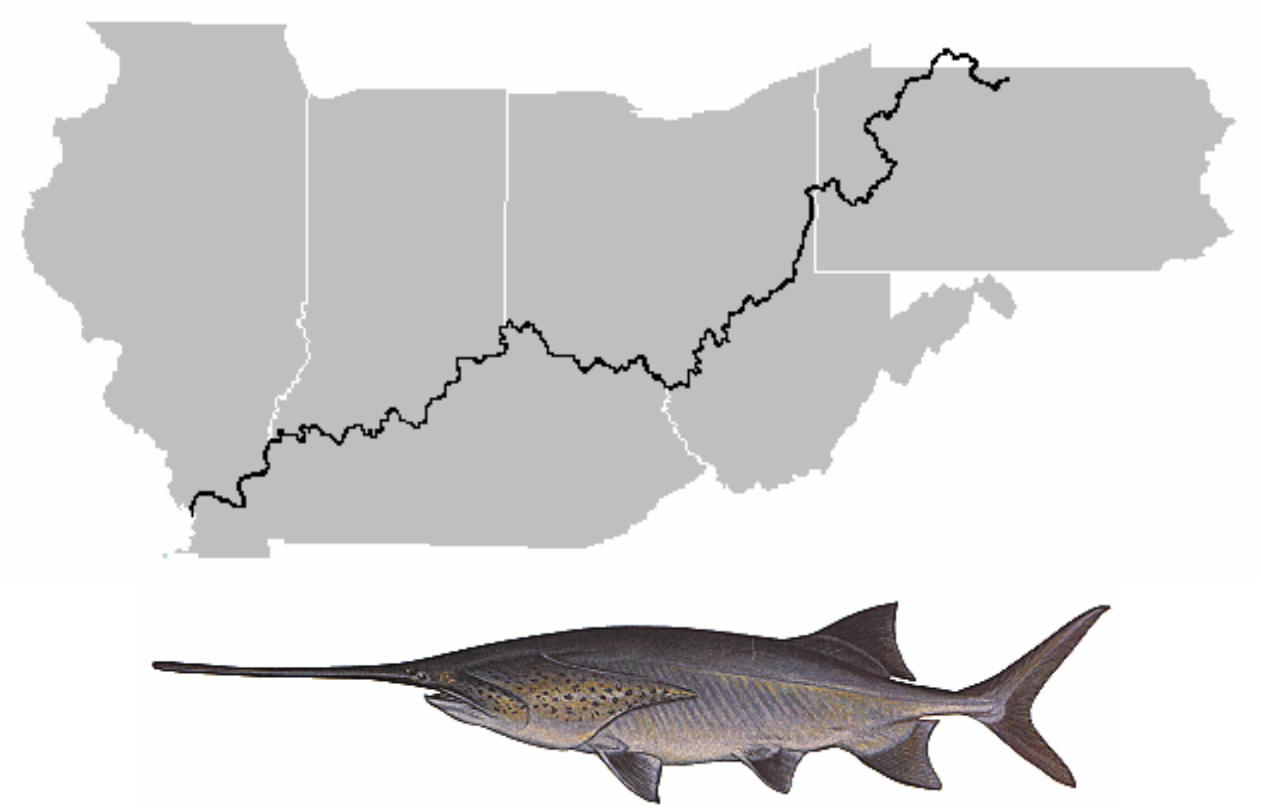
Section 8.3.3

Paddlefish Strategic Plan

Paddlefish in the Ohio River Sub-basin: Current Status and Strategic Plan for Management



Ohio River Fisheries Management Team

November 26, 2001

Paddlefish in the Ohio River Sub-basin:

Current Status and Strategic Plan for Management

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Executive Summary

The Ohio River Fisheries Management Team (ORFMT) Technical Committee has developed this overview of paddlefish status in the Ohio River Sub-basin at an important time. The Ohio River paddlefish population is a shared fishery resource at risk of overexploitation due to recent changes in global caviar markets that have increased the incentive for harvest. *Paddlefish in the Ohio River Sub-basin: Current Status and Strategic Plan for Management* provides current and historical information to guide management and policy. Our goal is to restore, enhance, and protect the paddlefish population in the Ohio River Sub-basin to ensure sustainable use and increase public awareness of paddlefish issues. To address this goal, strategic objectives were defined, fisheries problems were identified and prioritized, and problem-specific strategies were developed. Operational plans will be formed and implemented to address this strategic plan.

The paddlefish population in the Ohio River Sub-basin shows signs of extensive harvest that necessitate careful monitoring and a readiness to take regulatory action by the ORFMT. Estimates of total annual mortality, size structure, and age structure depict a population that is pushing its limit of sustainable harvest for optimal sustainable yield. Specific reasons for ORFMT concern include:

Current Status

- The Ohio River Sub-basin of the Mississippi River drainage comprises 22% of endemic paddlefish habitat.
- Paddlefish are listed as extirpated in Pennsylvania, protected in West Virginia, threatened in Ohio, a rough fish in Kentucky, and a sport and commercial fish in Indiana and Illinois.
- Exploitation, legal and illegal, is a serious threat to Ohio River Sub-basin paddlefish. The world supply of high-grade caviar decreased following collapse of Caspian Sea sturgeon fisheries, and demand for paddlefish eggs as a substitute is expected to increase.

Paddlefish are Mobile

- Paddlefish were highly mobile within pools of the Ohio River Sub-basin. Twenty-four percent of recaptured wild paddlefish were collected from a pool upstream or downstream of the original point of tagging, whereas 76% were recaptured within the original pool of tagging.
- One paddlefish tagged in Smithland Pool was recovered five pools upstream in Markland Pool (483 km (290 miles)), and another paddlefish tagged in Greenup Pool was recaptured five pools downstream in Cannelton Pool (526 km (316 miles)).
- Paddlefish tagged in other studies have been documented movement in and out of the Ohio River Sub-basin. One paddlefish tagged in South Dakota was recovered in the Ohio River Sub-basin (D. Henley personal communication) and three paddlefish tagged in the Ohio River Sub-basin were recaptured in Missouri and Arkansas (Timmons and Hughbanks 2000).

Paddlefish Caviar is a Valuable Resource

- Paddlefish eggs are marketed as high-grade caviar that retails for US$423/kg (US$192/lb) and yields commercial fishers at least US$100-200/kg (US$45-91/lb).

- Retail value of the Ohio River paddlefish egg harvest was nearly US$4.3 million in 2000.

- Ohio River commercial fishers recently reported an increase in wholesale egg prices.

Commercial Fishery Issues

- Harvest can increase substantially from one year to the next given adequate market incentive and favorable river conditions. Reported commercial harvest was 63,827 kg (140,419 lbs) of flesh and 2,733 kg (6,013 lbs) of eggs during 1999, and 159,109 kg (350,040 lbs) of flesh and 10,071 kg (22,156 lbs) of eggs during 2000.

- Kentucky and Indiana licensed 366 commercial fishers during 2000. A commercial crew of two fishers reported harvest of 15,707 kg (34,904 lbs) of flesh and 2,812 kg (6,248 lbs) of eggs during 2000, which represented 28% of the annual egg harvest.

- Current market prices provide incentives for fishery participation and the Ohio River fishery has few barriers to entry. A 9-kg (20-lb) female paddlefish can be worth nearly US$400 wholesale, yet a resident commercial fishing license costs US$35-125, a paddlefish gillnet costs US$100, and minimal equipment is required for a fisher with a small boat.

Red Flags for the Population

- Length-frequency distributions of Ohio River paddlefish were truncated at 85 cm eye-fork length (33 inches).

- The percentage of paddlefish estimated to be ages 10-14 declined by 2-12% annually between 1997 and 2001, and few older fish were observed in the population.

- Total annual mortality of Ohio River paddlefish ranged from 47-68% during 1995-2001, indicative of a population exposed to extensive harvest.

Important Sport Fishery

- A creel survey from Markland Tailwater during 2000-2001 indicated that 16% of anglers sought paddlefish and these anglers harvested 323 paddlefish during February through April.

Contaminant Advisories

- Contaminant advisories on Ohio River paddlefish products were downgraded from “do not eat” to a limit of six meals per year of flesh or eggs from the lower two-thirds of the river, although pregnant women, nursing mothers, infants, and children are advised to not eat paddlefish products.

<u>Management Recommendations</u>

- Establish full participation of all Ohio River Sub-basin states in cooperative management.

- Implement the proposed 2002-2010 strategic plan provided in this report.

- Initiate operational plans in 2002 to: 1) monitor abundance; 2) refine quantification of movement; 3) quantify exploitation; 4) monitor commercial harvest; 5) monitor sport fisheries; 6) improve data management; 7) provide public information.

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Introduction

Paddlefish (*Polyodon spathula*) are native to the Ohio River Sub-basin of the Mississippi River drainage, a linear distance that accounts for 20,856 km (13,035 miles), or 22% of endemic paddlefish habitats (Table 1). Habitat degradation, exploitation by sport and commercial fishers, and poaching have impacted paddlefish in the majority of their range for the past 100 years (Graham 1997). Exploitation, legal and illegal, is a renewed threat to paddlefish populations because paddlefish eggs are a high-grade substitute for sturgeon caviar that yield commercial fishers US$100-200/kg (US$45-91/lb) and currently retail for US$423/kg (US$192/lb).

Market demand for paddlefish is expected to increase because of declines in world sturgeon stocks and closure of Caspian Sea sturgeon fisheries (Birstein et al. 1997; Khodorevskaya et al. 1997). On June 25, 2001, a freeze on Caspian Sea sturgeon fisheries was initiated in Russia, Azerbaijan, Kazakhstan, and tentatively Turkmenistan through pressure from world trade regulators of the United Nations CITES Committee (Convention on International Trade in Endangered Species and Wild Fauna and Flora). This effort to help restore dwindling stocks of sturgeon did not include Iran, because their management practices are deemed acceptable (Associated Press International 6/25/2001). The Caspian Sea accounts for over 90% of the world supply of sturgeon caviar and value of the illegal trade is believed to exceed US$1 billion annually, which is ten times the value of the legal harvest. Legal harvest of Caspian Sea sturgeon during 2000 decreased to one twentieth of that reported two decades ago (CNN 6/25/2001). Availability of sturgeon has been inversely related to the demand for paddlefish flesh and eggs since the early 20th Century (Carlson and Bonislawsky 1981; Pasch and Alexander 1986). These biological and macro-economic factors necessitate a better understanding of paddlefish within the Ohio River Sub-basin of the Mississippi River Basin in order to protect paddlefish or maintain sustainable fisheries.

Market demand for paddlefish will affect the Ohio River Sub-basin paddlefish stock because commercial fisheries operate in three of six border-states, and illegal harvest is a potential problem basin-wide. Paddlefish, like other chondrostean fishes, have a combination of morphology, habits, and life history characteristics that make them extremely sensitive to exploitation (Boreman 1997).

Table 1. Total segment lengths (km and miles) and percentage of total segment lengths of each sub-basin with original paddlefish habitat excluding the Great Lakes region where paddlefish were historically reported, but are now considered extirpated (provided by Joanne Grady, USFWS).

Sub-basin	Segment length (km)	Segment length (miles)	Percent of total
Ohio River	20,856	13,035	22
Upper Mississippi River	8,707	5,442	9
Lower Mississippi River	27,330	17,081	29
Missouri River	27,638	17,274	30
Gulf Rivers	9,220	5,762	9

Approaches to paddlefish management differ among Ohio River Sub-basin states. Status of paddlefish in the Ohio River is categorized by border-states as extirpated in the upper river (Pennsylvania), threatened (Ohio) and protected (West Virginia) in mid-river reaches, and commercially harvested in mid-river and lower river reaches (Kentucky, Indiana, and Illinois). These differing strategies are a concern because separate management units, or stocks, are unlikely to exist in the Ohio River Sub-basin, the Ohio River, its tributaries, or navigational pools.

Paddlefish within the Ohio River migrate among inter-jurisdictional boundaries. Telemetry and tagging studies confirm that paddlefish are capable of traveling great distances and moving through navigational dams. Telemetry studies often indicate that inter-pool movement is common, although upstream movement has been less frequently reported than downstream movement. Southall and Hubert (1984), and Johnson et al. (1997) found that paddlefish in large rivers readily moved downstream through partially closed dam gates, yet exhibited limited upstream movement at high-flow conditions when dam gates were completely open. Under low-flow conditions, paddlefish monitored by Moen et al. (1992) moved downstream, but did not move upstream even when a lock and dam was fully open for 10 days. Downstream migrations of adult paddlefish (129-151 cm (52-60 in) eye-fork length) tracked by Johnson et al. (1997) were typically 70-130 km (42-78 miles) in 7-18 days during late spring in the Ohio River. Juvenile paddlefish (35-50 cm (14-20 in) eye-fork length) tracked by Pitman and Parks (1994)

traveled up to 270 km (162 miles) upstream in less than seven months and 161 km (97 miles) downstream in less than ten months in the Neches River system, Texas. The distances traveled by both adult and juvenile paddlefish monitored with radio-telemetry indicated that extensive movement is characteristic of paddlefish of all ages rather than limited to spring spawning movements by mature adults.

Extensive upstream and downstream movements of paddlefish also are verified through tagging studies. Rosen et al. (1982) reported average upstream movement of 21 km (13 miles) and downstream movement of 198 km (119 miles) in the Missouri River after the first year of a tagging study. An additional recapture was reported 2,000 km (1,200 miles) downstream. Other investigators have documented movement of over 167 km (100 miles) in the Yellowstone River, Montana, 242 km (145 miles) in the Missouri River, Montana, and 333 km (260 miles) in the Osage River, Missouri (Russell 1986). Reported recaptures from these studies verified upstream and downstream movements in rivers with and without lock and dam structures, although movement was more extensive in regions without navigational structures.

The highly migratory nature of paddlefish infers that gene flow is common among populations without definitive geographic isolation, therefore paddlefish within the Ohio River are unlikely to represent more than one genetic population. Epifanio et al. (1996) surveyed allozyme and mitochondrial DNA from six regions of the Mississippi River, Mobile Bay, and Pearl River drainages and identified essentially two major groups, one from the Mississippi River and Pearl River drainages, and the other from the Mobile Bay drainage. Results of their analyses did not indicate subdivisions of biological significance at local levels. However, the presence of rare alleles in maternal lineages of fish from Osage and Arkansas River populations, relative to other Mississippi River populations, lead Epifanio et al. (1996) to recommend a conservative approach of managing paddlefish at no less than major tributary levels when considering rehabilitation, restoration, or protection efforts. Carlson et al. (1982) also found little genetic variability among Mississippi River basin paddlefish when electrophoresis results were compared from Yellowstone, Missouri, Osage, Mississippi, and Cumberland river populations. The conclusions of Epifanio et al.

(1996) and Calson et al. (1982) were consistent with particularly low heterozygosity that characterizes the 120-chromosome acipenseriforms, which includes paddlefish (Birstein 1997).

Paddlefish harvest from the Ohio River Sub-basin has not been well documented during the past 20 years. Carlson and Bonislawsky (1981) reported that commercial harvest of Ohio River paddlefish declined from 1950-1980, but indicated that Ohio River Sub-basin harvest from the Tennessee and Cumberland rivers has historically represented a large portion of the total harvest in the United States. Pasch and Alexander (1986) described a historical pattern of overexploitation and recovery of paddlefish populations in the Tennessee River Valley, and provided case studies to demonstrate the ease at which these fish were overharvested in response to market demand. They suggested that sustainable fisheries are possible at exploitation rates of less than 15-20%, but expressed concern when harvest increased during the late 1970s after the United States stopped importing Iranian sturgeon caviar (Semmens and Shelton 1986). Following this period, Hoffnagle and Timmons (1989) documented 69% total annual mortality, a young population, and a low number of spawning paddlefish in the lower Tennessee River. High egg prices (US$110/kg (US$50/lb)) during 1984-1985 had encouraged harvest, but following the 1986 reintroduction of Iranian sturgeon caviar to the market egg prices decreased to US$44/kg (US$20/lb) and commercial fishery activity declined. Timmons and Hughbanks (2000) observed changes in the lower Tennessee River by 1992, where they estimated 3-year exploitation rates at 14%, a decrease in total annual mortality to 22%, and an increase in population size and age structure. During that time, 3-year cumulative exploitation in the lower Tennessee and Cumberland rivers ranged from 14% in Kentucky Lake, where 88% of harvest was commercial, to 25% in the Kentucky Dam tailwaters, where only sport fishing is permitted. Annual exploitation never exceeded 18% during any year of their study, and during 3 years never exceeded 12% by commercial fishers or 16% by sport fishers in Kentucky Lake, the Kentucky Dam tailwaters, or Lake Barkley.

Annual exploitation rates of less than 20% may be compatible with sustainable paddlefish fisheries. Combs (1982) documented annual exploitation rates of 15% (1979) and 19% (1980) in the Neosho River, Oklahoma sport fishery and believed that those harvest levels were not a detriment to the population. He also indicated that annual exploitation reported by researchers monitoring sport fisheries

of the Yellowstone, Missouri, Mississippi, and Osage rivers often ranged from 8-14% and had generally not been associated with overharvest. Exploitation rates are not presently known for Ohio River paddlefish, and commercial harvest of paddlefish had been coarsely quantified, or not at all, during the past two decades by the seven Mississippi River Basin states that allowed commercial fishing (Todd 1999).

The overwhelming documentation of paddlefish movement between pools of large river systems and vulnerability of paddlefish to overexploitaion indicate the need for an inter-jurisdictional management perspective in the Ohio River Sub-basin. The objective of this Ohio River Sub-basin report was to develop a current situation analysis from which to initiate comprehensive inter-jurisdictional management of paddlefish in the Ohio River Sub-basin and scope a course of action for paddlefish management within the Ohio River. Each border state recognizes the vulnerability of paddlefish to exploitation, volatility of the global caviar market, and the influence of that market on paddlefish, and is working cooperatively on paddlefish issues through the Ohio River Fisheries Management Team (ORFMT).

Ohio River Fisheries Management Team (ORFMT)

The ORFMT was formed in 1990 to develop an inter-jurisdictional perspective to management of Ohio River fisheries resources. Impetus for the formation of the team was United States Supreme Court settlements that changed jurisdiction of the Ohio River from the exclusive jurisdiction of Kentucky to concurrent jurisdiction with the states of Ohio, Indiana, and Illinois. The Ohio Decree was entered on April 15, 1985 (Ohio v. Kentucky, 471 U.S. 153); the Indiana Decree was entered on November 4, 1985 (Indiana v. Kentucky, 474 U.S. 1); and, the Illinois opinion was decided on May 28, 1991 (Illinois v. Kentucky, 500 U.S. 380, No. 106, Orig.) (www.megalaw.com/fed/usopinions.php3). Shared jurisdiction necessitated cooperative management and led to the development of a Memorandum of Understanding among natural resource agencies that manage fisheries in Pennsylvania, West Virginia, Ohio, Kentucky, Indiana, and Illinois. Team objectives specified in a Memorandum of Understanding were:

1) Develop shared fisheries management objectives;
2) Coordinate regulatory responsibilities, conduct joint management programs and facilitate technical information exchange among the states with other governmental, public, and private interests;
3) Designate and maintain at least one agency representative to serve on an “Ohio River Fisheries Management Team”;
4) Convene the “Ohio River Fisheries Management Team” at least annually to discuss, plan and report on cooperative fisheries management efforts;
5) Recognize that this memorandum of understanding shall neither obligate the parties to expenditure of funds nor in any way affect the legal authorities vested in the individual states; and,
6) Retain this memorandum of understanding until it is modified or terminated by those who signed this agreement.

