overnight in the Allegheny River and Allegheny Reservoir, New York, during May through June to document the presence of paddlefish and to capture specimens for subsequent radio transmitter insertion. Radio transmitters were implanted in all live fish and they were then released at their location of capture.

All captured paddlefish were weighed (nearest kilogram), measured (EFL to the nearest mm), and sexed (by postmortem necropsy [Pennsylvania and New York], expression of milt/eggs [Pennsylvania], or during implantation of radio transmitter [New York]). Paddlefish were evaluated for the presence of CWTs with a handheld wand detector (Northwest Marine Technology), and detected tags were obtained by removing a small section of the rostrum. Rostrums containing collected tags were either fixed in 10% formalin or packed in salt for subsequent analysis by MICRA to determine stocking origin. Paddlefish that did not possess a CWT were tagged prior to release.

During April–July 2006, a modified benthic trawl (Hesse and Mestl 1993; Herzog et al. 2005) was employed to capture juvenile paddlefish in Pennsylvania. Five, 2–6-min hauls were performed below Emsworth and Dashields Lock and dams in the Ohio River and locks 2, 3, and 5 in the Allegheny River. The 25 hauls occurred in scour pools over gravel/cobble/silt substrates at depths ranging from 0.91 to 6.1 m. The five samples at each site were pooled to form a composite that was preserved in 10% formalin and returned to the laboratory at California University of Pennsylvania for examination.

During May and June 2006, areas of the Allegheny, Beaver, and Ohio rivers below lock and dam structures were sampled for larval and juvenile paddlefish utilizing plankton gear described by Counahan (2004). Sampling gear was towed from 25 to 60 min during the daytime below Emsworth and Dashields Lock and dams in the Ohio River; locks 2, 3, and 5 in the Allegheny River; and below Beaver Falls to the mouth of the Beaver River. All contents captured in the plankton net were preserved on site in 10% formalin and returned to the laboratory at California University of Pennsylvania for examination.

Data were also collected from "reliable sources" in both states. A reliable source was considered someone (e.g., recreational boater, angler) in possession of a paddlefish or photographic documentation. Reliable source reports for paddlefish were solicited through ongoing press releases and informational posters targeting recreational boaters and anglers at public access areas. Anglers in possession of paddlefish were instructed to contact either the PFBC or NYS-DEC to report sightings. The majority of reports described fishes that were dead, moribund, or incidentally captured by anglers.

Results

Approximately 2,150 and 3,900 gill-net hours were expended in the Ohio and lower Allegheny rivers in Pennsylvania between 2005 and 2006, respectively (Table 3), yielding six paddlefish (Table 4). Five of the six captured paddlefish were in prespawn condition, expressing eggs or milt upon capture. All were taken at depths in excess of 3.6 m, typically with cobble/gravel substrates in areas adjacent to fast-flowing water. At the time of sampling, river discharges ranged from 424 to 1,132 m^3/s and water temperatures ranged from 12°C to 16°C. With the exception of the 14- and 18-kg fish captured in the Allegheny River on May 16, 2006 (laceration above operculum in both), all prespawn paddlefish appeared to be in excellent condition. The one postspawn paddlefish was captured June 20, 2006 above the Dashields Lock. It was a mature and was captured over a mixture of sand and gravel in slack water at a river discharge of 311 m^3/s. External examination indicated that it was in good health despite the lack of a significant distal portion of its rostrum. Internal examination revealed that the liver harbored several cestode parasites. This fish was taken in an area identified by the habitat suitability model as "high quality" (Nieman et al. 1999). Estimation of age based on length-frequency data (Paukert and

Table 3. Gill netting effort and paddlefish captured in Pennsylvania from 2005 to 2006 and in New York in 2008 from the Allegheny River (AR), Ohio River (OR), Beaver River (BR), and Kiskiminetas River (KR).

River	Upriver lock/dam	Number of net sets	Number of net-hours	Number of paddlefish captured
2005				
OR	Emsworth	55	664	0
OR	Dashields	22	413	1
AR	Lock #3	57	823	1
AR	Lock #4	12	246	0
2006				
OR	Emsworth	75	1,243	1
OR	Dashields	31	561	0
BR	Beaver Falls	11	151	0
AR	Lock #2	12	230	0
AR	Lock #3	54	751	3
AR	Lock #4	12	244	0
AR/KR	Lock #5	41	744	0
2008				
AR	River above Allegheny Reservoir	50	1,310	0
AR	Allegheny Reservoir	64	439	20
	Total	496	7,819	26

Table 4. Paddlefish collected in Pennsylvania in 2005–2006 and New York in 2008 by gillnetting in the Allegheny River (AR) and Ohio River (OR). EFL = eye-to-fork length.

