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THE USE OF HIGH EXPLOSIVES TO CONDUCT A FISHERIES SURVEY AT A BENDWAY WEIR FIELD ON THE MIDDLE MISSISSIPPI RIVER

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ABSTRACT

Fish sampling in a deep-water, high velocity, environment is extremely difficult. Conventional techniques such as electro-fishing and netting have been limited to depths generally less than 7 meters (m) and velocities below 1 meter per second (mps).

The goal of our study was to sample a bendway weir field on the Mississippi River to assess the effects of the weir field on the fishery. In a bendway weir field, depths can exceed 20 m, and velocities can exceed 3 mps, making conventional sampling techniques inefficient.

A 152-m section over a bendway weir field was blasted using a series of 3.4 kilograms (kg) charges of T-100 binary explosive. Preparation for the blast (placing charges and catch nets), took approximately 6 hours. A total of 217 fish was captured, representing 12 species. Freshwater drum (*Aplodinotus grunniens*) dominated the catch comprising 35.5% of the total catch, followed by gizzard shad (*Dorosoma cepedianum*) (27.2%), and blue catfish (*Ictalurus furcatus*) (16.6%). Conventional fish collection techniques (e.g., trotlines, trammel nets, and hoop nets) captured 12 fish specimens representing 7 species. One new species, the paddlefish (*Polyodon spathula*) was added to the species list by the conventional sampling. The most numerically abundant species taken by explosives (freshwater drum, 35.5%) was not taken by conventional sampling techniques.

INTRODUCTION

Bendway weirs (Figure 1) are low-level rock structures designed to create a variety of improvements to the navigation channel in the bendways (curved reaches) of large river systems. They consist of a series of submerged rock dikes (> 3 m below the low water reference plane) constructed around the outer edge of a river bend. Each dikes is angled 30° upstream of perpendicular to divert flow, in progression, toward the inner bank.

The structures are designed to redistribute flow and sediment within the bends to reduce or eliminate dredging requirements in river bends by controlling point bar development (Davinroy 1990). The redistribution of flow produces safer navigation conditions and has significantly reduced the number of accidents in each bend (Davinroy et al. 1998). The channel bottom affected by the dikes has increased structure and hydraulic variation, both positive changes with respect to aquatic habitat diversity in the river bends. A major challenge that faced fishery biologists was developing a methodology to sample fish populations within the dynamic and turbulent bendways. In a bendway weir field, depths can exceed 20 m, and velocities can exceed 3 mps, making conventional fish sampling techniques inefficient. Fish sampling in such deep-water, high velocity, environments is extremely difficult. Conventional techniques such as electro-fishing and netting have been limited to depths generally less than 7 m and velocities below 1 mps.

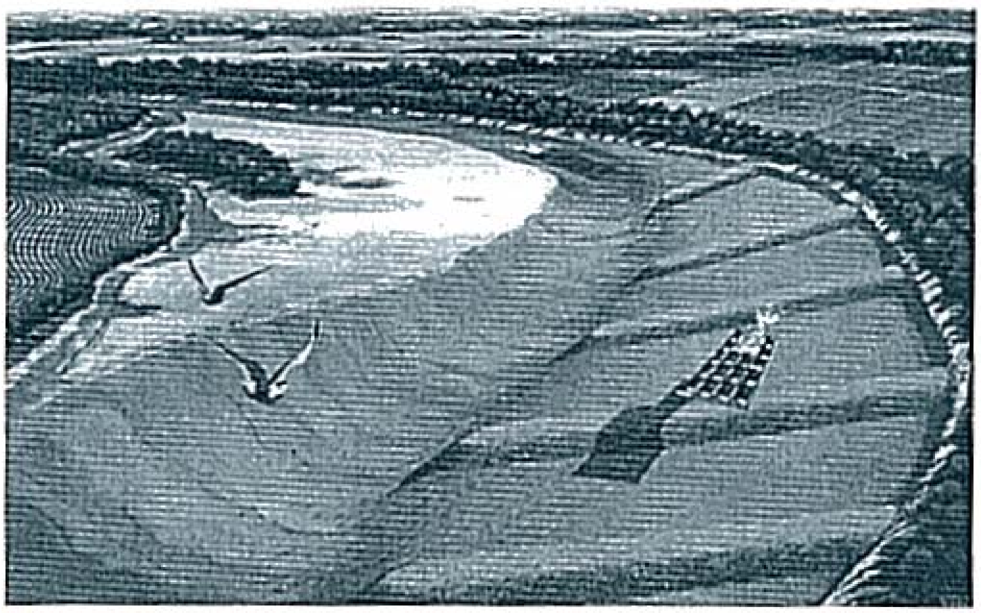

Figure 1.-Illustration of a towboat passing over a bendway weir field.