The Ohio River Sub-basin report for paddlefish was an outcome of these objectives and the result of ORFMT participation in a national study of paddlefish coordinated by the Mississippi Interstate Cooperative Resource Association (MICRA). Twenty-two of the 28 states within the Mississippi River

Basin have participated in the basin-wide study that initiated in 1995 (Oven and Fiss 1996). The goal of the study was to assess the condition of paddlefish stocks throughout the entire Mississippi River Basin.

International Status of Paddlefish

Paddlefish have been listed under the Convention on International Trade in Endangered Species and Wild Fauna and Flora treaty (CITES) as an Appendix II species since 1992. The CITES treaty is an agreement among 145 nations to protect specific plant and animal species from unregulated international trade. Appendices I, II, and III provide categories of species status and monitoring action for species addressed by CITES and list specific species under each category. Appendix I protects threatened species from all international commercial trade. Appendix II regulates trade in species not threatened with extinction but which may become threatened if trade goes unregulated. Appendix III gives countries the option of listing native species already protected within their own borders (http://international.fws.gov /facts/citesnew.html). The listing of paddlefish and other acipenseriforms resulted from concerns related to the caviar market in the presence of observed reductions in abundances of paddlefish and sturgeons in much of their native range, and a general lack of information about their status (Graham and Rasmussen 1999).

Export of paddlefish flesh, roe, or live hatchery products requires a permit from the United States Fish and Wildlife Service (USFWS), Division of Scientific Authority. The procedures for the permitting process were summarized in a letter from the USFWS to Willem Wijnstekers, Secretary General, CITES Secretariat (Appendix A). Applicants for an exporting permit indicate origin of the product, the amount to be exported, the recipient, and provide an indication from state controlling authorities in the United States that the harvest was not detrimental to the species. The USFWS Division of Management Authority reviews each application for completeness, compliance with local regulations, and the presence of adequate scientific information and forwards the application to the USFWS Division of Scientific Authority. The Division of Scientific Authority reviews each application and approves applications that are deemed non-detrimental. A CITES permit costs US$25 per shipment and can include a combination of products from different regions.

During 1997 through 2000, nine export permits were reviewed for paddlefish products with an Ohio River Sub-basin origin. All of the products, which were primarily paddlefish eggs sold for use as caviar, originated from Kentucky or Tennessee. Products included 6,247 kg (13,761 lbs) of eggs and an

undisclosed amount of live hatchery products (eggs, fry, and fingerlings), of which 3,206 kg (7,061 lbs) of eggs and all live hatchery products were deemed non-detrimental to fisheries and accepted for export. Permits from these transactions are available in Appendix B.

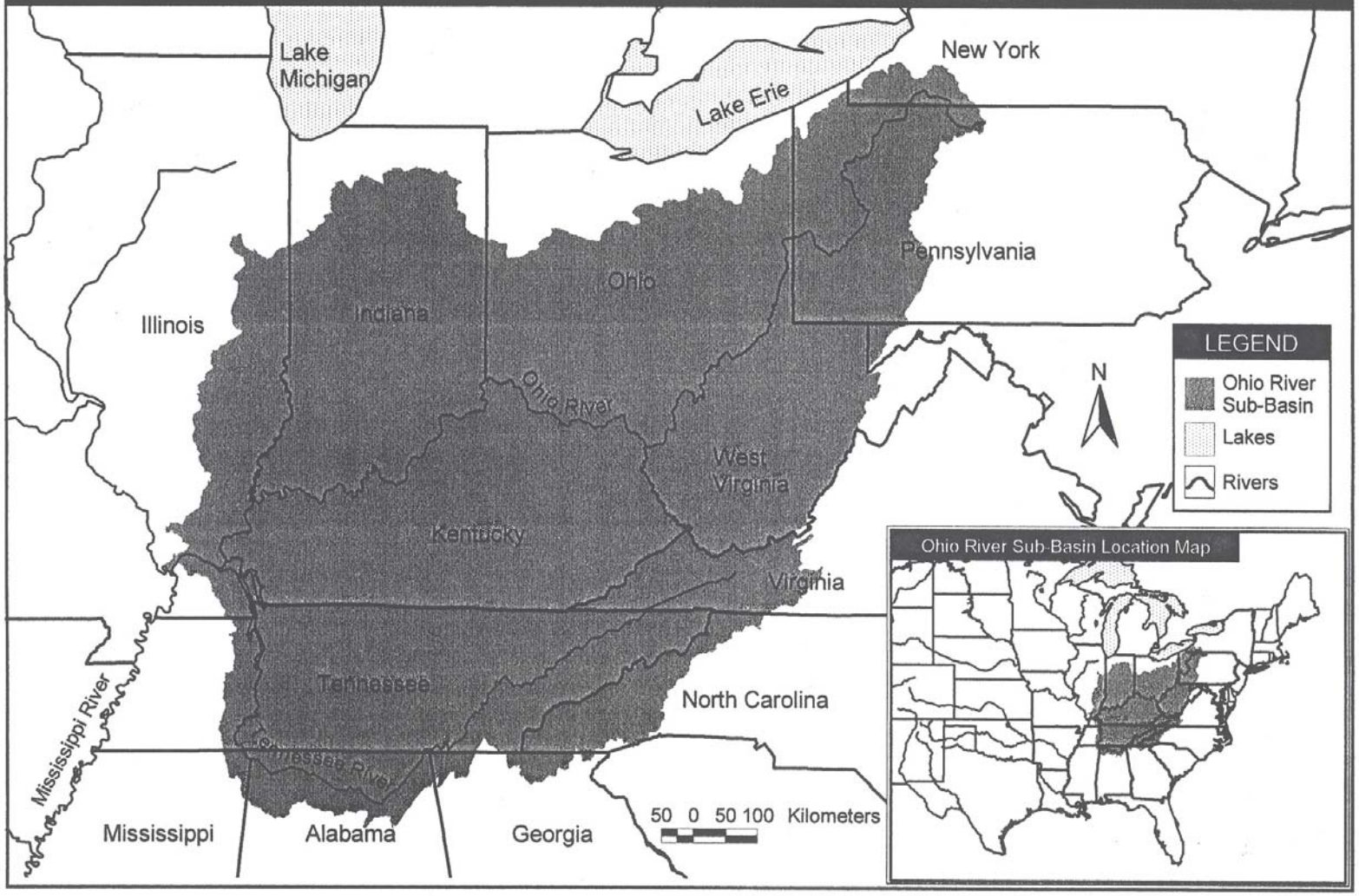
Study Area

The Ohio River Sub-basin includes portions of 11 states and comprises 20% of the Mississippi River watershed (Figure 1). Nearly 10 percent of the United States population lives in the 530,244 km^2 (203,940 square miles) Ohio River Sub-basin. The Ohio River forms in Pittsburgh, Pennsylvania at the confluence of the Allegheny and Monongahela rivers and flows 1,582 km (981 miles) to Cairo, Illinois where it enters the Mississippi River. A total of 69 tributaries with drainages greater than 2,600 km^2 (1,000 square miles) enter the Ohio River as it flows through Pennsylvania, West Virginia, Ohio, Kentucky, Indiana, and Illinois (Appendix C). The Tennessee, Wabash, and Cumberland rivers are the largest tributaries in the basin, and account for approximately 20%, 16% and 9% of the watershed, respectively (www.orsanco.org).

The Ohio River is an important source of water supply, commercial navigation, power generation, and recreation. Three million people currently use the Ohio River as a source of potable drinking water. Twenty navigational dams operate to facilitate commercial and recreational travel (Appendix D). These dams provide a 2.7 m (9 ft) minimum depth for commercial navigation. Over 207,000,000 metric tonnes (230,000,000 short (English) tons) of cargo transported on the river annually are composed primarily of coal and other energy products. Forty-nine power-generating facilities operate on the Ohio River and the combined capacity of these facilities exceeds 6% of the total generating capacity in the United States. Recreational fishing and boating also represents a significant portion of river use and these activities contribute to local and regional economies (Shell et al. 1996).

Approximately 159 fish species are found within the Ohio River and 285 are found within the sub-basin (Wallus et al. 1990). Species composition and abundance have changed dramatically during the past century as a result of dam construction, pollution and pollution abatement (Pearson and Krumholz 1984). Natural resource agencies of states which border the Ohio River currently consider 25 species sport fishes. No fish species indigenous to the mainstem of the Ohio River are federally listed as endangered, threatened, or are current candidates for federal listing.

Figure 1. Ohio River Sub-Basin



Historical Perspective, Status, and Current Management

Ohio River fisheries were important to native Americans and early European settlers who capitalized on the abundance and variety of fishes inhabiting the river. However, fish populations began to deteriorate by the late 1800s and early 1900s as a result of environmental degradation from settlement of the Ohio River Valley and commercial fishing (Ohio River Sanitation Commission (ORSANCO) 1962; Pearson and Krumholz 1984). Forests had been removed and products of eroded material entered the river. Factories discharged effluents into the river without restriction, urban centers discharged untreated human waste into the river, and dams were built along the entire reach. Concurrent with this environmental degradation was the advent of commercial fishing. The Ohio River has been fished commercially since the early 1800s and the harvest value of fishes such as lake sturgeon *Acipenser fulvescens*, shovelnose sturgeon *Scaphirhynchus platorynchus*, and paddlefish contributed to their decline in abundance (Pearson and Krumholz 1984).

Paddlefish, like other Ohio River fishes that require clean gravel substrates for spawning, have declined since dam construction began in the early 20th Century (Pearson and Krumholz 1984). Paddlefish were historically noted to be more abundant in the lower Ohio River, as is believed today. Lock-chamber studies along the Ohio River demonstrate historical gradients in paddlefish presence from the upper to the lower reaches of the river (Table 2).

Strategies for managing paddlefish vary among states within the Ohio River Sub-basin. Restoration and stocking programs are employed primarily in the upper Sub-basin where paddlefish harvest is prohibited, whereas commercial and sport fisheries operate in the lower Sub-basin. Five of eight states in the Ohio River Sub-basin have stocked 237,533 fish since 1986 (Table 3), and program objectives and stocking strategies vary. The Tennessee Wildlife Resources Agency (TWRA) has stocked the largest number of paddlefish in the Ohio River Sub-basin. During 1986-1997, TWRA stocked 154,889 paddlefish throughout the Tennessee and Cumberland river drainages. Unlike other states within the sub-basin that stock paddlefish, TWRA permits sport and commercial harvest of these fish.

Table 2. Mean number (± SE) of paddlefish sampled in lock-chamber studies each decade since 1960 in the Ohio River, 1960-1999. Sample size (N) in parenthesis indicates the number of lock-chamber studies during each decade (ORSANCO database).

Pool (lock)	1960-1969	1970-1979	1980-1989	1990-1999
Dashields	0 (3)	0 (6)	0 (6)	0 (1)
Montgomery	0 (3)	0 (1)	0 (2)	0 (5)
New Cumberland	0 (2)		0 (7)	0 (2)
Pike Island	0 (3)	0 (5)	0 (7)	0.2±0.2 (5)
Hannibal	0 (1)	0 (4)	0 (7)	0 (1)
Willow Island	0 (2)	0 (1)	0 (6)	0 (5)
Belleville	0 (3)	0 (6)	0 (6)	0 (1)
Racine	0 (2)		0.2±0.2 (5)	0.17±0.17 (6)
Byrd	0 (3)	0 (6)	0 (5)	0 (2)
Greenup	0 (3)	0 (1)	0.25±0.25 (4)	0.5±0.29 (4)
Meldahl	0 (4)	6.5±6.17 (4)	0.67±0.67 (3)	1.0±0.58 (4)
Markland	0 (3)	10.6±9.10 (5)	1.5±1.5 (2)	9.5±6.01 (4)
McAlpine	0 (3)	9.25±6.76 (4)	1.5±1.31 (6)	0 (1)
Cannelton	0 (3)	1.67±1.09 (6)	3.5±1.5 (2)	2.0±1.76 (5)
Newberg	0.50+0.50 (2)	1.67±0.67 (3)	0.33±0.33 (3)	0 (1)
Myers	0 (2)	1.0±0.58 (4)	0.50±0.34 (6)	0.20±0.20 (5)
Smithland	0.50+0.50 (2)	20.33+10.65 (3)	0.67+0.67 (3)	0 (3)
Pool 53			0 (1)	

Table 3. Paddlefish stocking in the Ohio River Sub-basin, 1986-2000.

State	Year	Broodstock source	Location stocked		Number
New York	1998	Gavins Point	Allegheny River-Kinzua Reservioir		48
	1999	Ohio River	Allegheny River-Kinzua Reservioir		535
				Sub-total	583
Pennsylvania	1991	Gavins Point	Ohio/Allegheny Rivers		2,195
	1992	Gavins Point	Ohio/Allegheny Rivers		5,950
	1993	Gavins Point	Ohio/Allegheny Rivers		2,360
	1994	Gavins Point	Ohio/Allegheny Rivers		4,940
	1995	Gavins Point	Ohio/Allegheny Rivers		8,806
	1996	Gavins Point	Ohio/Allegheny Rivers		6,677
	1997	Gavins Point	Ohio/Allegheny Rivers		23,236
	1998	Gavins Point	Ohio/Allegheny Rivers		4,663
	1999	Gavins Point	Ohio/Allegheny Rivers		760
	2000	Gavins Point	Ohio/Allegheny Rivers		10,830
				Sub-total	70,417
West Virginia	1992	Gavins Point	Kanahwa River		62
	1992	Gavins Point	Ohio River		81
	1993	Gavins Point	Kanahwa River		400
	1993	Gavins Point	Ohio River		6,094
	1994	Gavins Point	Ohio River		65
	1995	Gavins Point	Ohio River		1
	1996	Gavins Point	Kanahwa River		156
	1996	Gavins Point	Ohio River		1,459
	1997	Gavins Point	Kanawha		97
	1997	Gavins Point	Ohio River		1,300
	1998	Gavins Point	Kanahwa River		150
	1998	Gavins Point	Ohio River		1,365
	1999	Ohio River	Ohio River		7
	2000	Ohio River	Ohio River		300
				Sub-total	11,537
Ohio	1992	Ohio River	Deer Creek Lake		81
	1993	Ohio River	Scioto River		26
				Sub-total	107

Table 3 (continued). Paddlefish stocking in the Ohio River Sub-basin, 1986-2000.

State	Year	Broodstock source	Location stocked	Number
Tennessee	1986	Edgar Farmer	Tennessee River-Cherokee Reservoir	10,709
	1987	Edgar Farmer	Tennessee River-Cherokee Reservoir	4,880
	1989		Cumberland River-Center Hill	1,600
	1990		Tennessee River-Cherokee Reservoir	3,523
	1990		Cumberland River-South Cross Creek	12
	1991		Tennessee River-Cherokee Reservoir	434
	1991		Cumberland River-Center Hill	250
	1992	Osage Catfish	Tennessee River-Cherokee Reservoir	3,035
	1992		Cumberland River-Old Hickory Reservoir	1,797
	1993		Cumberland River-Old Hickory Reservoir	1,000
	1993	Pvt John Allen NFH	Tennessee River-Cherokee Reservoir	5,255
	1993		Cumberland River-Center Hill	1,000
	1993		Tennessee River-Norris Reservoir	100,000
	1994	Carbon Hill	Tennessee River-Cherokee Reservoir	8,798
	1995		Cumberland River-Old Hickory Reservoir	2,931
	1995		Tennessee River-Cherokee Reservoir	2,934
	1997		Elk River	102
	1997	Pvt John Allen NFH	Big Elk Creek	3
	1997	Pvt John Allen NFH	Mississippi River	6,626
			Sub-total	154,889

In the northernmost portion of the Ohio River Sub-basin, paddlefish were among a group of highly migratory fishes present in the upper Allegheny River, New York before 1900. Paddlefish were overlooked in this region until Eaton et al. (1982) drew attention to early records at Olean and Salamanca, New York (Fowler 1907). Renewed interest in paddlefish and a loss of paddlefish in these habitats prompted the New York State Department of Environmental Conservation (NYSDEC) to initiate a program to re-establish paddlefish. The recovery plan was implemented in 1998 with experimental stocking of 46 fingerlings from the Gavins Point National Hatchery, South Dakota and the intent to stock 500 fingerling per year for the next five years. Five hundred and thirty-five fish were stocked in 1999 and 132 were stocked in 2000, all of which originated from McAlpine Pool, Ohio River broodstock (Table 3). Stocking at the mouth of Onoville Bay (Kinzua Reservoir) was in multi-jurisdictional waters and had the approval of Seneca Nation of Indians (SNI), Pennsylvania Fish and Boat Commission (PFBC), and United States Army Corps of Engineers (USACE).

Evaluation efforts by NYSDEC have not been planned for New York waters, which are upstream of Kinzua Reservoir, because sampling would be most successful in the reservoir but it is managed under the multi-jurisdictional authority of the PFBC, SNI, and USACE. Angler reports of incidentally caught paddlefish or sightings may be used to indicate stocking success. During 2000, one fish was incidentally caught by an angler below the tailrace near Warren, Pennsylvania (reported to Bill Martin, Pennsylvania Waterways Conservation Officer) and another floated ashore near Quaker Run of the upper reservoir, both of which were of sizes presumed to be from the 1998 stocking.

Similar to New York, paddlefish were native to Pennsylvania waters but became so rare that they were considered extirpated, and are now the focus of a restoration program. Restoration of paddlefish in Pennsylvania began in 1991 in response to improvements in Ohio River water quality during the past 30 years that aided recovery of native white bass (*Morone chrysops*), freshwater drum (*Aplodinotus grunniens*), smallmouth buffalo (*Ictiobus bubalus*), mooneye (*Hiodon tergisus*) and sand shiner (*Notropis stramineus*). A 64 km (40-mile) reach of the upper Ohio and lower Allegheny rivers were chosen for restoration stocking to reintroduce paddlefish to their historical range and develop a self-sustaining population. The PFBC believes that habitat in the Allegheny River will support a self-sustaining

population and has stocked 73,000 fish during the past 10 years (Table 3). Since 1995, these fish have been implanted with coded wire tags and stocking has been evaluated by sampling with gillnets. No fish have been sampled to date, but anglers have incidentally captured increasingly larger paddlefish since 1990 when stocking began, including a 10 kg fish (23 lbs) last year. Prior to 1990, the closest capture of a paddlefish was 480 km (300 miles) downstream.

Paddlefish were endemic to the West Virginia reach of the Ohio River and several large tributary rivers, but were considered extirpated since the early 1900s. Poor water quality, navigational structures, and over overexploitation were considered the primary factors leading to the decline of paddlefish and other large river species. Since the mid-1980s, the West Virginia Division of Natural Resources has implemented several measures to restore paddlefish. Commercial fishing was halted in 1989 on all species, including paddlefish, after concerns of overexploitation and contaminants were expressed. Paddlefish were reintroduced in 1992 and have been reported from the R.C. Byrd, Belleville, and Hannibal tailwaters on the Ohio River. Annual stocking is planned through 2005.