River	Location	Water depth (m)	Mesh size (cm)	EFL (mm)	Weight (kg)	Sex[a]	Released
2005							
OR	Below Dashields L & D	3.6	12.7	1,015	14.5	F	N
AR	Below Lock #3	4.5	12.7	1,015	9.0	M	Y
2006							
AR	Below Lock #3	6.0	20.3	960	17.7	F	Y
AR	Below Lock #3	6.0	20.3	1,000	19.0	M	Y
AR	Below Lock #3	6.0	15.2	1,010	16.3	F	N
OR	Above Dashields L & D	4.3	15.2	910	13.2	M	N
2008							
AR	Allegheny Reservoir	4.3	20.3	700	10.1	I	Y
AR	Allegheny Reservoir	4.3	20.3	780	11.4	M	N
AR	Allegheny Reservoir	4.3	20.3	800	11.7	M	N
AR	Allegheny Reservoir	5.5	20.3	910	18.2	M	N
AR	Allegheny Reservoir	6.1	25.4	660	9.5	I	Y
AR	Allegheny Reservoir	5.5	25.4	680	9.0	I	Y
AR	Allegheny Reservoir	4.9	25.4	680	9.5	I	Y
AR	Allegheny Reservoir	6.1	25.4	685	10.6	I	Y
AR	Allegheny Reservoir	4.9	25.4	690	11.1	I	Y
AR	Allegheny Reservoir	6.1	25.4	700	10.2	I	Y
AR	Allegheny Reservoir	5.5	25.4	720	9.5	I	Y
AR	Allegheny Reservoir	4.9	25.4	720	12.5	I	Y
AR	Allegheny Reservoir	4.9	25.4	740	10.0	I	Y
AR	Allegheny Reservoir	4.9	25.4	750	9.1	I	Y
AR	Allegheny Reservoir	4.9	25.4	770	10.7	I	Y
AR	Allegheny Reservoir	6.1	30.5	630	9.1	I	Y
AR	Allegheny Reservoir	6.1	30.5	675	9.5	I	Y
AR	Allegheny Reservoir	6.1	30.5	690	9.1	I	Y
AR	Allegheny Reservoir	6.1	30.5	820	13.2	I	Y
AR	Allegheny Reservoir	6.1	30.5	970	24.9	M	Y

[a] I = immature.

Fisher 2001) revealed that the captured paddlefish were between 8 and 9 years old (1997–1998 cohorts) when stocking densities were up to 17 fish/ha.

New York expended 1,749 h gillnetting in the upper Allegheny River and Allegheny Reservoir and captured 20 paddlefish ranging in length from 630 to 970 mm EFL (Tables 3 and 4). Necropsies performed on the three expired fish revealed no external injuries or abnormalities. Seventeen fish were fitted with radio transmitters for subsequent tracking.

Benthic trawl hauls performed in selected pools along the Allegheny and Ohio rivers yielded no juvenile paddlefish during 2006, even in areas that were stocked with up to 58 fish/ha during the previous year. No larval paddlefish were collected by plankton tows.

From 1992 to 2006, 47 reliable source accounts of paddlefish were reported to the PFBC. Twenty-one were captured by angling, four were observed near the surface, and 18 were found dead (Table 5). The highest concentration of reliable source reports in Pennsylvania were from the Allegheny River, below Lock and Dam #3

Table 5. Subadult and adult paddlefish reported in Pennsylvania by reliable sources, 1992–2006 from the Allegheny River (AR), Beaver River (BR), Conemaugh River, Loyalhanna Creek (LC), Monongahela River (MR), Ohio River (OR), Tionesta Creek (TC), and Youghiogheny River (YR).