A deep-water sampling group was formed, made up of various interagency members, including the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Missouri Department of Conservation, the Illinois Department of Natural Resources, and the University of Southern Illinois Department of Fisheries. The team, comprised of engineers and fisheries biologists, developed a deep water sampling strategy that included a combination of hydroacoustic surveys and blast fishing (Davinroy et al. 1998).

The use of explosives to collect fish is not considered a "standard" fish sampling technique in the United States (Nielsen and Johnson 1983). However, explosives have been successfully used to conduct fishery surveys in a number of different aquatic habitat types (Table 1) and have been found effective in large river systems where sampling is difficult using conventional techniques (Forbes and Richardson 1913; Averett and Stubbs 1962; Hesse et al. 1979; Rasmussen et al. 1985).

The goal of our study was to sample a single weir at Price Towhead weir field, a bendway weir field on the Middle Mississippi River, to determine the species composition at the bendway weir using both hydroacoustics and blast fishing. A hydroacoustic survey was conducted by Kasual and Baker (1996) to provide quantitative information on fish numbers, location, and size; however, hydroacoustics does not provide information on the species being observed. The blast survey was conducted to identify the fish species present at the bendway weir, thus complimenting the hydroacoustic survey.

MATERIALS AND METHODS

On 20 September 1995, a 152-m section over a bendway weir (Mississippi River Mile 30.3) at Price Towhead weir field was surveyed with explosives to document fish use.

Explosive. IBLAST (Coastline Environmental Services Ltd 1986), a fish mortality model, was used to determine the explosive charge size required to kill fish within 30 m of the blast. The calculated charge weight was then increased by 1/3 to ensure mortality. Fish sampling blasts utilized 3.4 kg charges of T-100 Two Component (green stick) explosive and initiated by two Atlas #8 instantaneous electric blasting caps. Slurry Explosive Corporation's T-100 Two component is a water-resistant, Class A, high explosive with a 1.6 relative bulk strength equivalency to ammonium nitrate and fuel oil (ANFO). It has a detonation velocity of 14,000 mps and a density of 1.22 grams per cubic centimeter (Slurry Explosive Corporation 1991).

A 12.5 mm steel cable was attached to a 680 kg anchor and a buoy on the other end of the cable to keep the line taut. Five sticks of T-100 were attached to the cable 1.2 m above the anchor. Two blasting caps were attached to each explosive charge. A kill area of 30.5 by 91.5 m was divided into five cells of 30.5 (upstream-downstream) by 18.3 m cross current. An anchor/charge system was placed at the center of each cell. Thus, five 3.4 kg charges were set in place on 18.3 m centers along the center of 30.5 m upstream-downstream areas (15.2 m downstream of the weir toe) using a crane operated from a work barge.

Recovery. Six chase boats and sixty-three catch nets were used to capture fish. Each chase boat had a minimum crew of three, a boat operator and two dip netters. The catch nets each had a 1.2 m diameter opening and either 4.8 mm or 19.05 mm mesh. The catch nets had a bridle with a swivel clip to keep the net from fouling in the current. Catch nets were fastened to a 12.5 mm steel cable that was attached to a 680 kg anchor and a buoy on the other end of the cable to keep the line taut. Twenty-one lines, each with three catch nets, were set. Catch nets were attached at 3 m below the buoy (surface), 3 m above the anchor (bottom), and at the mid-point between the two (middle) based on depth.

Conventional Fishery Survey Methods. Two 91.5 m trotlines, each with 50-hooks baited with cut shad were set on September 26, 1995, parallel to the shoreline at River Mile (R.M.) 29.8 and R. M. 29.6.

Two 45.7 m trammel nets (outer panel 25.4 cm, inner panel 5.08 cm bar mesh) were set on September 26th. The first was set below the weir, parallel to the shoreline at R.M. 30.1 and the second was set at R.M. 29.8, parallel and downstream of the weir. Three hoop net sets, each with 4 hoop nets, were set on September 25th at R. M. 30.5,5, 30.5 and 30.3, parallel to and downstream of a weir in the field. Each hoop net had a 1.2 m diameter mouth, two had 38.1 mm mesh and two had 19.05 mm mesh. All gear was retrieved on September 27th (trotlines, 24 hr. set, trammel nets, 24 hr. set, hoop nets 48 hr. set).