The goal of the WVDNR paddlefish program is to restore the population to provide a recreational fishery. Stocking, strict no harvest regulations, biological assessment, and habitat restoration are the program cornerstones. Paddlefish reared at the Palestine Hatchery since 1992 have been stocked in the Ohio and Kanawha rivers. Eggs were initially acquired from the Missouri River, South Dakota (The National Hatchery at Gavins Point Dam, SD), but since 1999 broodstock have been collected from the R.C. Byrd Tailwater, Ohio River (Table 3). All hatchery-reared paddlefish have been implanted in the rostrum with coded wire tags.

The WVDNR began assessment of Ohio River paddlefish and their habitat in 2000. The study will help evaluate the stocking program and indicate size structure, population structure, and movement patterns. It will also include targeted paddlefish collections throughout the Ohio River, tagging of all adult paddlefish encountered, and an evaluation of fatty acid composition as a measurement of population similarity. Additional studies will be conducted through a navigational cumulative impact assessment on the Ohio River. Habitat restoration and the mitigation of navigational activities will be addressed through the USACE Ohio River Ecosystem Restoration Program, as well as the Kanawha

River Mitigation Program. Efforts will be made to enhance instream paddlefish habitat and to mitigate for loss of habitat attributed to navigational activities.

In Ohio, paddlefish were once common in large Ohio River tributaries and portions of the mainstem. Abundance of paddlefish conspicuously declined during 1925-1950 following significant river and tributary impoundment circa 1915. Trautman (1981) noted that during the post-impoundment period paddlefish were more common west of Portsmouth, Ohio near the confluence of the Scioto and Ohio rivers, and this appears to remain true today.

Paddlefish were listed as an Ohio endangered species in 1974 under Section 1531.25 of Ohio Revised Code. This statute was the initial species protection act in Ohio. An Ohio endangered species is, "A native species or subspecies threatened with extirpation from the state. The danger may result from one or more causes, such as habitat loss, pollution, predation, inter-specific competition, or disease." Paddlefish were downlisted to threatened status in 1987 under the same statute as information about their distribution increased. An Ohio threatened species is, "A species or subspecies whose survival in Ohio is not in immediate jeopardy, but to which a threat exists. Continued or increased stress will result in its becoming endangered." Paddlefish remain listed as a state threatened species in Ohio (ODNR, DOW 1999).

Within Kentucky, paddlefish are native to the Mississippi, Ohio, Tennessee, Cumberland, Green, Salt, Kentucky, and Licking rivers, and Bayou du Chien (Burr and Warren 1986). Paddlefish were once considered a species of special concern among a list of state endangered, threatened, or rare fishes (Branson et al. 1981), but this listing has been considered unnecessary for over 15 years because paddlefish are more common than previously believed. Currently, paddlefish are designated as a rough fish in Kentucky under statute 301 KAR 1:060, and they are harvested by sport and commercial fishers.

Paddlefish were historically common to abundant in the larger Indiana rivers in the Wabash River drainage and bayous and oxbow lakes associated with the Ohio River. Most large Ohio River tributaries in Indiana historically contained paddlefish. Paddlefish also were found in some natural glacial lakes such as Lake Tippecanoe, located in the most upstream portion of the Wabash River drainage (Gerking 1945). Paddlefish were likely found in the Indiana portion of the upper Mississippi River Sub-basin at one

time because they currently exist in the Illinois River, Illinois; however, upstream movement of paddlefish into the Kankakee River, Indiana is blocked by dams on the Illinois River and prevents repopulation. Historical records of paddlefish do not indicate that they were ever found in the Indiana portion of the Lake Erie or Lake Michigan watersheds. Gerking (1945) first reported that paddlefish populations were declining during the 1940s, but also indicated that paddlefish were still abundant in some locations based on conversations with commercial fishers. Decreased abundance was attributed to excessive harvest with dynamite and large seines, poor water quality, and habitat degradation; and particularly dam construction, drainage of backwater lakes, and channelization. Little was known about paddlefish in Indiana until the INDNR began to participate in inter-jurisdictional paddlefish research during 1995. Prior to 1995, INDNR personnel occasionally collected paddlefish at various locations throughout the state and abundance was thought to be common to rare, and declining.

Paddlefish were commercially harvested throughout Indiana prior to creation of the Indiana Fish Commission. The Commission, later renamed the Indian Department of Natural Resources (INDNR), prohibited commercial paddlefish harvest prior to 1985. Sport fishing regulations prohibited anglers from harvesting paddlefish by snagging or foul-hooking, however, most sport-caught paddlefish were captured in this manner. Therefore, regulations that prohibited illegal capture were difficult for conservation officers to enforce. A November 1985 United States Supreme Court settlement between the State of Indiana and Commonwealth of Kentucky granted Indiana control over a portion of the Ohio River. Following this settlement, the INDNR aligned Ohio River regulations in Indiana with those of Kentucky to create a commercial and sport classification for paddlefish in the Ohio River.

Paddlefish have been harvested in Illinois for over 100 years. Commercial harvest is primarily for roe that is processed and sold as high-grade caviar. In 1899, the Illinois harvest was 88,609 kg (195,174 lbs), but 100 years later in 1999, it had declined to 29,502 kg (64,983 lbs). Commercial harvest is now only permitted in the Ohio River and portions of the Illinois and Mississippi Rivers. Paddlefish are both a sport and commercial species in Illinois.

Overview: Sport Fisheries

Paddlefish can be harvested in Kentucky and Indiana by sportfishers snagging with rod and reel or setting trotlines. Snagging fisheries typically operate below the major tailwaters of dams on the lower Ohio, Tennessee, and Cumberland rivers. Sport trotlines are those with 50 hooks or less and paddlefish caught with this gear are generally incidental.

Snagging for paddlefish has been popular in Kentucky since the 1940s. The first major fishery using this method was below Kentucky Lake Dam on the Tennessee River. This fishery still exists and is open year round. Several additional snagging fisheries have developed on the Ohio River. These fisheries are regulated by a season that opens on February 1 and closes on May 10. Anglers are restricted to snagging only from the bank and cannot snag from a boat or platform. Fish may be taken by snagging using a single hook or a treble hook. Paddlefish snagging is permitted statewide during all hours, except where specifically prohibited by administrative regulation. However, snagging is prohibited within 180 m (600 ft) of any dam and paddlefish snagged within this area, except in the Kentucky Dam Tailwater, must be released. The KDFWR enforces a 15 paddlefish creel limit at the Kentucky Dam Tailwater, but has no creel limit for paddlefish snagged elsewhere.

Indiana began regulation of an Ohio River sport paddlefish fishery in 1988. Initially, snagging for paddlefish was restricted to February 1 through May 10, but the number of fish harvested was not restricted. During this time, anglers were limited to snagging from shore with a single hook or a treble hook. Snagging from a boat, platform, or along a bay or tributary to the Ohio River was prohibited. Despite these regulations, INDNR concern grew for paddlefish because poaching and other illegal activity were being reported, particularly in the Indiana portion of the Ohio River. Most non-Ohio River violations involved snagging paddlefish in protected areas, whereas most Ohio River incidents involved egg sales from sport-snagged paddlefish.

Rampant illegal and questionable fishery activity related to paddlefish taking in Indiana resulted in emergency rule changes effective March 1998 that later became regulations. These regulations were developed under the belief that current levels of legally caught sport and commercial paddlefish would be

sustainable if illegal harvest was curbed and if “no harvest” or “sanctuary” areas were delineated. Of the six regulation changes, the following five pertained to sport fisheries:

1) **Prohibit the take of paddlefish from all waters of Indiana except for the Ohio River.** This regulation change eliminated any confusion over whether a paddlefish was snagged or legally caught on a baited hook. It also designated most of the state as a paddlefish sanctuary.
2) **Establish a two-paddlefish bag limit and four paddlefish possession limit from the Ohio River.** Biologists wanted to maintain a sport paddlefish harvest but could only do this by eliminating the means for sport harvest to provide illegal economic gain. An unlimited bag limit for a large fish with premium dollar value like paddlefish encouraged the illegal sale of sport-caught fish. The reduced bag limit is easily enforced and provides a reasonable amount of food for anglers who choose to eat their catch.
3) **Require that the first two paddlefish taken by an Ohio River angler must be kept (there is no sorting or release of sport caught paddlefish).** This regulation change was intended to reduce the illegal sale of sport-caught fish by preventing sorting for large, egg-bearing females. Restricting harvest to the first two fish snagged reduces the opportunity to use snagging for commercial gain.
4) **Require that an angler must stop snagging for the day after two paddlefish are harvested.** This was an attempt to eliminate a loophole whereby a sport fisher could say that they were snagging for other species after they caught their two paddlefish limit, even though they intended to cull for large female paddlefish.
5) **Prohibit snagging within 183 m (600 ft) of a dam on the Ohio River.** This regulation change aligned Indiana and Kentucky regulations and provided paddlefish with a sanctuary from snagging within the Ohio River.

Overview: Commercial Fisheries

Commercial fishing for paddlefish has a strong tradition among lower Ohio River fishers and is presently permitted in Kentucky, Indiana, and Illinois. Commercial fishers licensed by these states have been required to report harvest of paddlefish flesh and eggs on a monthly basis since 1999 through a mandatory catch reporting system.

Commercial fishing in West Virginia has been prohibited since 1989 on all species, including paddlefish. Prior to this time, limited commercial fisheries for catfish operated primarily on the Ohio River.

The Ohio Department of Natural Resources (ODNR) has never licensed commercial fishing in the Ohio River. State of Ohio Statute 1533.54 prohibited citizens from commercial fishing outside of specific inland fishing districts in Ohio waters. However, Ohio residents were permitted to store commercial gear under specified conditions to accommodate fishers licensed as non-residents by Kentucky. The statute allowed Ohio residents that fished the Ohio River to possess nets for the sole purpose of storage, repair, drying, and tarring in specified southern portions of the state with the purchase of a US$10 permit for each net (Appendix E).

Commercial fisheries have operated in Kentucky since the early 1800s. Beginning in the early 1920s, fishers were required to tag their gear by the Kentucky Division of Game and Fish (presently the Kentucky Department of Fish and Wildlife Resources (KDFWR)). Under Kentucky Revised Statute 150.025, the KDFWR regulated commercial fishers on the Ohio River and its tributaries by restricting gear types and the areas where gear could be fished. Fishery biologists began to assess the annual weight of the catch from the fishery in 1950 when only bait lines (baited trotlines), snag lines (unbaited trotlines), hoop and wing nets, and haul seines were legal gear (Tompkins et al. 1951). During 1950, 1,460 licensed fishers reported a total catch (all species) of 675,000 kg (1,500,000 lbs). Additional commercial fishery assessments were conducted in 1958 and 1959 (Carter 1959). Fishers noted that 1958 was a poor fishing year and 1,100 resident fishers reported a catch of 810,000 kg (1,800,000 lbs), of which 211,430 kg (469,845 lbs) were harvested from the Ohio River. The 1958 paddlefish harvest from the Ohio River was 3,394 kg (7,543 lbs). In 1959, 38% of the 2,583 licensed fishers worked the Ohio River and caught 675,000 kg (1,500,000 lbs) of fish, including 24,524 kg (54,498 lbs) of paddlefish. Gill and

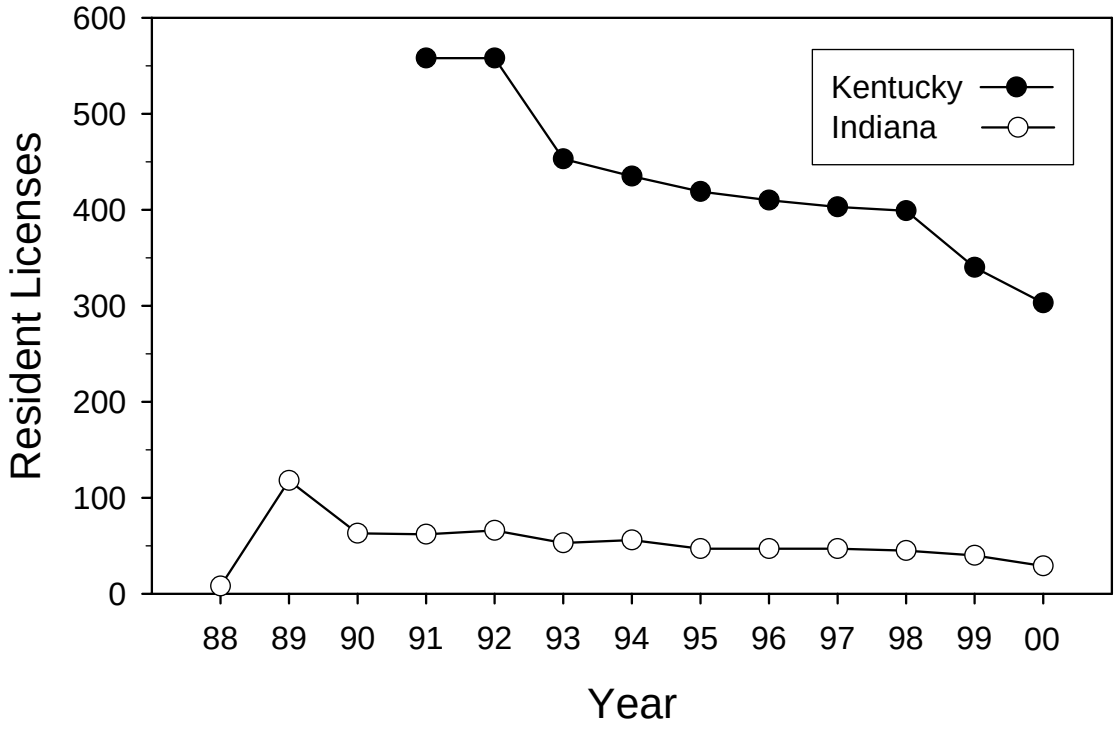
trammel nets became legal commercial gear in the early 1960s. Renaker and Carter (1968) surveyed fishers in 1965 (3,015 licensed) and 1966 (3,116 licensed) about their harvest from the Ohio River and reported paddlefish catches of 5,804 kg (12,897 lbs) in 1965 and 869 kg (1,932 lbs) in 1966. Commercial harvest was not monitored again until 1999 when 301 KAR 1:155 Section 6 required commercial fishers to report their catches from Kentucky waters. Current commercial fishery regulations are provided in Appendix F.

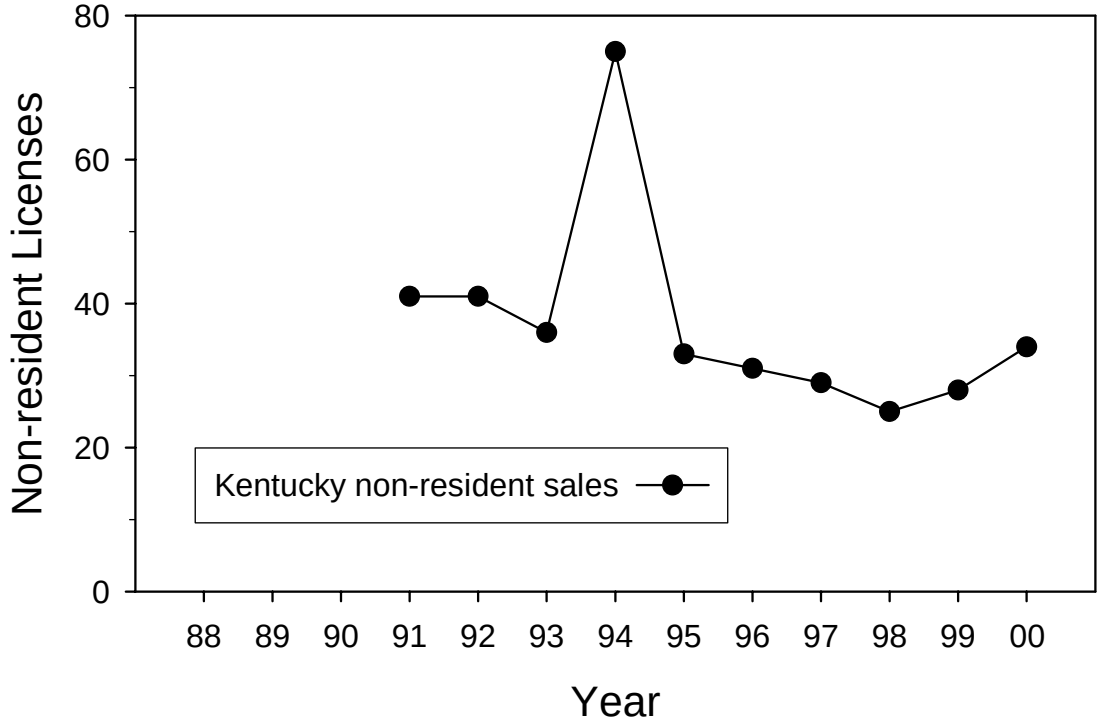
Indiana began selling Ohio River commercial fishing licenses to residents in 1988, but does not does not sell commercial fishing licenses to non-residents. Licensed Indiana commercial fishers may harvest an unlimited number of paddlefish with hoop nets, wing nets, straight-lead nets, heart-lead nets, gill nets, trammel nets, trotlines, seines, and slat traps. Commercial fishing is limited to the Ohio River mainstem and prohibited in embayments, backwaters, or tributary streams. In addition, commercial gear cannot be used within 45 m (150 ft) of the mouth of a stream and no gear except for slat traps may be used upstream of the outer lock wall of a dam. Baited hoop nets and slat traps may not be left unattended for more than 72 h. All other gear types must be tended not less frequently than once every 24 h (Appendix G).

The Illinois portion of the Ohio River was fully opened to commercial fishing in 1995 by an agreement between the KDFWR and ILDNR. Ohio River commercial fishers must keep daily records and report their harvest monthly. Paddlefish may be harvested from the Illinois portion of the Ohio River by hoop nets, trotlines, seines, and trammel or gill nets (102-mm (4-inch) bar mesh) as specified by the ILDNR (Appendix H).

Sales of commercial fishing licenses have declined in Kentucky and Indiana during the past decade (Figure 2). Resident license sales in Kentucky declined from 558 in 1991 to 303 in 2000, whereas Indiana sales declined from 118 in 1989 to 29 in 2000. Non-resident licenses sold by Kentucky have ranged from 25-75 during the past decade. Commercial license sales may have declined because of: 1) lack of recruitment of new participants; 2) fish consumption advisories; 3) competition from aquaculture products; 4) competition with the job market; and, 5) the increased difficulty in making a living

Figure 2. Annual sales of resident commercial fishing licences in Indiana (legalized in 1988) and Kentucky (data available since 1991) and non-resident licenses in Kentucky, 1988-2000, Ohio River Sub-basin.





as a commercial fisher. Prices of annual commercial fishing licenses vary by state. Kentucky charges residents US$125 for a license with a block of ten gear tags and an additional US$15 for each block of 10 gear tags, and non-residents US$600 for a license with a block of 10 year tags and US$90 for each additional block of gear tags. Indiana charges US$72 for a resident commercial license and does not sell non-resident licenses. Illinois charges residents US$35 for a commercial license and an additional US$18.50 for each 100 m of net, and charges non-residents US$150 for a commercial license and US$36.50 for each 100 m of net.