Report date	River	Location	Total length (mm)	Encounter
1/15/1992	AR	Below L&D #3	508	Angling
1/15/1992	AR	Below L&D #3	584	Angling
8/15/1992	LC	At Dam Tailrace	711	Angling
8/15/1992	AR	Below L & D #3	787	Angling
8/31/1992	AR	Harmarville area	787	Angling
2/15/1993	AR	Below L & D #5	940	Dead
6/15/1993	AR	Below L & D #3	813	N/A
8/15/1993	AR	Below L & D #3	838	N/A
5/03/1994	AR	Below L & D #6	813	N/A
6/08/1995	CR	Below Conemaugh Dam	1,067	Observed alive
7/02/1995	BR	At New Brighton	635	Angling
1/06/1996	MR	Below L & D #3	1,219	Dead
7/15/1996	OR	Neville Island	1,219	Dead
8/15/1997	YR	Near Boston	305	Dead
5/18/1998	OR	Front Channel Dam	1,016	Dead
7/15/1998	MR	Below Maxwell L & D	1,270	Observed alive
6/21/1998	OR	Emsworth L & D back-Channel	1,016	Angling
7/03/1998	MR	Lower end of L & D #4	1,219	Angling
10/15/1998	AR	Near Blawnox	1,295	Angling
10/15/1998	AR	Near Blawnox	1,321	Dead
11/15/1998	AR	Near Blawnox	1,270	Dead
2/12/2000	MR	Below Braddock L & D	610	Angling
7/02/2000	OR	Ohio River, Emsworth	1,270	Dead
7/15/2000	AR	Stilling Basin of Kinzua Dam	762	Angling
8/15/2000	OR	Below Emsworth L & D	1,372	Dead
3/12/2001	AR	Kinzua Dam tailrace	914	Dead
9/15/2001	TC	Tionesta tailrace	914	Angling
10/20/2001	AR	Kinzua Dam	406	Angling
5/26/2002	AR	Kinzua Dam	1,016	Dead
5/30/2002	AR	12 m from Kinzua Dam tailrace	1,118	Angling
6/14/2002	AR	Allegheny Reservoir	965	Angling
7/13/2002	AR	Below Kinzua Dam	1,524	Observed alive
7/15/2002	AR	Near Oil City Marina	N/A	Observed alive
7/01/2003	OR	Back channel of Neville Island	737	Angling
9/04/2003	AR	Kinzua Dam tailrace	1,168	Angling
6/28/2004	AR	Belwo Kinzua Dam	1,219	Angling
10/20/2004	AR	RM 54.5, Templeton PA	1,118	Dead
2/17/2005	AR	RM 62.18	635	Dead
5/12/2005	OR	Below Dashields L & D	1,219	Dead
5/15/2005	AR	Below Lock & Dam #2	1,372	Angling
5/24/2005	AR	Hydroplant 8, at L & D #9	1,118	Angling
6/29/2005	MR	RM 26.56, Elizabeth	1,016	Dead
7/18/2005	MR	Below Elizabeth L & D	610	Dead
7/30/2005	AR	Section 21, RM 14.53	610	Dead
9/22/2005	AR	RM 36.35, Clinton, below Dam	914	Dead
3/15/2006	AR	Below Lock & Dam #2	N/A	N/A
5/16/2006	AR	Below Lock & Dam #3	457	Angling

(23%) and the Ohio River, below Emsworth Lock and Dam (15%).

From 2000 to 2006, 31 reliable source paddlefish were reported to NYS-DEC (Table 6). Twenty were observed or collected below Kinzua Dam with the remainder from Allegheny Reservoir (Table 6; Figure 1). Several of those collected below the dam exhibited external signs of abrasion, presumably from passage through the discharge gates.

Discussion

Efficiency of gill netting as a sampling tool where paddlefish populations are self-sustaining varies widely. In the Neches, Trinity, Angelina, and Sabine River systems of Texas, gill nets captured a total of 13 paddlefish over 4,000 net-hours of effort (Betsill 1999). Gill netting in Keystone Reservoir and the Arkansas River captured 1,412 paddlefish over 77 nights of effort (Paukert and Fisher 2001). The capture efficiency in Pennsylvania (one paddlefish/1,112 net-hours) was lower than that of Betsill (1999) who reported one paddlefish/308 net-hours.

New York gill-net catch and reliable source data showed that paddlefish from the earliest stockings were likely approaching sexual maturity. These reports also in-

Table 6. Reliable source paddlefish reports to the New York Department of Environmental Conservation from 1999 to 2006 in the Allegheny River.