RESULTS

A total of 217 fish was captured using blast fishing, representing 12 species (Table 2). Freshwater drum (*Aplodinotus grunniens*) dominated the catch, comprising 35.5% of the total catch, followed by gizzard shad (*Dorosoma cepedianum*) (27.2%), and blue catfish (*Ictalurus furcatus*) (16.6%). Catch nets (water column) and surface collections produced similar total numbers of fish collected. Ninety-nine specimens of ten species were collected in catch nets and 118 specimens of eight species were dip netted from the surface ("floaters"). Species composition differed by capture method (Table 2). Four species, shovelnose sturgeon (*Scaphirhynchus platorynchus*), skipjack herring (*Alosa chrysochloris*), stonecat (*Noturus flavus*) and freckled madtom (*Noturus nocturnus*), were collected only in the catch nets. Two species, carp (*Cyprinus carpio*) and smallmouth buffalo (*Ictiobus bubalus*), were collected only in the surface collections. The catch nets were more effective than surface collecting in sampling gizzard shad (58 vs. 1 specimen) and blue catfish (24 vs. 12 specimens), while surface collecting was more effective in collecting freshwater drum (75 vs. 2 specimens).

The total length of all fish captured also varied by capture method. Ninety-two percent of the fish collected (floaters) from the surface by chase boats were greater than 200 mm total length, while 100% of fish collected in catch nets were less than 200 mm total length.

Two freckled madtoms and two stonecats were captured in the mid-water catch nets. Both of these species occupy the interstitial areas of the rocky habitat along the river. Apparently, these two species were dislodged from the rocks by the blast.

Conventional fish collection techniques (e.g., trotlines, trammel nets, and hoop nets) captured twelve fish specimens representing seven species (Table 3). One blue catfish was caught on the two trotlines. Four specimens of four species (1 gizzard shad, 1 carp, 1 paddlefish (*Polyodon spathula*), 1 sturgeon) were caught in gill nets. Three species (4 flathead catfish, 2 blue catfish and 1 channel catfish) were captured in hoop nets.

DISCUSSION

Hyrodacoustic studies (Kasual and Baker 1996) have indicated that bendway weirs can increase the local abundance of fish in affected areas of the river channel by approximately two-fold. Kasul and Baker (1996) conducted a pre-blast hydroacoustic survey of the of the test weir in the Price Towhead weir field. They estimated the density of fish surrounding the test weir at 2,003/ha, approximately twice the mean density of fish obtained from the entire weir field (984/ha). Fish were found throughout the water column from near surface to near bottom. More fish were detected along the channel-ward half of the weir than along the shore-ward half. Inspection of echo detections also suggested that in 6 of 8 passes over the weir, fish were more often found immediately downstream of the weir than immediately upstream of it.

Fish detected in the pre-blast hydroacoustic survey of Price Towhead (Kasual and Baker 1996) varied in size from approximately 3 to 96 cm. The mean fish size was approximately 9 cm. Approximately 80% of the fish were ≤ 5 cm. Based on the abundance and size distribution of fish collected during the blast survey, it would appear that many of these fish were gizzard shad. Eight echoes of fish that were approximately 50 cm or larger were all found on the downstream side or downstream base of the weir. Blast fishing produced four species: blue catfish, channel catfish, drum, and buffalo that exceed 50 cm total length.

Comparisons of fish densities (number of fish per ha) between the hydroacoustic survey and the blast survey are impossible. Fish mortality is species specific (Ogawa et al. 1978; Teleki and Chamberlain 1978; Goertner et al. 1994), size specific (Yelverton et al. 1975), and undoubtedly depth specific. Because each of these factors can affect fish mortality, the kill radius for the test blast was not precisely known making it impossible to calculate fish density at the weir. If 100% fish mortality occurs within a measured area (i.e., a small pond, lake, or netted off area in a larger lake, stream, or canal), then calculating fish density would have been possible. However, the use of nets to completely enclose a measured area at the test weir was impossible because of the water depth and high velocities.

Published, incidental observations indicate that the number of dead fish floating on the surface immediately after an explosion does not represent the total number of fish killed (Brown and Smith 1972; Coker and Hollis 1950; Gitschlag 1997; Ferguson 1962; Fitch and Young 1948; Indrambarya 1949; Kearns and Boyd 1965; Knight 1907). The proportion of "floaters" to the actual number of fish killed is species specific, but has never been documented. In this study, species composition differed dramatically with respect to the location of fish capture. Four species were collected only from the water column using catch nets while two species were collected only in the surface collections. The catch nets were more effective in sampling gizzard shad and blue catfish, while surface collecting was more effective in collecting freshwater drum. These results indicate that researchers have to sample the surface (floaters), water column, and in slack water, the stream or lake bottom to obtain a total picture of species composition and density. A number of fish surfaced but could not be collected by the limited number of chase boats. Additional boats would have increased the sample size.