Indiana currently has five to seven crews that target paddlefish during the October to May egg harvest season. Each crew consists of two to four licensed commercial fishers that operate one or two boats. Approximately 10 to 20 (25 to 69%) of Indiana licensees target paddlefish, but less than half of them fish for alternative species such as buffalo or catfish during the remainder of the year.

Methods

Primary and secondary data pertaining to the Ohio River Sub-basin were collected and compiled to provide a contemporary assessment of paddlefish. Primary sources of data included state stocking records, sport and commercial harvest records, and sampling data collected by state agencies. Most field data were the result of participation of six Ohio River Sub-basin states in the MICRA Paddlefish and Sturgeon Sub-committee and the paddlefish research developed by the Sub-committee. Contaminant data were provided through secondary sources as referenced.

Paddlefish were collected and marked according to protocols developed by the MICRA Paddlefish and Sturgeon Sub-committee. These procedures, which describe methods for tagging both hatchery and wild paddlefish, were provided in the 1995 MICRA Interim Report (Oven and Fiss 1996). Recaptures were obtained by biologist during sampling and voluntarily by sport and commercial fishers that harvested paddlefish. Fishers were offered an incentive to return paddlefish rostrums, the area of the paddlefish tagged, through a reward program that offered a hat and a raffle ticket for a prize drawing for each rostrum returned. Rostrums sent to biologist were scanned to test for the presence of a tag. Data were submitted to a central processing center and later returned to project biologists in a master database.

Biologists within the Ohio River Sub-basin collected paddlefish with electrofishing and entanglement gear, and obtained additional information from participants in the sport snag fishery. Entanglement gear was predominately 102-mm (4-inch) or 127-mm (5-inch) mesh square measure, although mesh ranged from 76 mm (3 inch) to 152 mm (6 inch). Gear and methods of capture were not standardized; therefore, catch-per-effort (CPE) was calculated in a simplified way to provide a coarse estimate of abundance. Estimates of CPE were reported as the number of fish captured per meter of 127-mm (5-inch) mesh entanglement gear herein, similar to the method required of commercial fishers in Kentucky. Additional paddlefish data were obtained from commercial fishers using entanglement gear or sport fishers that snagged paddlefish with rod and reel. Data were analyzed for each of the following locations: 1) entire Ohio River Sub-basin; 2) Ohio River (without Hovey Lake); 3) Wabash River; 4) Hovey Lake (a backwater area of the Ohio River within Myers Pool); and, 5) Cumberland River.

All paddlefish were measured to the nearest 1-mm eye-fork length and weighed to the nearest 0.1 kg. Mean length at capture was reported for each major location during 1995-1999 for fish captured with 102-mm (4-inch) mesh entanglement gear, 127-mm (5-inch) mesh entanglement gear, and electrofishing, and from only 127-mm (5-inch) mesh gillnets in the Ohio River during 2000 and 2001. Relative weight (Wr) was calculated for five length categories of paddlefish <600 mm (24 in), 600-799 mm (24-31 in), 800-999 mm (31-39 in), >999 mm (39 in), and all lengths combined using equations proposed by Brown and Murphy (1993). Mean relative weights among the four major areas were compared with analysis of variance and Tukey's Honest Significant Difference tests to control for Type I error rate (Dowdy and Wearden 1991) at alpha=0.05. Standard and $\log_{10}$ transformed length-weight equations were also developed.

Paddlefish sampled by biologists or stocked in the Ohio River were tagged with coded wire tags following the MICRA protocol. The rostrums of fish captured by biologist were scanned with a wand detector to determine the presence of a coded wire tag (CWT). If a tag was detected, it was removed and replaced with a new tag. If a tag was not present, then a CWT was injected in the rostrum. Once a first-caught or recaptured fish was tagged, it was released near the capture site. Additional fish were sought to test for the presence of tags through commercial and sport fishers. Fishers were encouraged to return all paddlefish rostrums from harvested fish via a reward system. Because CWT were not externally visible, all rostrums were scanned and tags were removed when detected. Paddlefish stocked in the Ohio River Sub-basin during 1995-1999 were tagged with batch coded wire tags. Tagging results were used to estimate gross movement of paddlefish within the Mississippi River Basin and the Ohio River Sub-basin.

The KDFWR and ODNR collected additional data during 1990-2001. Sport fishery information was collected at the Markland Tailwater, where dentary bones used to determine age were sampled from the May 1996 catch and a creel survey was conducted during November 2000 through April 2001. Dentary bones were also collected from random samples of the commercial catch in the McAlpine and Cannelton tailwaters during spring 1996. Dentary bones were removed from paddlefish captured by both biologists and fishers. When possible, the sex and the presence of eggs was determined and fish were

measured and weighed according to procedures previously described. Dentaries were sectioned and the age of each fish was determined by counting annuli with procedures described by Scarnecchia et al. (1996). Age determinations from the sport and commercial fisheries provided insight into the growth of paddlefish and age structure of the catch from each fishery. Paddlefish also were collected from the Greenup, Meldahl, McAlpine and Myers tailwaters during 1990, 1991, 1998, and 1999 for contaminant surveys of the flesh and gonads.

Age data from the sport fishery were used to estimate the age structure of paddlefish sampled by biologists and to estimate total annual mortality of Ohio River paddlefish. A regression of age on length from the sport catch for both sexes of paddlefish combined was developed to estimate the age of each fish sampled by biologists with 127-mm (5-inch) mesh entanglement gear. Age-frequency results were used to develop catch curves based on the regression of the natural logarithm of frequency on age between ages 10-14. Slope of the regression provided an estimate of instantaneous mortality (Z), survival (S) was estimated from $S=e^{-Zt}$, and total annual mortality (A) was estimated from A= 1-S, expressed as a percentage (Ricker 1975).

Results and Discussion

Sport Fisheries

The 1996 sample of the sport fishery harvest from the Markland Tailwaters, Ohio River provided a preliminary description of the snagging-fishery catch. The sample was comprised of 29 female and 28 male paddlefish, of which 5 females contained eggs. Mean length of the catch was 776±9 mm (31 in) and mean length at age differed little among males and females (Table 4). Most females were in the 80 and 85-cm (31-33 in) length classes and most males were in the 70 and 75-cm (28-30 in) length classes (Figure 3). Ages ranged from 5 to 13 years and ages 8-11 were most common (Figure 4). The equation AGE=0.0178(LENGTH) – 4.085 (R^2=0.65, P<0.0001, F=99.99, N=57), where LENGTH = eye-fork length (mm) and AGE = age in years provided estimates of ages for known-length fish.

Indiana has a substantial sport paddlefish snagging fishery below Markland Dam at which 504 paddlefish were harvested in 1997. In addition, a few paddlefish are sport harvested annually from the Falls of the Ohio fossil bed area below McApline Dam.

The 2000-2001 Markland Tailwater creel surveys quantified the importance of the sport paddlefish fishery. Paddlefish anglers made 246 trips, or 16% of all angler trips even though the paddlefish season was only open during three of the six creel-survey months. By comparison, 50% of all trips were made anglers seeking Stizostedion spp. and those seeking Morone spp made 19% of all trips. Paddlefish anglers harvested 323 fish with a mean length of 772 mm, and a length range of 590 to 900 mm. Peak harvest was during March (53%), followed by February (31%), and April (16%).

Table 4. Mean length-at-age (mm) of paddlefish sampled from the sport snagging fishery Markland Tailwater, Ohio River, 1996.

	Length (mm) ± SE					
Age	Female	N	Male	N	Combined	N
5	579	1			579	1
7	674±25	2	699	1	682±17	3
8	672±17	2	707±9	5	697±10	7
9	748±4	2	738±4	8	740±4	10
10	821±11	9	778±10	7	802±9	16
11	792±16	10	792±16	5	820±13	15
12	835±55	2	838±66	2	836±35	4
13	831	1			831	1

Figure 3. Length-frequency distributions of a sub-sample sport-snagged paddlefish, Markland Tailwater, Ohio River, May 1996.

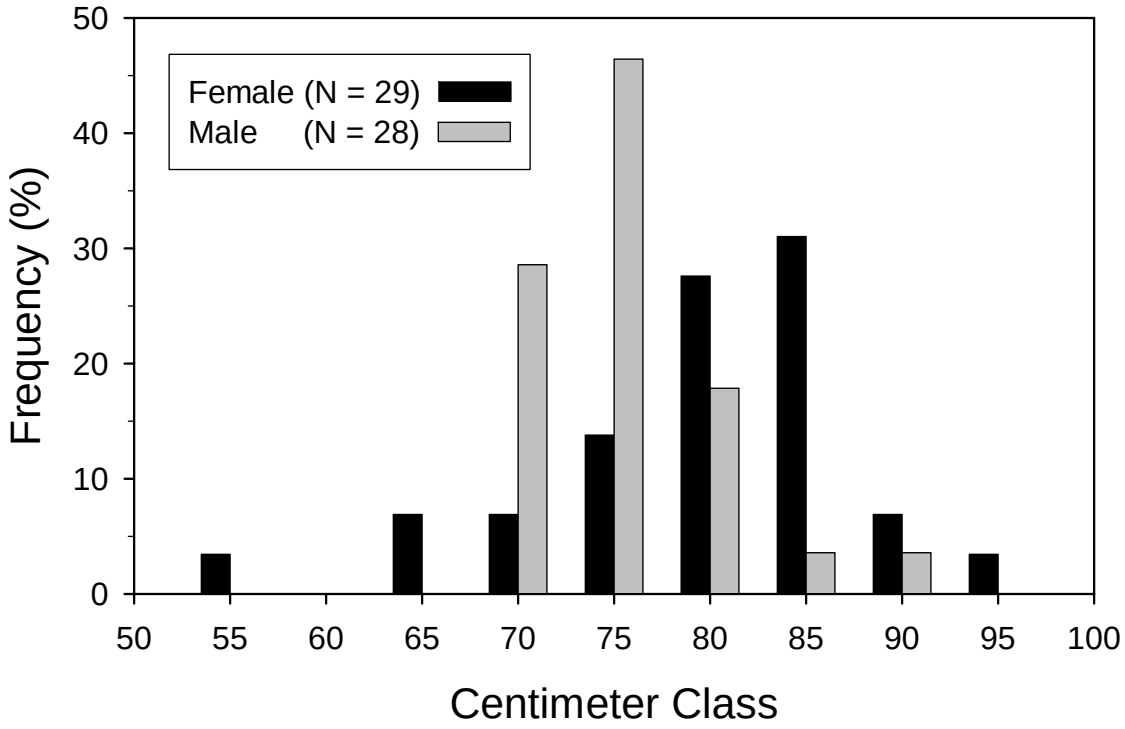
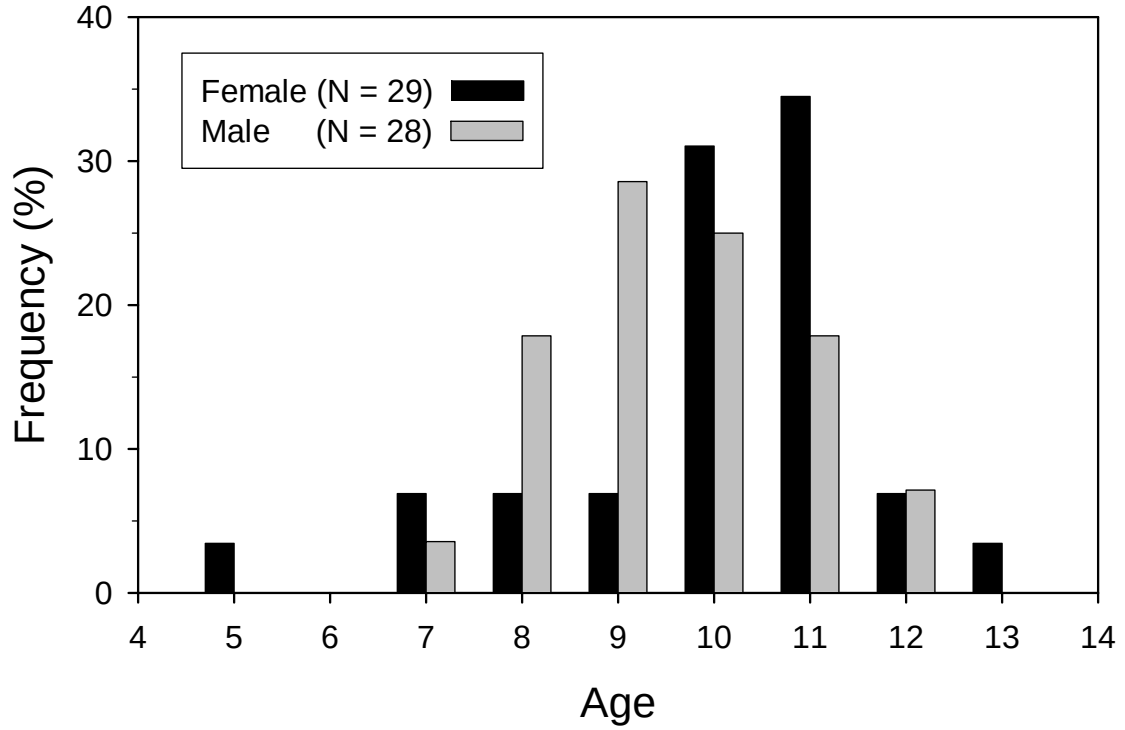


Figure 4. Age-frequency distributions of a sub-sample of sport-snagged paddlefish, Markland Tailwater, Ohio River, May 1996.



Commercial Fisheries

Commercial fishers in Kentucky, Indiana, and Illinois have been required to report harvest of paddlefish flesh and eggs since 1999. Prior to 1999, only fishers in Illinois reported harvest. However, Illinois fishers reported no egg harvest during any year of reporting, which suggested problems with their reporting or recording procedures because fishers are unlikely to discard paddlefish eggs. Licensed Kentucky commercial fishers, both residents and non-residents, accounted for 89% of the flesh and 80% of the eggs reported in the 1999 catch, and 90% of the flesh and 72% of the eggs reported in the 2000 catch. Some fishers licensed by Kentucky were residents of Indiana and Illinois (Table 5).

Total combined commercial harvest of flesh and eggs (Kentucky, Indiana, and Illinois) was greater during 2000 than 1999. Flesh harvest increased from 63,827 kg (140,419 lbs) in 1999 to 159,109 kg (350,040 lbs) in 2000, and egg harvest increased from 2,733 kg (6,013 lbs) 1999 to 10,071 kg (22,156 lbs) in 2000. Indiana data from 1999 and 2000, which provided the only estimate of the number of fish harvested in addition to the weight of the harvest, suggested that the mean size at harvest was 5.45 kg (12.11 lbs), or 710 mm (28 in), and mean age at harvest was 8.5 years. Based on this estimate, approximately 11,711 paddlefish were harvested in 1999 and 29,194 paddlefish were harvested in 2000. One Indiana crew of two fishers licensed through Kentucky reported a harvest 15,707 kg (34, 904 lbs) of flesh and 2,812 kg (6,248 lbs) of eggs during 2000, which represented 28% of the egg harvest during that year.

Table 5. Annual harvest (January-December) of paddlefish flesh and eggs reported by commercial fishers, Ohio River Sub-basin, 1995-2000.

	Kentucky (kg)		Indiana (kg)		Illinois (kg)		Total (kg)	
Year	Flesh	Eggs	Flesh	Eggs	Flesh	Eggs	Flesh	Eggs
1999	56,535	2,177	6,168	556	1,124	0	63,827	2,733
2000	143,175	7,255	14,113	2,816	1,821	0	159,109	10,071

*Kentucky records include harvest from the Ohio River, Kentucky Lake, and Lake Barkley.

The elevated harvest during 2000 was a reflection of increased effort and river conditions that were more conducive to harvest compared to the previous year. Ohio River fishers licensed by the KDFWR harvested approximately 0.03 fish/m in 313,323 m (1,044,411 ft) of gillnets during 1999 and 0.06 fish/m in 419,750 m (1,399,167 ft) of gillnets during 2000. The Ohio River mainstem represented 38% (1999) and 37% (2000) of the reported fishing effort in the Ohio River Sub-basin (excluding Tennessee), but provided the majority of flesh harvest in 1999 (84%) and 2000 (91%), as well as nearly all of the egg harvest. Catch rates of fishers in the Ohio River mainstem (0.03 fish/m of net) were also considerably greater than those in Kentucky Lake and Lake Barkley, which were less than 0.005 fish/m during both years in each reservoir. Lower catch rates in these reservoirs may have been a result of fishers targeting other species such as buffalo fishes *Ictiobus spp.* rather than paddlefish.

The paddlefish fishery in the Ohio River Sub-basin is a unique artisanal fishery because economic value of the fishery is derived primarily from paddlefish eggs as a source of caviar, rather than the value of paddlefish flesh. The flesh harvest was valued at US$69,616 in 1999 and US$175,020 in 2000 based on a current price of US$1.10/kg (US$0.50 per lb) paid to commercial fishers for whole fish. Retail price varies significantly depending upon processing and the market. For example, smoked paddlefish may sell for three to four times that of raw paddlefish fillets or steaks.

The estimated wholesale value of the total egg harvest ranged from US$273,300- US$546,600 in 1999 and US$1,007,100-US$2,014,200 in 2000 based on a historical price range of US$100-200 per kg (US$45-91 per lb) paid to fishers. Current retail price of paddlefish caviar (smallest quantity of order) is approximately US$423/kg (US$192/lb) (www.aristoff-cavair.com/price.htm; www.caviarstar.com/paddlefish.htm; www.northstarcaviar.com/northstar/orderform.htm), which suggested that the market value of the reported harvest from the Ohio River was US$1.2 million in 1999 and US$4.3 million in 2000.

Monthly harvest records from Kentucky and Indiana indicated that March-April were the period of greatest harvest, although significant harvest also occurred during October, November, and December (Figure 5). In 2000, a much greater percentage of flesh (45%) and eggs (67%) were taken during March - April than in the fall and winter months compared to 1999.

Paddlefish generally recruited to the fishery as they began to reach sexual maturity. A minimum of nine age groups was represented in the age structure estimated from a random sample of 76 commercially-caught fish from the McAlpine and Cannelton tailwaters. Full recruitment to the fishery likely occurs between ages 8 and 9 (Figure 6), but no lengths were associated with these data to provide additional details.

Figure 5. Monthly harvest of paddlefish eggs and flesh by commercial fishers in Kentucky and Indiana, 1999 and 2000, Ohio River Sub-basin.