Report date	Location	Total length (mm)	Encounter
7/22/2000	Kinzua Dam tailrace	914	Angling
8/27/2000	Allegheny Reservoir	845	Dead
3/12/2001	Kinzua Dam tailrace	N/A	Dead
6/26/2001	Allegheny Reservoir	890	Dead
10/20/2001	Below Kinzua Dam	406	Angling
11/08/2001	Below Kinzua Dam	965	Angling
5/26/2002	Below Kinzua Dam	1,067	Dead
5/30/2002	Below Kinzua Dam	1,143	Dead
6/14/2002	Allegheny Reservoir	965	Angling
6/14/2002	Below Kinzua Dam	1,041	Dead
7/26/2002	Kinzua Dam tailrace	914	Angling
10/12/2002	Below Kinzua Dam	610	Dead
11/23/2002	Below Kinzua Dam	500	Dead
4/19/2003	Below Kinzua Dam	1,041	Dead
6/28/2003	Below Kinzua Dam	864	Dead
9/05/2003	Kinzua Dam tailrace	1,168	Angling
6/05/2004	Allegheny Reservoir	1,000	Dead
6/17/2004	Allegheny Reservoir	7,111	Observed alive
7/04/2004	Allegheny Reservoir	914	Dead
7/08/2004	Allegheny Reservoir	686	Dead
7/22/2004	Kinzua Dam tailrace	975	Angling
7/29/2004	Allegheny Reservoir	1,016	Dead
6/26/2005	Kinzua Dam tailrace	610	Angling
7/02/2005	Allegheny Reservoir	914	Dead
8/05/2005	Kinzua Dam tailrace	914	Angling
5/14/2006	Allegheny Reservoir	533	Dead
6/18/2006	Below Kinzua Dam	889	Observed alive
9/07/2006	Allegheny Reservoir	864	Observed alive
9/15/2006	Kinzua Dam tailrace	1,143	Dead
9/19/2006	Kinzua Dam tailrace	1,168	Observed alive
10/05/2006	Kinzua Dam tailrace	1,168	Dead

Total responses: 31

dicated a tendency by some paddlefish to leave Allegheny Reservoir through the discharge gates of Kinzua Dam during high flows. Paddlefish that survived downstream passage may recruit to Pennsylvania's paddlefish population, but many morbid or variously injured paddlefish were observed in the Kinzua Dam tailrace. The highest incidence of reliable source reports in Pennsylvania came from the Allegheny River below Lock and Dam #3 and the Ohio River below Emsworth Lock and Dam, which also contained areas frequently used by juvenile paddlefish (Barry 2004). In 2006, this information was used to direct stocking and sampling efforts in these two areas.

Although benthic trawling in Pennsylvania captured several fish species ranging in size from 20 to 410 mm total length (TL), no paddlefish were taken. The same gear captured 181 paddlefish from the Mississippi River in 281 net hauls (Herzog et al. 2005). Paddlefish larvae have been collected using plankton nets in the Mississippi (Elzinga 2003), Missouri (J. Dillard, University of Missouri, personal communication) and Tennessee/Cumberland (Wallus 1986) rivers, but no larval paddlefish were collected by plankton tow in Pennsylvania.

The low catch of paddlefish of all life stages during the Pennsylvania assessment suggests that survival of stocked paddlefish in the Ohio and the lower Allegheny rivers was markedly lower than that observed in other waters (Timmons and Hughbanks 2000; Barry 2004), and there was no indication of natural reproduction. Several studies on recently released hatchery-reared paddlefish indicated mortalities ranging from 5% (Pitman and Gutreuter 1993) to 33% (Barry 2004). Stocking fry in waters with high populations of piscivorous predators had limited success, and the stocking of fingerlings less than 200 mm EFL at densities less than 2.5 fish/ha failed to establish recreational paddlefish fisheries in Missouri (Graham 1986). In Pennsylvania, the practice of stocking large predators (e.g., tiger muskellunge [muskellunge *Esox lucius* × northern pike *E. masquinongy*], walleye *Sander vitreus*, hybrid striped bass (striped bass *Morone saxatilis* × white bass *M. chrysops*) in the Allegheny and Ohio rivers may have been an impediment to fingerling paddlefish (EFL < 200 mm) survival. These popular sport fish along with channel catfish *Ictalurus punctatus* were collected in relatively high numbers (20% of total catch) at lengths capable of consuming recently stocked paddlefish. Predation by walleye and sauger *Sander canadensis* on paddlefish (170–255 mm TL) has been shown to be a significant source of mortality (Tidwell and Mims 1990; Mero et al. 1994; Parken and Scarnecchia 2002). Long-distance movement of paddlefish (Pitman and Parks 1994; Jennings and Zigler 2000; Rousch et al. 2003; Zigler et al. 2003) may also account for the low capture rates experienced during these surveys; however, additional telemetry work needs to be completed to evaluate dispersal patterns in these waters.

Poststocking survival in Pennsylvania may have been reduced by the paucity of preferred juvenile paddlefish habitat. Approximately 10% of the Dashields pool was identified as high quality habitat for juvenile paddlefish (Nieman et al. 1999). Deepwater habitats in the Pennsylvania sections of these rivers were associated with the lock and dam systems that provided little or no preferred substrate and were regularly degraded by maintenance dredging. Discharges in the Ohio River were regulated by the lock and dam systems constructed to maintain navigation channels. Regulated river discharges fail to mimic natural spring flow regimes that are important cues for paddlefish spawning (Unkenholz 1986), and dams may obstruct paddlefish migrations, causing them to spawn in inferior habitats (Southall and Hubert 1984;

Unkenholz 1986; Runstrom et al. 2001). The loss of habitat from the construction of locks and dams may be the most significant component affecting suitable spawning areas for paddlefish. Because discharge in the Ohio/Allegheny system is regulated according to navigational needs and flood control, preferred spawning temperatures (10–15°C) and flow requirements may not concur to optimize paddlefish movement and reproduction (Zigler et al. 1999). Although the presence of sexually mature paddlefish in Pennsylvania showed that reproduction may occur, the coordination of preferred temperatures and enhanced flows during the spawning period would certainly increase the likelihood of natural reproduction.

While dams, with their associated flow restrictions and limited spawning habitat, remain challenges to paddlefish restoration in the lower Allegheny and Ohio rivers, the Allegheny River above Kinzua Dam is free-flowing. The Allegheny Reservoir simulates the backwater, oxbow-type riverine habitat preferred by juvenile paddlefish (Graham 1986). Zooplankton are abundant in the upstream sections of the reservoir and the fluctuating nature of the flood control pool supports a relatively low abundance of piscivorous predators (R. Hoskin, U.S. Army Corps of Engineers, personal communication). Stocking of Conewango Creek, New York will provide an opportunity to evaluate survival in a relatively undisturbed, low-gradient lacusterine-like channel habitat.

Results of Pennsylvania and New York paddlefish sampling along with published reports indicate that stocked paddlefish should be at least 200 mm EFL to reduce the incidence of predation by piscivores (Mero et al. 1994; Parken and Scarnecchia 2002) and increase overall survival (Graham 1986). Further, the stocking of fish at densities of at least 9/ha could enhance the establishment of reproducing paddlefish populations within New York and Pennsylvania. Future adult paddlefish monitoring efforts in Pennsylvania should be concentrated during the first few weeks of May in deep holes below lock and dam chambers as paddlefish appear to stage in anticipation of spawning. Because of the difficulties cited earlier in sampling these areas, a cooperative venture between the PFBC and the U.S. Army Corps of Engineers may be required to ensure suitable flow for paddlefish during the spring migratory and spawning period.

The goal of Pennsylvania and New York's paddlefish restoration programs is to achieve self-sustaining populations of paddlefish in the upper Ohio basin by (1) increasing overall stocking efforts, (2) stocking larger fish, (3) targeting specific sites for high stocking densities, and (4) continuing monitoring. Ongoing restoration efforts (2007 forward) of paddlefish in Pennsylvania's portion of the upper Ohio basin will include the stocking of fingerlings ≥ 200 mm EFL at densities of 10 fish/ha through 2011. The increased stocking densities will be implemented on an alternating yearly pool by pool basis. The goal of establishing self-sustaining populations will be temporally evaluated by a systematic monitoring program. In New York, the stocking of fingerling paddlefish ≥ 195 mm EFL will continue and stocking densities will be increased as hatchery space permits. Radio-telemetry coupled with gillnetting surveys will assess mortality, habitat preferences, behavioral patterns, and seasonal movement and migration.

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