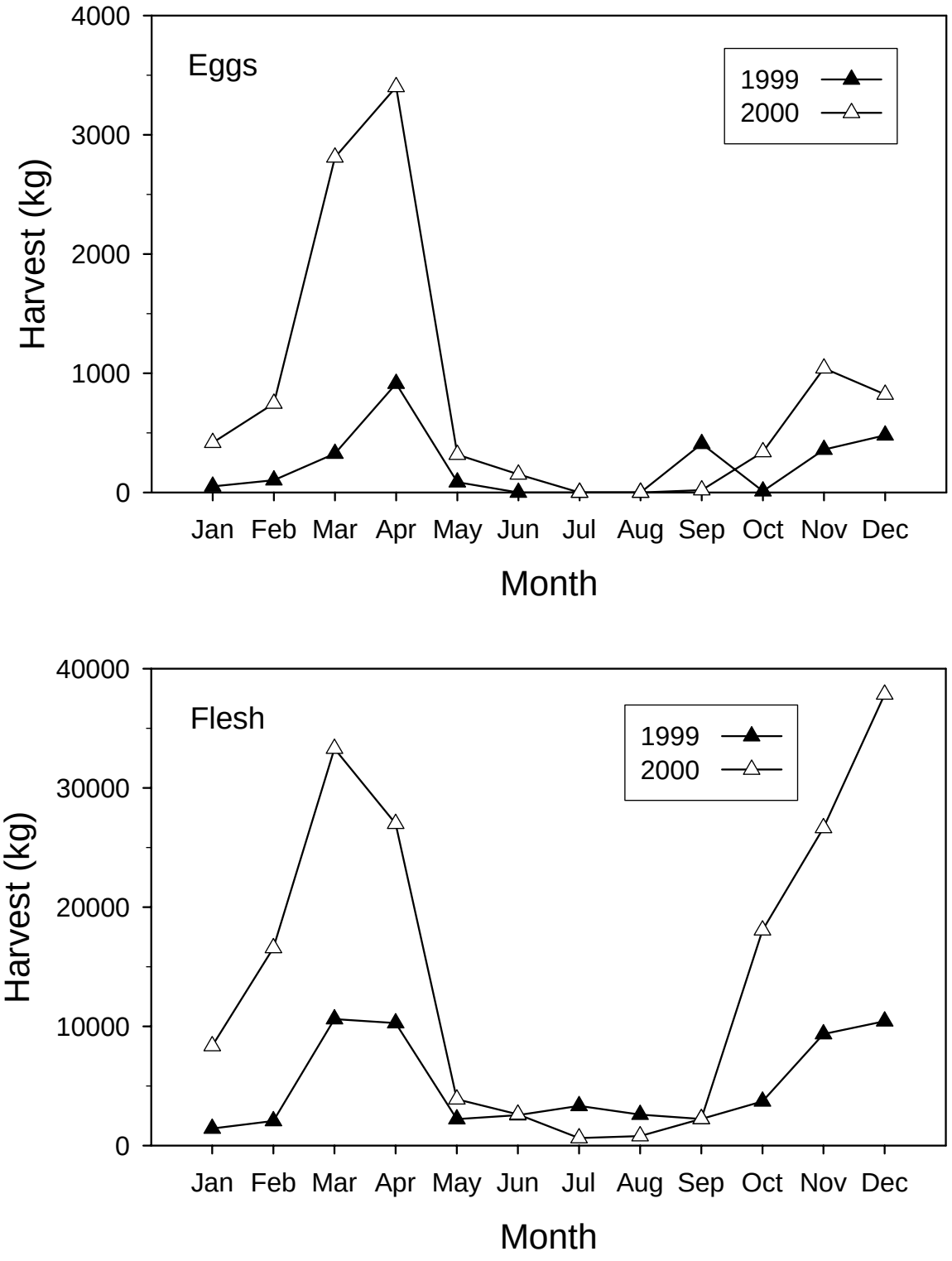
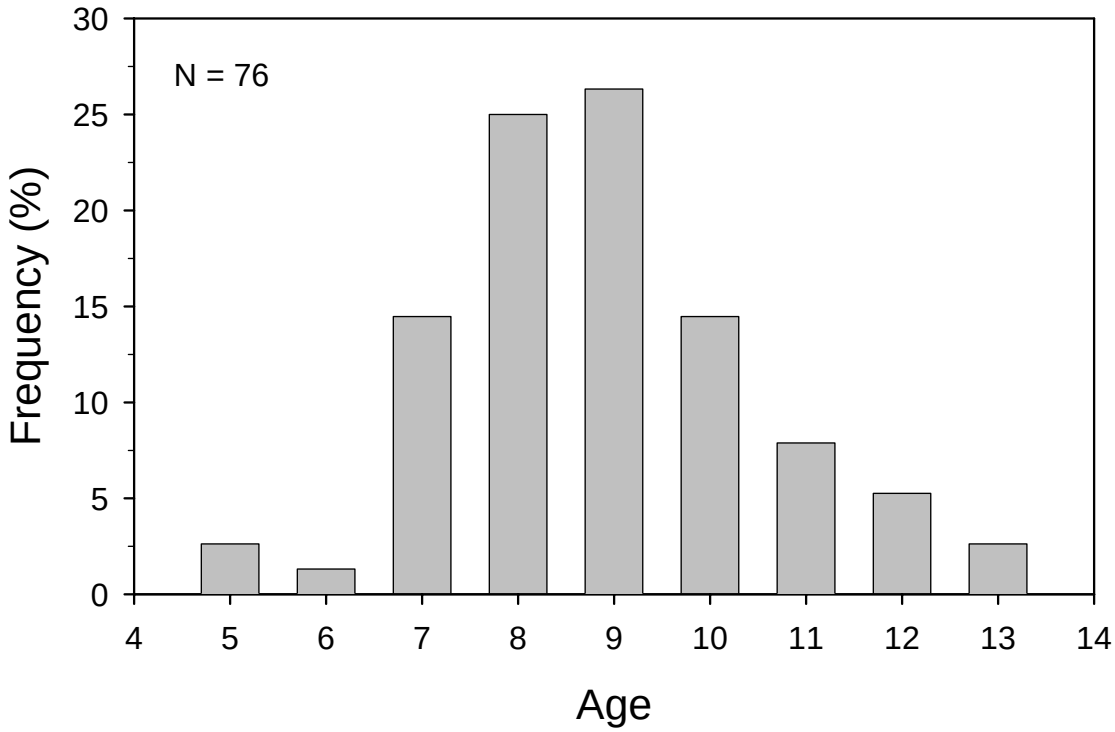


Figure 6. Age-frequency distribution of a random sample of commercially harvested paddlefish from the McAlpine and Cannelton tailwaters, Ohio River, 1996.



Field Sampling

Biologists in the Ohio River Sub-basin tagged 4,191 wild paddlefish with CWT during 1995-1999. Forty percent of these fish were tagged in pools of the Ohio River, 27% were tagged in Hovey Lake, 24% were tagged in the Wabash River, and 7% were tagged in the Cumberland River. Overall recapture rate during the five-year period was 5%, and was greatest in Hovey Lake (8%), followed by the Wabash River (7%), the Cumberland River (6%), and the Ohio River (3%). The majority of recovered paddlefish were captured within two years of the initial tagging. Twenty percent of these fish were recaptured one year after tagging, 44% were recaptured two years after tagging, and 23% were captured three years after tagging.

All CWT recaptures were initially captured and tagged in the Ohio River Sub-basin and no CWT-tagged Ohio River Sub-basin paddlefish have been reported from either the Mississippi River or the Missouri River systems. However, a few paddlefish tagged in other studies were recently reported to have moved great distances and traveled to and from the Ohio River Sub-basin. On July 17, 2001, a Kentucky angler captured a paddlefish in the Lake Barkley Tailwater that had been jaw-tagged in Lake Francis Case, South Dakota (Missouri River) in 1995. This fish passed through the dam of Lake Francis Case and the dam at Lewis and Clark Lake (Gavins Point, South Dakota) before reaching the Missouri River. Inter-basin movement was also documented by Timmons and Hughbanks (2000), who reported recaptures of paddlefish they tagged in the Kentucky Dam Tailwater in the Missouri River, near Jefferson City, Missouri (649 km (295 miles)) and another in the St. Francis River, Arkansas (584 km (265 miles)). One paddlefish they tagged in a Cumberland River sub-impoundment was also recaptured in the Osage River, Missouri, 902 km (410 miles) from the original tagging site.

Among paddlefish tagged by ORFMT states, wild paddlefish accounted for 192 of 197 CWT tag returns, and five recaptured hatchery fish were collected by biologists in West Virginia (Table 6). Seventy percent of recaptures were made by biologists sampling for the MICRA project and 30% were from rostrums turned in by commercial fishers. The greatest percentage of wild recaptures (41%) were collected during 1999 when the most tagged fish were at large, but 38% of all recaptures were from fish tagged during 1996 (Table 7). All recaptured hatchery-reared fish were originally stocked by WVDNR

Table 6. Recapture by state of wild tagged and hatchery tagged (stocked) paddlefish implanted with coded wire tags, Ohio River Sub-basin, 1995-1999.

	Wild tagged		Hatchery tagged		Recapture source		
State	Number	Percent	Number	Percent	Biologist	Commercial	Other
Illinois	25	13	0	0	25	0	0
Indiana	103	54	0	0	72	31	0
Kentucky	26	13	0	0	2	24	0
Ohio	29	15	0	0	29	0	0
West Virginia	0	0	5	100	3	1	1
Tennessee	9	5	0	0	6	3	0
Total	192		5		137	59	1

Table 7. Recapture by year of paddlefish implanted with coded wire tags, Ohio River Sub-basin, 1995-1999.

	Year recaptured					
Year tagged	1995	1996	1997	1998	1999	Total
Unknown	0	0	0	0	1	1
1995	3	8	8	4	8	31
1996		8	36	15	14	73
1997			5	17	21	43
1998				10	23	33
1999					11	11
Total	3	16	49	46	78	192

and recaptured near the stocking sites. Two of these fish were captured within 30 days of release and one was captured five months after release. The remaining two fish were captured 1.5 and 2.5 years after release within the same river reach.

Major upstream movement was more common among tagged paddlefish than major downstream movement. Twenty-six percent of paddlefish recaptures with known points of release and recapture were collected from major locations which differed from the original point of tagging (Table 8). Seventy percent of these fish moved upstream and thirty percent moved downstream, and some movement was extensive. One paddlefish tagged in the Smithland Pool was recovered five pools upstream in the Markland Pool, and had traveled a minimum of 483 km (290 miles) upstream passing through five high-lift navigation dams. Another paddlefish, tagged in the Greenup Pool, was recaptured five pools downstream in the Cannelton Pool, and had traveled a minimum of 526 km (316 miles). However, no paddlefish tagged downstream of Greenup Pool were recaptured upstream. Of 81 paddlefish originally tagged in Hovey Lake that were recaptured, 56 were recaptured in Hovey Lake, but 20 moved upstream, two moved downstream, and two were recaptured directly downstream in the Wabash River.

Paddlefish were captured primarily in 102-mm (4-inch) mesh (18%), 127-mm (5-inch mesh) (59%), and 152-mm (6-inch) mesh (>1%) entanglement gear and by electrofishing (17%) (Table 9). The 127-mm (5-inch) mesh entanglement gear was used to capture the greatest number of fish. Length-frequency distributions of the catch were gear-dependent (Figure 7) and mean lengths of paddlefish differed significantly among gears (ANOVA: $P<0.0001$, $F=257.09$, $df=3,923$; Duncan's Multiple Range Test, alpha=0.05). The greatest mean length of paddlefish captured with the primary gears was obtained with 127-mm (5-inch mesh) nets, followed by 102-mm (4-inch) mesh nets, and electrofishing. Differences in length distributions among gears precluded combining results from the three major gear types.

Paddlefish sampled in all three primary gear types tended to be larger than average in Hovey Lake and smaller than average in the Wabash River (Tables 10-12). Combined length-frequency distributions from 1995-1999 for each major location suggested that paddlefish size structure was not severely truncated after recruitment to the gear, but few larger fish were apparent in the Wabash River (Figure 8). However, annual length-frequency distributions of paddlefish captured with 127-mm (5-inch)

Table 8. General origin of tagging and point of recapture of 192 wild paddlefish collected from the Ohio River Sub-basin, 1995-1999.

	Tagging locations									
	Ohio River pools						Tributary rivers			
Recapture location	Smithland	Newburgh	Cannelton	Markland	Greenup	Hovey Lake	Wabash	Cumberland	Unknown	Total
Ohio River										
Smithland	0	0	0	0	0	2	0	0	0	2
Newburgh	2	7	1	0	0	17	0	0	0	27
Cannelton	0	3	5	2	1	3	0	0	0	14
Markland	1	0	3	36	0	0	0	0	1	41
Hovey Lake	2	1	2	3	0	56	1	0	0	65
Tributaries										
Wabash	0	0	0	0	0	2	24	0	0	26
Cumberland	0	0	0	0	0	0	0	5	0	5
Unknown	1	0	3	3	0	1	0	4	0	12
Total	6	11	14	44	1	81	25	9	1	192
Net movement										
Upstream	5	3	3	0	0	20	1	0		32
Downstream	0	1	3	5	1	4	0	0		14
No interchange	0	7	5	36	0	56	24	5		133

Table 9. Mean (±SE), minimum, and maximum lengths (mm) of paddlefish sampled by different types of gear, Ohio River Sub-basin, 1995-1999.

		Length (mm)		
Gear Type	N	Mean (± SE)	Minimum	Maximum
Entanglement gear				
76-mm (3-inch) mesh	9	788 ± 71	420	976
89-mm (3.5 inch) mesh	1	698	698	698
94-mm (3.7 inch) mesh	1	870	870	870
102-mm (4-inch) mesh	746	763 ± 4	271	1,150
107-mm (4.2 inch) mesh	1	910	910	910
117-mm (4.6 inch) mesh	1	940	940	940
127-mm (5-inch) mesh	2,508	803 ± 2	270	1,240
132-mm (5.2-inch) mesh	1	690	690	690
140-mm (5.5 inch) mesh	1	780	780	780
152-mm (6-inch) mesh	38	869 ± 23	526	1,092
Electrofishing	728	673 ± 7	168	1,311
Snagging	55	664 ± 12	420	791
Missing gear data	140			

Figure 7. Length-frequency distributions of paddlefish sampled with 102-mm (4-inch) mesh gillnets, 127-mm (5-inch) mesh gillnets, and electrofishing, Ohio River Sub-basin, 1995-1999.

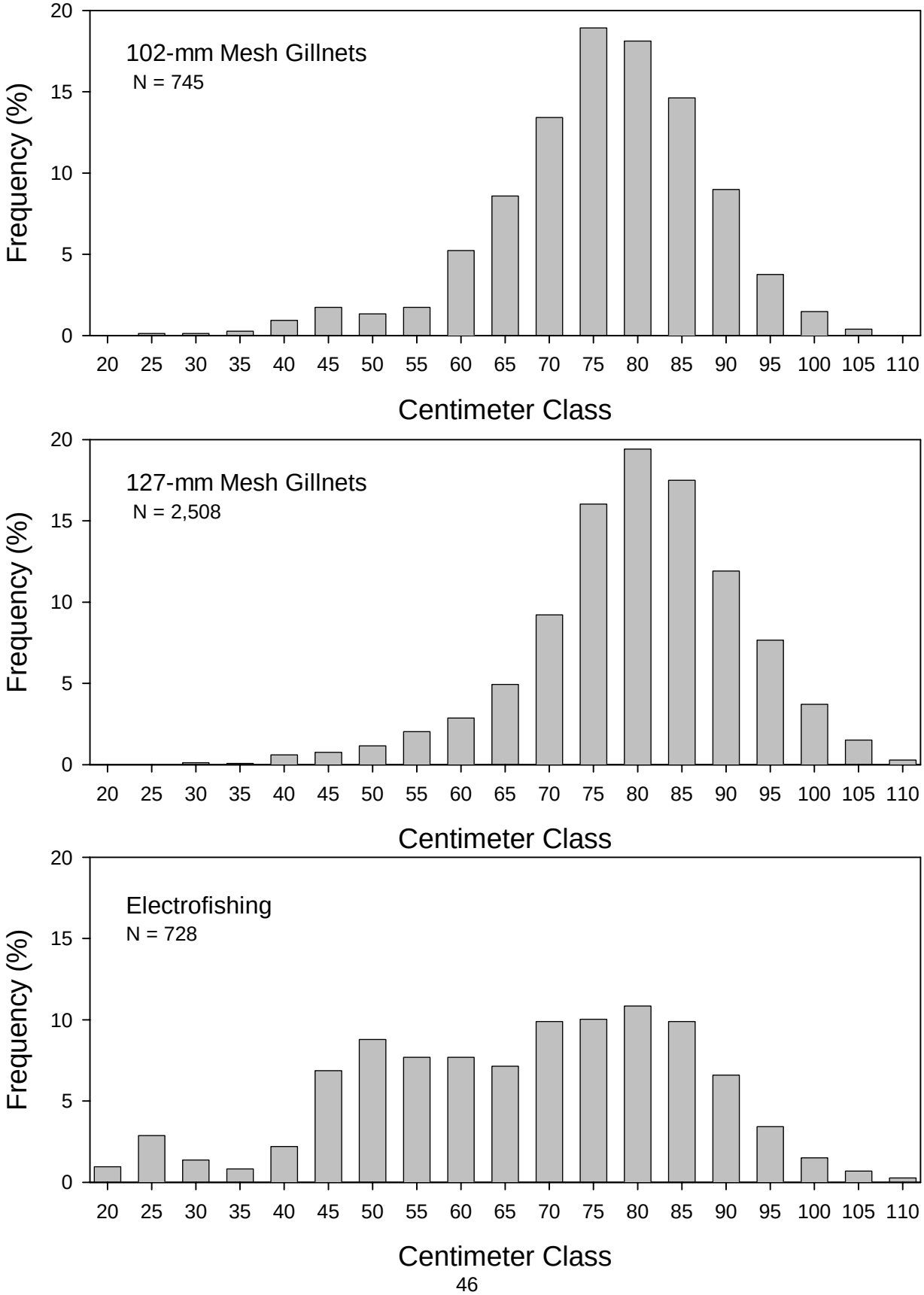


Table 10. Mean length (mm) ± SE and sample size (below) of paddlefish captured with 102-mm (4-inch) mesh gillnets by biologists, Ohio River Sub-basin, 1995-1999.

	Year					
Location	1995	1996	1997	1998	1999	All years
Ohio River		747 ± 40 12	514 ± 96 7		753 ± 26 20	708 ± 28 39
Hovey Lake	808 ± 35 9		827 ± 15 41	847 ± 13 64	838 ± 17 34	837 ± 8 148
Wabash River	694 ± 23 4	705 ± 39 3	770 ± 7 168	712 ± 8 217	778 ± 9 153	748 ± 5 545
Cumberland River						
Ohio River Sub-basin	773 ± 29 13	738 ± 32 15	772 ± 8 216	742 ± 7 294	786 ± 8 207	763 ± 4 745

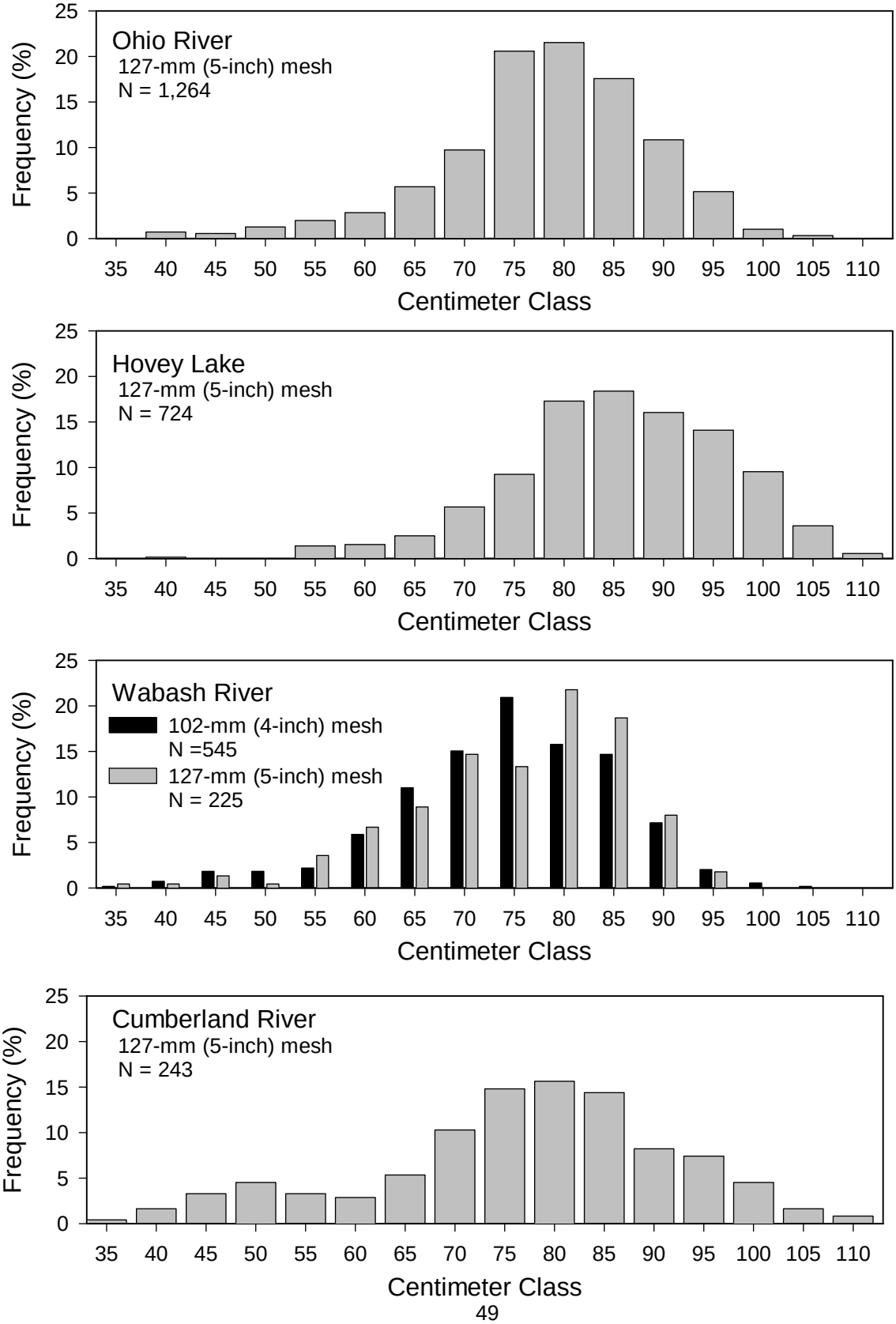
Table 11. Mean length (mm) ± SE and sample size (below) of paddlefish captured with 127-mm (5-inch) mesh gillnets by biologists, Ohio River Sub-basin, 1995-1999.

	Year					
Location	1995	1996	1997	1998	1999	All years
Ohio River	747 ± 15 91	776 ± 7 286	810 ± 6 276	798 ± 6 269	772 ± 5 342	785 ± 3 1,263
Hovey Lake	885 ± 13 74	863 ± 7 226	848 ± 9 156	857 ± 9 173	850 ± 11 95	859 ± 4 724
Wabash River	740 ± 36 3	741 ± 20 42		715 ± 14 66	789 ± 8 114	758 ± 7 225
Cumberland River	740 ± 21 82	817 ± 16 47	805 ± 48 10	762 ± 14 104		767 ± 10 243
Ohio River Sub-basin	796 + 10 265	809 + 5 612	824 ± 5 442	798 ± 5 618	789 ± 4 571	803 ± 2 2,508

Table 12. Mean length (mm) ± SE and sample size (below) of paddlefish captured by electrofishing, Ohio River Sub-basin, 1995-1999.

	Year					
Location	1995	1996	1997	1998	1999	All years
Ohio River	737 ± 16 100	291 ± 23 35	822 ± 17 57	795 ± 31 7	629 ± 45 10	682 ± 16 209
Hovey Lake	714 ± 18 44	771 ± 18 59	803 ± 18 57	754 ± 17 89		762 ± 9 249
Wabash River	632 ± 11 111	484 ± 64 13	496 ± 96 3	611 ± 31 31	540 ± 11 93	586 ± 8 251
Cumberland River	493 ± 43 5					493 ± 43 5
Ohio River Sub-basin	683 ± 9 263	582 ± 26 108	804 ± 13 117	708 ± 15 137	549 ± 11 103	673 ± 7 728

Figure 8. Length-frequency distributions of paddlefish sampled with gillnets in the Ohio River, Hovey Lake, Wabash River, and Cumberland River, Ohio River Sub-basin, 1995-1999.



mesh within the entire Ohio River Sub-basin (Figure 9) became progressively more truncated at larger sizes from 1995 to 1999. The frequency of large fish captured was lowest during 1999. Likewise, the size structure of paddlefish captured with 127-mm (5-inch) mesh within the Ohio River (Figure 10), and the sub-set of Ohio River data that included only Hovey Lake (Figure 11), indicated similar patterns. Sufficient data were not available from the Wabash or Cumberland rivers for similar comparisons.

Total catch-per-effort of all paddlefish captured with 127-mm (5-inch) mesh entanglement gear was 0.03 fish/m of net for the entire Sub-basin during 1995-1999, similar to that reported by commercial fishers. The greatest catch rates were in Hovey Lake (0.10 fish/m of net) and the Wabash River (0.06 fish/m of net). Lower rates of capture were in the Ohio River (0.03 fish/m of net) and the Cumberland River (0.02 fish/m of net).

The Ohio River sample was comprised of progressively fewer age-10 and older paddlefish from 1997 through 2001 (Figure 12). The percentage of age 10-14 paddlefish sampled by biologists with 127-mm (5-inch mesh) entanglement gear peaked at 71% in 1997 and progressively decreased by 2-12% annually to a low of 46% in 2001. Total annual mortality (ages 10-14) ranged from 47-68% during 1995-2001, with a mean of 55% (SE=3). Hoffnagle and Timmons (1989) observed 69% total annual mortality in the Tennessee River following heavy fishing pressure and high egg prices and considered that rate indicative of overharvest. Total annual mortality of an unexploited population of paddlefish in the upper Mississippi River was 27% (Runstrom et al. 2001) and of a lightly exploited population in Keystone Reservoir, Oklahoma ranged from 27-34% (Paukert and Fisher 2001). Results of these studies suggested that within the Ohio River Sub-basin, paddlefish exploitation from sport and commercial fisheries significantly contributed to total annual mortality during 1995-2001.

Our mortality estimates suggested that current exploitation rates may be a concern, but these data must be interpreted with caution for two primary reasons. First, the age estimates were based upon predictions of age at length from a small sample of the sport fishery catch in one location during 1996. And second, the estimates did not separate male and female paddlefish, for which there is clearly discriminate harvest and likely differential mortality. The intent of these analyses was to provide a glance

Figure 9. Length-frequency distributions of paddlefish sampled with 127-mm (5-inch) mesh gillnets, Ohio River Sub-basin, 1995-1999.

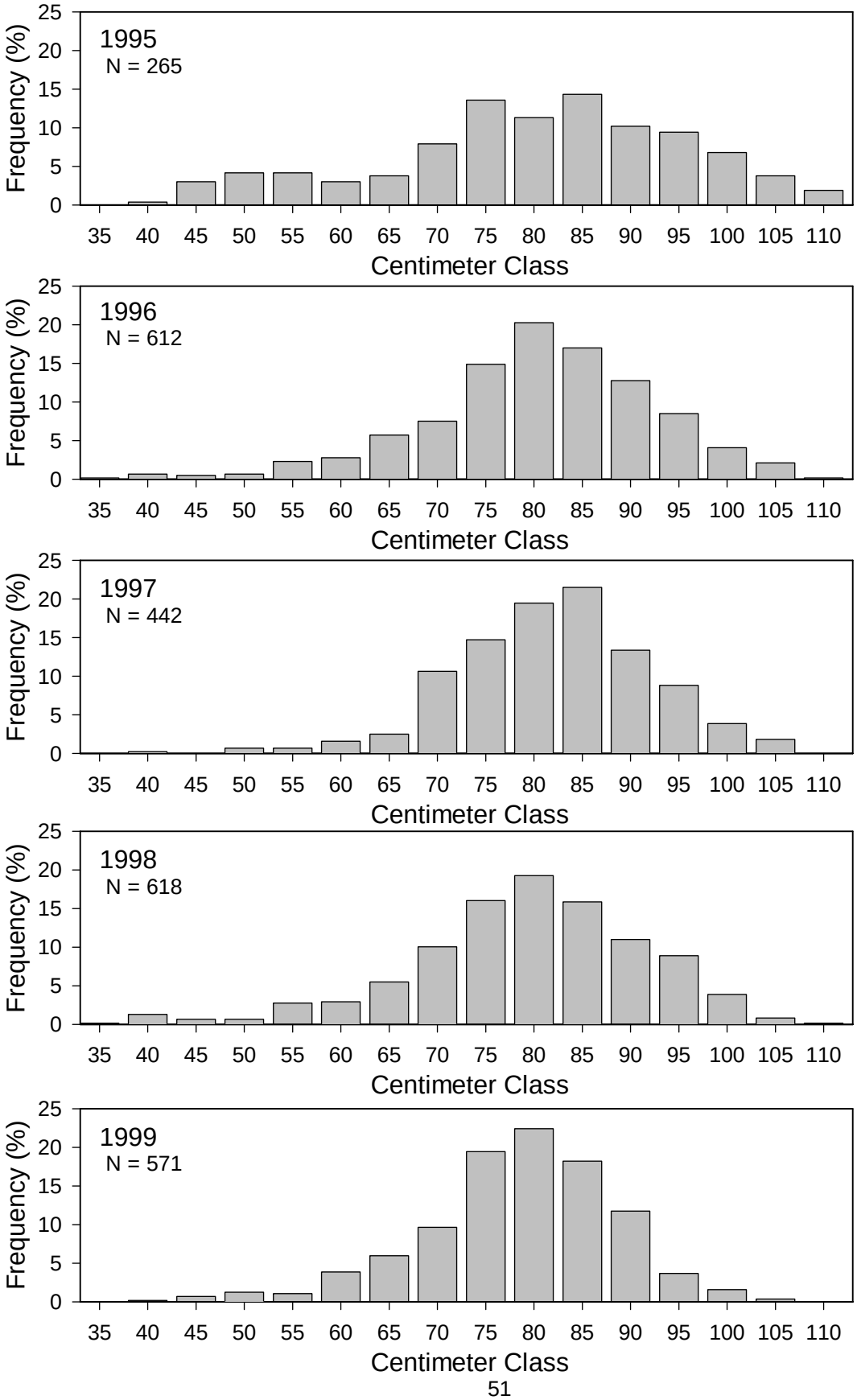


Figure 10. Length-frequency distributions of paddlefish sampled with 127-mm (5-inch) mesh gillnets, Ohio River, 1995-2001.

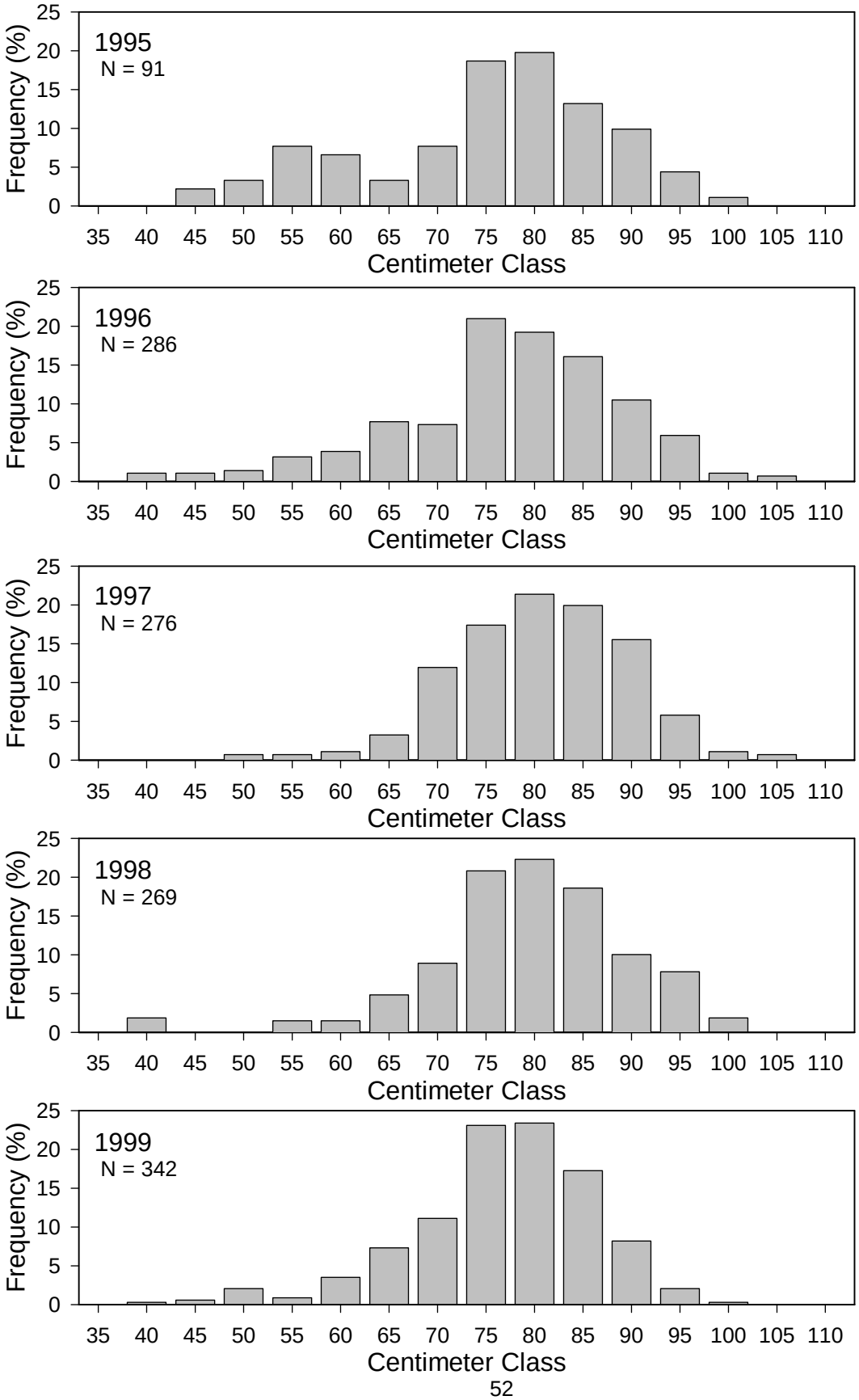


Figure 10 (continued). Length-frequency distributions of paddlefish sampled with 127-mm (5-inch) mesh gillnets, Ohio River, 1995-2001.

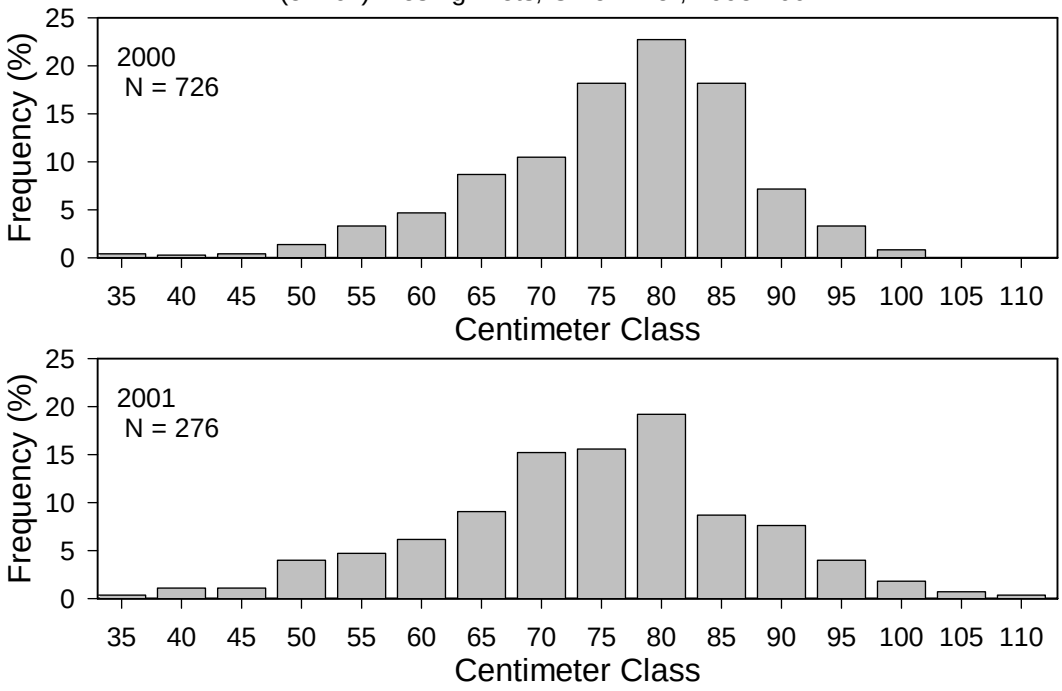


Figure 11. Length-frequency distributions of paddlefish sampled with 127-mm (5-inch) mesh gillnets, Hovey Lake (Myers Pool, Ohio River), Ohio River Sub-basin, 1995-1999.

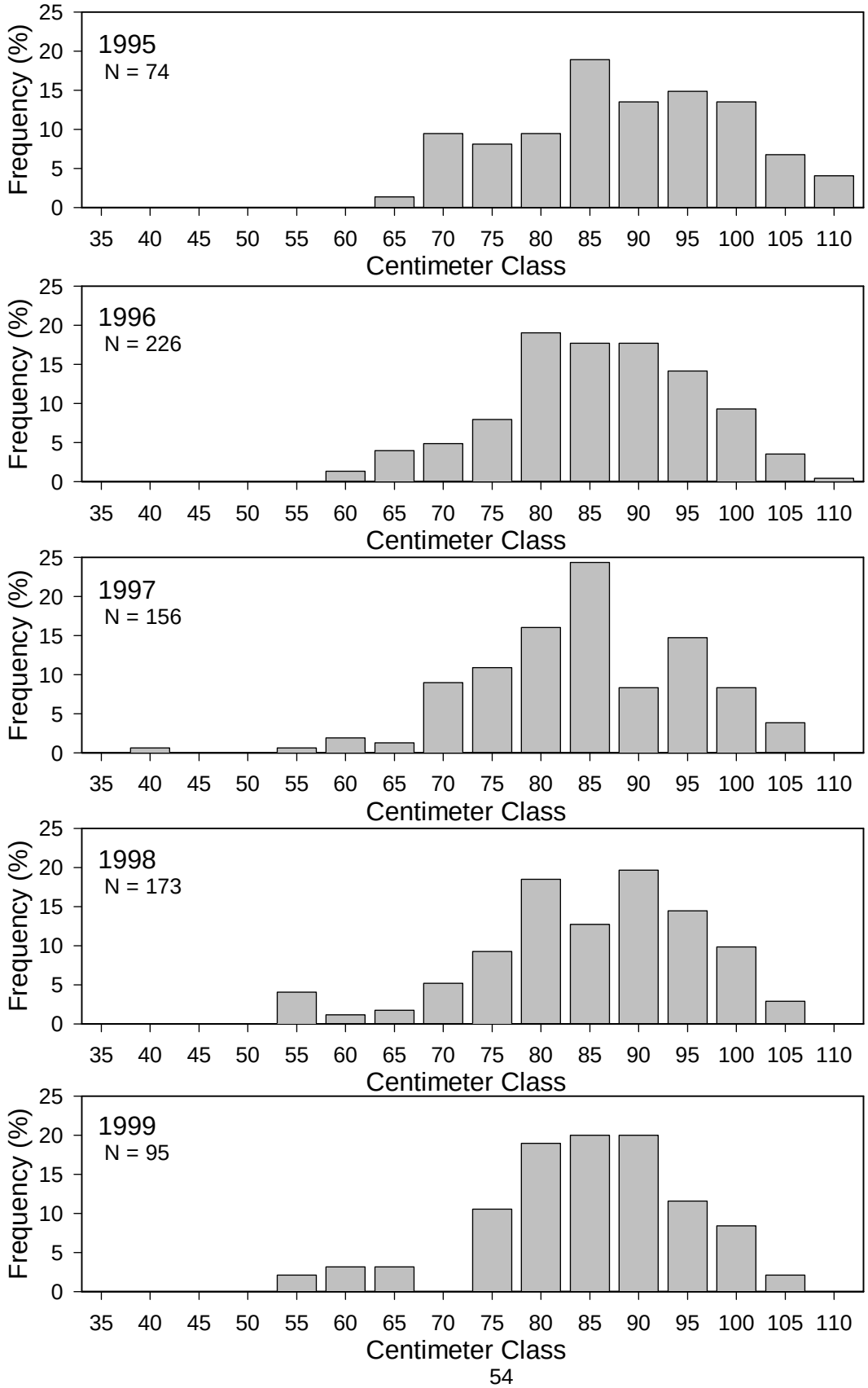


Figure 12. Estimated age-frequency distributions of paddlefish sampled with 127-mm (5-inch) mesh gillnets and estimated instantaneous mortality (Z) and total annual mortality (A), Ohio River, 1995-2001.

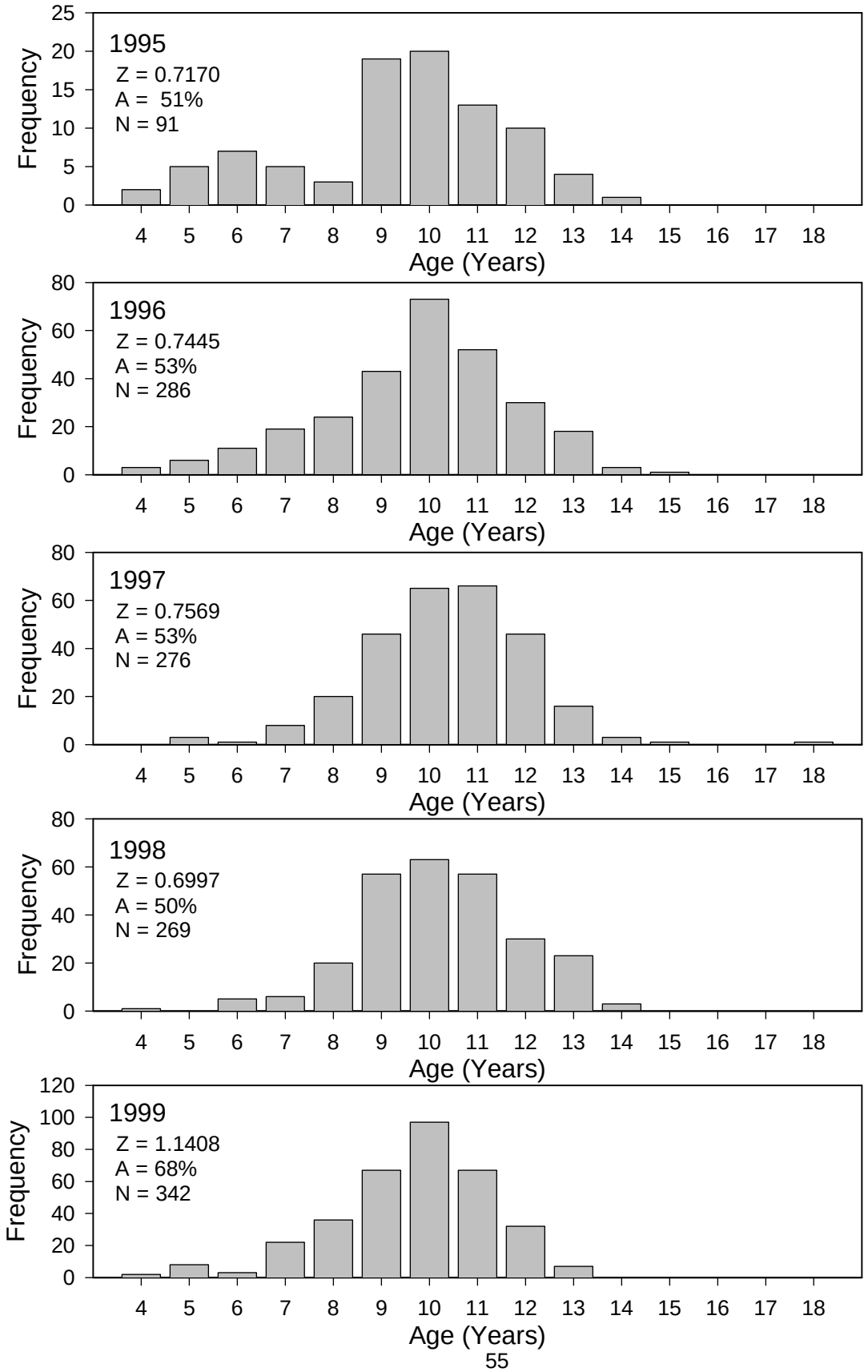
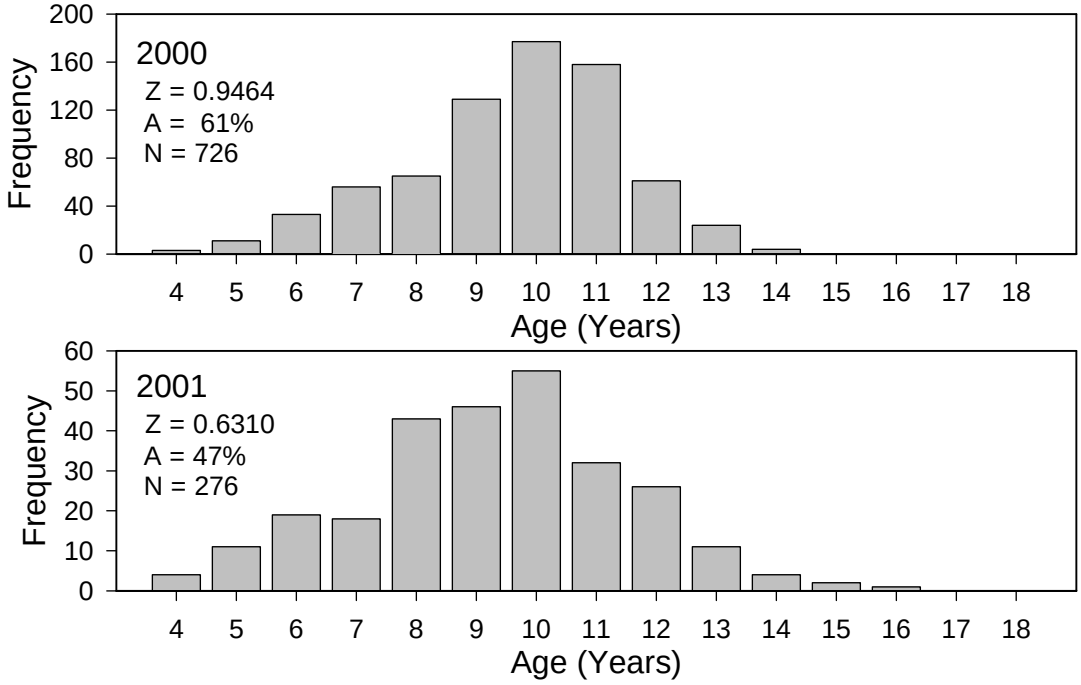


Figure 12 (continued). Estimated age-frequency distributions of paddlefish sampled with 127-mm (5-inch) mesh gillnets and estimated instantaneous mortality (Z) and total annual mortality (A), Ohio River, 1995-2001.



at mortality through a standardized approach using the only available data. We do so with a clear understanding of the shortcomings of these estimates of age structure and annual mortality.

The paucity of large paddlefish sampled, limited number of older fish estimated in the samples, and high total annual mortality were indicative of a population exposed to excessive harvest. These data suggested that the current level of harvest is pushing the limit of sustainable harvest for optimal sustainable yield.

Body condition of paddlefish, expressed as relative weight (Wr), ranged from 95-99 among all size categories and locations indicating good condition of paddlefish within the Ohio River Sub-basin (Table 13). Relative weight for paddlefish of all lengths combined was significantly greater in Hovey Lake than the Ohio River, Cumberland River, or Wabash River, similar between the Ohio River and Cumberland River, and lowest in the Wabash River (ANOVA: $P<0.001$, $F=37.53$ df=3,835; Tukey's procdudure $P<0.05$). Paddlefish less than 600 mm had similar relative weights in Hovey Lake, the Wabash River and the Ohio River; but, those in Hovey Lake and the Wabash River were greater than those in the Cumberland River (ANOVA: $P=0.01$, $F=3.82$, DF=404; Tukey's procedure $P=0.05$). Other differences among length classes of the four locations were minimal.

Length-weight relations of fish in each location were described by polynomial and $\log_{10}$transformed equations (Table 14). Plots of the polynomial equations demonstrated the slight differences in length-weight relations among locations (Figure 13). Differences detected in relative weights among paddlefish were minimal from Hovey Lake, Ohio River, Cumberland River, and Wabash River, so investigators could justify the use of one length-weight equation for the entire Sub-basin, or separate equations for each habitat, to estimate weight of individual fish. Tables were provide as quick references for estimating paddlefish weight based on length for 400-1,300 mm (16-51 in) fish in each location and the entire sub-basin (Appendix I and Appendix J).

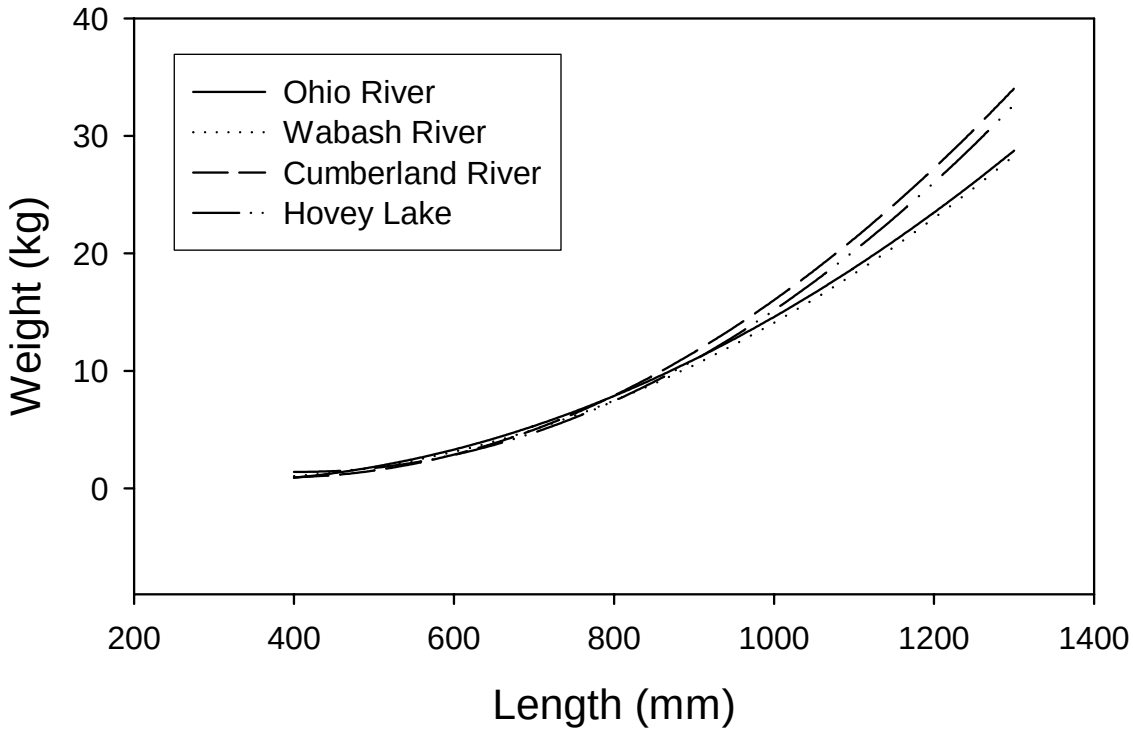
Table 13. Relative weight (Wr) ± SE and sample size (below) of paddlefish in the Ohio River Sub-basin, 1995-1999.

	Relative weight ± SE (sample size below)				
Location	< 600 mm	600-799 mm	800-999 mm	>999 mm	All Lengths
Ohio River	98 ± 0.4 122	98 ± 0.1 707	98 ± 0.1 654	98 ± 0.5 9	98 ± 0.1 1,492
Hovey Lake	98 ± 0.3 53	98 ± 0.1 322	98 ± 0.1 682	99 ± 0.1 84	98 ± 0.0 1,141
Wabash River	98 ± 0.2 214	97 ± 0.1 504	98 ± 0.1 307	95 ± 0.1 2	97 ± 0.1 1,027
Cumberland River	96 ± 0.8 16	98 ± 0.3 69	98 ± 0.3 79	99 ± 0.5 12	98 ± 0.2 176
Ohio River Sub-Basin	98 ± 0.2 420	98 ± 0.1 1,638	98 ± 0.0 1,745	99 ± 0.1 112	98 ± 0.0 3,915

Table 14. Polynomial and $\log_{10}$ transformed length-weight equations for paddlefish, Ohio River Sub-basin (L=length, mm; LSQ= length (mm) squared; W=weight, kg).

Location	Equation	N	R^2
Ohio River	$W = 2.587 – 0.015L + 2.701x10^{-5}LSQ$	1,492	0.82
	$Log_{10}W = -7.790 + 2.983Log_{10}L$	1,492	0.93
Hovey Lake	$W = 7.932 – 0.032L + 3.923x10^{-5}LSQ$	1,141	0.90
	$Log_{10}W = -8.193 + 3.126Log_{10}L$	1,141	0.93
Wabash River	$W = 3.695 – 0.018L + 2.840x10^{-5}LSQ$	1,027	0.87
	$Log_{10}W = -7.823 + 2.986Log_{10}L$	1,027	0.94
Cumberland River	$W = 6.357 – 0.029L + 3.867x10^{-5}LSQ$	283	0.85
	$Log_{10}W = -8.929 + 3.376Log_{10}L$	283	0.91
Ohio River Sub-basin	$W = 5.288 – 0.025L + 3.470x10^{-5}LSQ$	3,915	0.87
	$Log_{10}W = -8.055 + 3.074Log_{10}L$	3,915	0.94

Figure 13. Length-weight relations for paddlefish in four locations of the Ohio River Sub-basin, 1995-1999.



Contaminant Monitoring

Organic chemical and heavy metal contamination of fish flesh from the Ohio River has been suspected since the early 1960s. Fish flesh from the upper two-thirds of the river was anecdotally reported to have objectionable tastes that were described as oily, muddy, or gasoline flavors (Pearson and Krumholz 1984). By 1977, ORSANCO began preliminary examination of fish flesh for polychlorinated biphenyl (PCB) and chlordane, and found contaminant levels in some fishes that warranted more extensive analysis, particularly in the upper reaches of the river (ORSANCO 1977).

In the late 1980s, the U.S. Food and Drug Administration (FDA) established the action levels of 2.0 ug/g for PCB and 0.3 ug/g for chlordane in fish tissue. Contaminant concentrations at or greater than these levels were considered unsafe for human consumption. State agencies in the Ohio River Sub-basin, in conjunction with ORSANCO, began collecting fish flesh and reporting contaminant level advisories to the public in 1987, although paddlefish were not initially included in these advisories. Researchers began to test paddlefish flesh and eggs in the Kentucky portion of the Ohio River as market demand for these fishery products increased. Gundersen and Pearson (1992) found PCB in paddlefish white and red muscle, and gonads (Table 15). They determined that red muscle concentrations of PCB (1.98-6.30 ug/g) were greater than white muscle concentrations (0.05-3.35 ug/g) because lipid concentrations were greater in red muscle, and found the FDA action limit exceeded in white muscle of only one sample. Gundersen and Pearson (1992) also theorized that the high lipid content in ovaries and testes made gonads strong concentrators of these lipophilic contaminants. Upon evaluation, they found considerably greater concentrations of PCB in testes (5.63-23.00 ug/g) than ovaries (0.05-18.70 ug/g). The elevated levels of PCB in paddlefish reproductive tissue became a concern for both human health reasons, because fishery products are consumed, and paddlefish population reasons, because contamination may affect paddlefish reproductive success.

The KDFWR, Kentucky Division of Water (KDW), and Kentucky Cabinet for Health Services (KCHS) responded to the preliminary findings of Gundersen and Pearson (1992) by implementing more extensive tests of paddlefish tissue. The KDFWR sampled paddlefish flesh and eggs from the Ohio River for contaminant analysis and the KCH, Division of Laboratory Services tested samples for Chlordane and

Table 15. Polychlorinated biphenyl (PCB) contaminant levels (ug/g) in paddlefish tissue, McAlpine Tailwaters, Ohio River, 1988-1989 (Gunderson and Pearson 1992).

Tissue	Sex	N	PCB (ug/g)
Eggs	F	12	0.05-18.70
Testes	M	5	5.63-23.00
Red muscle	F	4	1.98-6.30
White muscle	F	13	0.05-1.03
White muscle	M	19	0.05-3.35

PCB in 1990 (36 fish) and 1991 (18 fish). Egg samples from both years exceeded the action levels for chlordane with levels that ranged from 0.03 ug/g to 1.07 ug/g (Table 16), but PCB concentrations remained under the action level, despite elevated levels in some samples. Paddlefish were listed on the river-wide consumption advisory as not recommended for consumption in 1991 because of these results.

In 1998-1999, the KDFWR, KDW, and KCHS continued cooperative evaluation of contaminant levels (Table 17). Sampling methods and sites were similar to those of the 1990-1991 study. In 1998, the FDA relaxed chlordane action levels to 18.9 ug/g, whereas the PCB action level remained at 2.0 ug/g. Paddlefish contaminant levels (flesh and eggs) were considerably lower in the 1998-1999 study than the 1990-1991 study. Egg chlordane levels were below the action level and ranged from 0.02 to 0.51 ug/g. Polychlorinated biphenyl levels, although not exceeding the action level of 2.0 ug/g, remained elevated (range in eggs, 0.10-1.78 ug/g; range in fillets (0.10-1.72 ug/g) and remained the primary source of organochlorine contaminant advisories.

The consumption status of paddlefish products was modified in 2000. After being listed as "do not eat" for 10 years, paddlefish flesh and egg consumption advisories were relaxed to 6 meals per year in the lower two thirds of the Ohio River. Paddlefish eggs still contain elevated levels of PCB and should

Table 16. Contaminant levels (ug/g) of chlordane and polychlorinated biphenyl (PCB) in paddlefish eggs and fillets (flesh) from Ohio River tailwaters, 1990-1991 (Kentucky Cabinet for Health Services, Division of Laboratory Services).

Location (Tailwater)	Year	Sex	N	Mean length (mm)	Mean weight (kg)	Eggs (ug/g)		Fillets (flesh, ug/g)	
						Chlordane	PCB	Chlordane	PCB
Meldahl[a]	1990	F	10	953	11.520	0.27-1.07	0.33-1.44	0.06-0.55	Tr*-0.99
McAlpine[a]	1990	F	4	892	9.855	0.11-0.60	Tr*-1.5	0.11-0.27	0.24-0.40
Cannelton[b]	1990	F	2	897	11.070	0.51	0.73	0.22	0.23
Newburgh[b]	1990	F	10	965	13.815	0.03	0.56	0.11	0.12
Smithland[b]	1990	F	10	945	12.825	0.04	Tr	0.17	0.17
Greenup[a]	1991	F	1	978	12.150	0.45	1.20	0.11	[c]
Greenup[a]	1991	M	2	864	8.550			0.19-0.20	[c]
Markland[a]	1991	F	2	914	11.250	0.49-0.65	1.14-1.60	0.16-0.31	0.17-0.42
Markland[a]	1991	M	5	836	6.525			0.13-0.36	0.17-0.65
Cannelton[a]	1991	F	3	960	15.300	0.06-0.30	0.48	0.12-0.24	0.47-0.53
Newburgh[a]	1991	F	1	919	13.050	0.54	[c]	0.13	[c]
Newburgh[b]	1991	M	4	737	5.220			0.03-0.06	[c]

*reported as “trace” with no value given
[a] samples not composited
[b] samples composited
[c] not reported

Table 17. Contaminant levels (ug/g) of chlordane and polychlorinated biphenyl (PCB) in paddlefish eggs and fillets (flesh) from Ohio River tailwaters, 1998-1999 (Kentucky Cabinet for Health Services, Division of Laboratory Services[1]).

Location (Tailwater)	Year	Sex	N	Mean length (mm)	Mean weight (kg)	Eggs (ug/g)		Fillets (flesh, ug/g)	
						Chlordane	PCB	Chlordane	PCB
Greenup[a]	1998	F	5	947	11.790	0.17-0.26	0.10	0.05-0.15	0.10
Meldahl[a]	1998	F	2	907	10.260	0.18-0.19	0.10	0.05-0.19	0.10
Markland	1998	F	1	932	11.700	0.05	0.10	0.12	0.10
McAlpine	1998	F	1	820	8.550	0.13	0.10	0.09	0.10
Myers	1998	F	4	912	13.275	0.05-0.09	0.10	0.05-0.13	0.10
Smithland[a]	1998	F	2	884	10.890	0.05	0.10	0.05	0.10
Myers[b]	1998	M	3	701	4.995			0.06	0.10
Smithland[b]	1998	M	3	742	4.770			0.02	0.10
Meldahl[a]	1999	F	5	897	9.900	0.13-0.21	0.70-1.68	0.08-0.22	0.15-1.53
McAlpine[a]	1999	F	42	897	10.710	0.21-0.32	0.59-1.78	0.10-0.22	0.25-1.72
Myers[a]	1999	F	5	904	12.375	0.10-0.51	0.45-0.82	0.06-0.26	0.28-1.50

[1] Male paddlefish samples were collected at the same time as the female samples, but analysis of the fillets was performed by the Illinois Environmental Protection Agency.
[a] samples not composited
[b] samples composited

be consumed with caution. News releases from state agencies along the Ohio River currently recommend that pregnant women, nursing mothers and their infants, and children do not eat paddlefish eggs or flesh, and women who may be, or plan to become, pregnant are also advised to avoid similar consumption.

Concentrations of contaminants in Ohio River paddlefish may pose physiological problems for paddlefish. The contaminant levels observed in paddlefish gonads during 1989 and 1990 were much greater than those found in flesh samples (Gundersen and Pearson 1992), suggesting reproductive implications of contamination. Likewise, recent findings by Gundersen et al. (1998) confirmed high PCB concentrations in gonadal tissue (Table 18). Although they could not identify a significant reduction in hatch related to organochlorine contamination in spawning experiments, the greatest percent hatch was observed in eggs that had the lowest PCB and chlordane concentrations. Gundersen et al. (2000) also found that PCB and chlordane concentrations in paddlefish gonads were greater in the Ohio River than the Cumberland River, a less industrialized river, and suggested that organochlorine (PCB and chlordane) exposure may jeopardize the long-term health of Ohio River paddlefish.

Table 18. Contaminant levels (ug/g) of chlordane and polychlorinated biphenyl (PCB) in paddlefish eggs, immature ovaries, and testes, Ohio River, 1996 (Gunderson et al. 1998).

			Eggs (ug/g)		Immature ovary (ug/g)		Testes (ug/g)	
Location	Sex	N	Chlordane	PCB	Chlordane	PCB	Chlordane	PCB
Markland Pool	F	3	0.69	1.10	0.26	3.85		
Markland Pool	M	3					0.22	4.43
Meldahl Tailwater	F	3			0.29	3.80		
Meldahl Tailwater	M	1					0.26	2.40
McAlpine Tailwater	F	3	0.46	0.59				
Myers Tailwater	F	2	0.27	0.28				

Recommendations of the ORFMT Technical Committee

Paddlefish have persisted in the Ohio River Sub-basin despite severe habitat degradation over the past two centuries. Deforestation of watersheds, dewatering of backwater habitats, dam construction, contamination of water with industrial effluents and septic waste, and destruction of gravel bars have challenged the continued viability of paddlefish populations. As water quality in the Ohio River and its major tributaries has improved and habitat alterations have slowed, environmental conditions are no longer the greatest threat to paddlefish. The most significant current threat to paddlefish is excessive exploitation, both legal and illegal, and coordinated management and improved commercial fishery monitoring are necessary to reduce this threat.

Exploitation of paddlefish increases quickly in response to market demand for caviar, because incentives for profit are great and barriers to fishery entry are minimal. Current market prices provide substantial incentive for legal or illegal entry into the fishery. A 9-kg (20-lb) female paddlefish may be worth as much as US$400 wholesale, and US$768 retail. By contrast, a resident commercial fishing license costs US$35-125, a gillnet suitable for harvesting paddlefish costs slightly more than US$100, and minimal equipment is required for a fisher with a small boat. Given adequate market incentive and river conditions that facilitate fish capture, harvest of flesh and eggs can triple from one year to the next, as indicated by the commercial harvest reported in 1999 and 2000.

Paddlefish egg prices are projected to increase in response to a dwindling global supply of sturgeon caviar. The supply of the highest grades of sturgeon caviar from the Caspian Sea will decrease if Russia, Azerbaijan, Kazakhstan, and Turkmenistan conform to a harvest freeze and reduce illegal harvest, as desired by the United Nations CITES Committee. Supply of Caspian Sea sturgeon caviar has declined precipitously during the past two decades because of stock collapse, and rapid stock recovery is unlikely; therefore, increased demand for paddlefish eggs as a substitute product will not be a short-term phenomenon.

Current harvest levels of paddlefish in the Ohio River Sub-basin are not well quantified, but estimates of total annual mortality from fish sampled by biologist are a “red flag”, warning against increases in exploitation. Total annual mortality rates that ranged from 47-68% during 1995-2001 were

indicative of a population exposed to extensive harvest. Annual mortality rates higher than these would not be compatible with a sustainable fishery for paddlefish because these fish require 6-10 year to reach sexual maturity, lived up to 30 years, and require more than one year to develop mature ova. Our estimates of mortality were twice as high as recent estimates from populations without strong sport or commercial harvest components (Paukert and Fisher 2001; Runstrom et al. 2001). Therefore, despite the decline in commercial license sales observed in Kentucky and Indiana during the past decade, current levels of fishing activity impact the population.

Paddlefish move both upstream and downstream in the Ohio River, and interchange of pools is not uncommon. During our five-year tagging study, one-fourth of recaptured paddlefish were collected from a pool upstream or downstream of the original point of tagging, and some fish passed through multiple lock and dam structures. These results confirm that paddlefish are a shared fishery resource throughout much of the Ohio River Sub-basin. In addition, movement of paddlefish to the Missouri and Mississippi rivers from the Ohio River Sub-basin, and movement in the opposite direction, has been documented.

Paddlefish are an inter-jurisdictional resource in the Ohio River, yet are managed differently by border-states. States in the upper reaches of the Ohio River have historically lower paddlefish abundance coupled with more dam construction, leading to protection and restoration efforts. Kentucky, with its large shoreline and long history of commercial fishing, has historically supported the most extensive Ohio River paddlefish fishery. Therefore, state management perspectives evolved along a longitudinal gradient of the river and current management practices range from “stock and protect” in the upper reach, to “protect” and “harvest” in the middle reach, and “harvest” in the lower reach.

<u>We recommend the following based upon this report</u>:

- Establish full participation of all Ohio River Sub-basin states in cooperative management of paddlefish.
- Continue paddlefish management as directed by the 2002-2010 strategic plan.
- Encourage states stocking paddlefish in the Ohio River Sub-basin to use only Ohio River broodstock to promote a conservative approach to protection of genetic integrity of the stock.
- Improve procedures for oversight and assessment of commercial fisheries.

- Continue to work closely with law enforcement officials to monitor and curtail illegal activities.
- Align sport fishery regulations for paddlefish among Ohio River states permitting fisheries.
- Monitor retail and wholesale prices of eggs and caviar and CITES exporting permits for sturgeon and paddlefish.
- Continue participation in the MICRA Paddlefish/Sturgeon Sub-committee and national paddlefish study through 2010, but modify sampling protocols.
- Annual review of strategic and operational plans.
- Annual reporting of results from operational plans, commercial and sport harvest, and stocking activities.
- Beginning in 2002, implement these operational plans to monitor and manage paddlefish:

    1. Monitor abundance. Implement standardized surveys in the Byrd, Greenup, McAlpine, Newburgh, and Myers pools of the Ohio River using gillnetting and fisheries acoustics.

    2. Movement and exploitation. Augment the MICRA tagging protocol with use of external tags to better quantify paddlefish movement among Ohio River pools and aid estimation of exploitation.

    3. Commercial-catch characteristics. Conduct onboard monitoring of a limited number of commercial catches in the Cannelton, Markland, and McAlpine pools to estimate age and size structure and sex ratio of the commercial catch.

    4. Monitor sport fisheries. Use existing creel surveys in tailwaters of the Ohio River to obtain harvest, tag return, catch-per-effort, and age and size structure data.

    5. Data management. Develop a shared database for ORFMT paddlefish management.

    6. Public information. Write an article to summarize paddlefish issues in the Ohio River Sub-basin.

SWOT ANALYSIS (May 16-17, 2001)

Mission Statements of Participating Agencies

Wildlife Resources Section, West Virginia Division of Natural Resources. It is declared to be the public policy of the State of West Virginia that the wildlife resources of the State shall be protected for the use and enjoyment of all citizens of this State. All species of wildlife shall be maintained for values which may be either intrinsic or ecological or of benefit to man. Such benefits shall include (1) hunting, fishing, and other diversified recreational uses; (2) economic contributions in the best interest of the people of the State; and (3) scientific and educational uses.

Division of Wildlife, Ohio Department of Natural Resources. We are dedicated to preserving and improving the fish and wildlife resources and their habitats, and promoting their use and appreciation by the people so that these resources continue to enhance the quality of life for all Ohioans.

Kentucky Department of Fish and Wildlife Resources. We are stewards of Kentucky's fish and wildlife resources and their habitats. We manage for the perpetuation of these resources and their use by present and future generations. Through partnerships, we will enhance wildlife diversity and promote sustainable use, including hunting, fishing, boating and other nature-related recreation.

Indiana Department of Natural Resources. To professionally manage Indiana's fish and wildlife for present and future generations, balancing ecological, recreational, and economic benefits.

Illinois Department of Natural Resources. Provide leadership to manage, protect, sustain, and promote Illinois' natural and cultural resources.

Paddlefish Technical Committee Scope

To provide current information and management recommendations to agency leadership for sound inter-jurisdictional management of paddlefish in the Ohio River Sub-basin.

Internal Considerations: Strengths and Weaknesses

Strengths	***Weaknesses***
ORFMT agency commitment	MICRA participation
MICRA participation of ORFMT states	Incomplete knowledge of the Ohio River
Knowledge of the Ohio River	Data storage and access (MICRA database)
Financial resources	MICRA study protocols
Current data (7 years of recent data)	MICRA study designs
ORFMT organizational structure	Lack of fundamental management data
MICRA study methods (somewhat standardized)	
Joint interest in paddlefish (shared values)	

External Considerations: Opportunities and Threats

Opportunities	***Threats***
MICRA participation	MICRA leadership
MICRA Paddlefish-sturgeon Sub-committee leadership	MICRA Paddlefish-sturgeon Sub-committee leadership
Public interest	Participation outside of ORFMT in management
Sport fishery potential	Lack of all participation in joint paddlefish management of all Ohio River Sub-basin states
Commercial value of eggs	Stocking strategies and philosophies
Lock and dam structure (concentrates fish for fishery use)	Public interest
USFWS (info;CITES; SAR trust species listing)	Commercial fishery regulation (lack thereof)
MICRA Paddlefish-sturgeon Sub-committee	Exploitation (sport and commercial)
Sustainable commercial harvest	Commercial value of paddlefish eggs
Habiat restoration	Political interests (many Potentially Affected Interests)
USFWS	Habitat loss (and water quality)
	Navigational barriers (lock and dam structures)
	Large management area (Ohio River Sub-basin)

Opportunities	***Threats***
	Differential management strategies for one stock
	USFWS
	Exotic species
	Paddlefish life history
	Poaching
	Law enforcement interest (or lack thereof)
	Aquaculture
	Genetic engineering (gynogens)
	Declining sturgeon stocks
	Caviar trade (local and international)
	Commercial fishers (as a political unit)
	MICRA stability (and Paddlefish-sturgeon Sub-committee)
	MOU specifications among states for river use
	Non-compliance of reporting commercial harvest
	Status discrepancies among Ohio River states

Strategic Plan: 2002-2010

Goal

Restore, enhance, and protect the paddlefish population in the Ohio River Sub-basin to ensure sustainable use and increase public awareness of paddlefish issues.

Objectives

1) Abundance. Maintain or restore paddlefish abundance at catch rates of 0.03 fish per meter of net per 2 hour set determined by standardized gillnet surveys in five pools of the Ohio River.
2) Total Annual Mortality. Limit total annual mortality of paddlefish to less than 50% (both sexes combined).
3) Exploitation. Limit annual exploitation to less than 20% (both sexes combined) in areas of the Ohio River where sport and commercial harvest are permitted.
4) Movement. Quantify paddlefish movement among Ohio River pools over a five-year period.
5) Restoration. Restore paddlefish in the upper Ohio River reaches by stocking age-0 fish that are produced from Ohio River broodstock and developed without genetic alteration.
6) Harvest. Monitor annual sport and commercial harvest.
7) Data Management. Develop and maintain an ORFMT paddlefish database.
8) Public Information. Condense the background and situation analysis into a popular article for distribution to the public.

Problems and Strategies

Objective 1. Abundance

Problem: Abundance of paddlefish is low in the upper Ohio River.

Strategy: Annually stock paddlefish in the PA and WV portions of the Ohio River with broodstock derived from the Ohio River.

Problem: Abundance of paddlefish is not well quantified in specific pools of the Ohio River.

Strategy: Use annual standardized gillnetting and fisheries acoustics surveys to estimate abundance of paddlefish at fixed sites within five pools.

Problem: Aquatic Nuisance Species (ANS) are invading the Ohio River and may have a negative impact on paddlefish.

Strategy: Record data from non-target species captured in standardized surveys and during onboard commercial catch monitoring.

Objective 2. Total Annual Mortality

Problem: The ORFMT currently lacks male and female age structure of the catch from 127-mm (5-inch) mesh gillnets to obtain sex-specific growth rates, age structure, and catch curves.

Strategy: Collect sex-specific age data from commercial catch samples from 5” mesh nets.

Problem: The sex of paddlefish cannot be externally determined.

Strategy: Explore the use of gonad biopsy as a method for external sex determination.

Problem: Total annual mortality of paddlefish may exceed 50%.

Strategy: Implement fishery management regulations to reduce harvest.

Objective 3. Exploitation

Problem: Rates of sport and commercial exploitation are currently unknown.

Strategy: Determine sport and commercial exploitation via external tagging of Ohio River paddlefish.

Problem: Non-reporting of tags may bias estimates of exploitation from tagging studies.

Strategy: Evaluate non-reporting bias through design of the tagging study.

Problem: Combined commercial and sport fishery exploitation may exceed 20%.

Strategy: Implement fishery management regulations to reduce harvest.

Objective 4. Movement

Problem: Current tagging methodology (internal tags) does not provide the necessary resolution to best quantify paddlefish movement among pools of the Ohio River.

Strategy: Supplement MICRA methodology with external tagging methods throughout the Ohio River.

Objective 5. Restoration

Problem: Genetic integrity of the native paddlefish population may be compromised by stocking paddlefish derived from broodstock sources outside of the Ohio River Sub-basin.

Strategy: Encourage all Ohio River Sub-basin states to only stock paddlefish that are produced from Ohio River Sub-basin broodstock.

Objective 6. Harvest

Problem: Reporting of commercial fishery harvest is incomplete and not uniform.

Strategy: Implement standardized reporting of paddlefish catches by commercial fishers in Kentucky, Indiana, and Illinois that includes reporting the numbers of fish harvested.

Strategy: Use onboard monitoring of commercial fishers to record harvest, sex ratio, size and age structure of the harvest, tag returns and bycatch.

Problem: Sport fishery harvest is not monitored in all tailwaters with paddlefish fisheries.

Strategy: Use the existing creel surveys to monitor the sport fishery harvest of paddlefish.

Objective 7. Data Management

Problem: The current MICRA database is cumbersome to use and insufficient for ORFMT needs.

Strategy: Develop an ORFMT database to house and share field sampling, tagging, commercial fishery, sport fishery, and contaminant data.

Objective 8. Public Information

Problem: An ORFMT publication does not currently address paddlefish issues for the general public.

Strategy: Develop a popular article or publication to summarize findings and implications of the ORFMT sub-basin report.

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