Conventional fish collection techniques (e.g., trotlines, trammel nets, and hoop nets) were ineffective capture methods in the bendway weir field when compared with the blast fishing. Twelve fish specimens were collected using conventional collection methods compared with 217 by blast fishing. There were only two species (blue catfish, 3 specimens and flathead catfish, 4 specimens) with more than one specimen collected by conventional methods. The larger number of fish collected using blast fishing produced a better size distribution of specimens to compare with the hydroacoustic survey data. Only seven species were collected using conventional techniques compared with 12 species taken by explosives. One new species, the paddlefish (*Polyodon spathula*) was added to the species list by the conventional sampling. The most numerically abundant species taken by explosives (freshwater drum, 35.5%) was not taken by conventional sampling techniques. The gill net set parallel to the revetted shoreline became twisted in the high water currents and no fish were collected in this net.

The shots did not fire flawlessly. Only the two shots nearest the shoreline (charges 1 and 2) fired. An open circuit in down line 3 isolated charges 4 and 5, which in turn led to a 10-minute firing delay for shooting charges 4 and 5. Charge number 3 was fired approximately 3 hours later. The down line to charge 3 was severed after the circuit was checked, when wiring the circuits together. The cut in the down line was likely due to: abrasion by the skiff against the buoy; water-borne debris snagging the line, or, most probably, the continued twisting of the buoy in the swift current pulling on the down line. Explosive engineering also proved difficult in the deep water with fast currents.

In August of 1994, an attempt was made to sample the same bendway weir field using explosives. Capture boats and a 91.4 m long experimental gillnet were deployed to capture fish. The net was deployed downstream of the blast. After the blast the net was gone. The ropes attaching the net to the anchor buoys had snapped in the high currents. The 1.2 m mouth opening catch nets used during 1995 sampled only a small fraction of the water column below the bendway weir. Deployment of large gill nets would have sampled a much larger portion of the water column than possible with the catch nets. It may be possible to design gillnets to withstand the high currents and increase catch efficiency. Because of the high current, small mesh sizes may be impractical. Although more fish may be captured, they may be larger specimens. Another potential sampling method would be to drift experimental gill nets between two boats that are moving downstream slower than the currents. Should additional bendway weir blast sampling be conducted, it is recommended that the drift net capture method be tested and nets should be specially designed to withstand the high water velocities, thus increasing catch efficiency.

The results of this study indicate that blast sampling provided an effective technique to sample the bendway weir field when combined with the hydroacoustic survey. Blast sampling provided species composition data and the hydroacoustic survey provided fish location, density, and size data. Fish species composition and density data would have been extremely difficult, if not impossible, to obtain using conventional fishery techniques.

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Table 1.-Published studies of fishery surveys employing explosives as a sampling method.

Habitat Sampled	State	Explosive Type	Authors
Large Rivers			
Upper Illinois River	Illinois	dynamite	Forbes & Richardson 1913
Clark Fork River	Montana	dynamite	Averett & Stubbs 1962
Hiwassee & Ocoee Rivers	Tennessee	dynamite	Stubbs 1964
Blackwater River	Florida	detonating cord	Bass & Hitt 1977
Niobrara-Missouri River	Nebraska	detonating cord	Hessee et al. 1979
Upper Mississippi River	Iowa/Illinois	detonating cord	Rasmussen et al. 1985
Small Streams			
Salmon streams		detonating cord	Platts 1974
Stillwater Creek	Oklahoma	detonating cord	Layher and Maughan 1984
Canals			
Canal systems	Florida	detonating cord	Metzger and Shafland 1986
Impoundments			
	Florida	detonating cord	Metzger and Shafland 1986
	Illinois	detonating cord	Bayley & Austin 1988

Table 2.-Fish species collected using catch nets (water column collection) and chase boats (surface collection) during blast-sampling of the Price Towhead bendway weir.

Species	Catch Nets (Water Column Collection)	Chase Boats (Surface Collection)	Total
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	1	0	1
Gizzard shad (*Dorosoma cepedianum*)	58	1	59
Skipjack herring (*Alosa chrysochloris*)	2	0	2
Carp (*Cyprinus carpio*)	0	11	11
Smallmouth buffalo (*Ictiobus bubalus*)	0	6	6
Stonecat (*Noturus flavus*)	2	0	2
Freckled madtom (*Noturus nocturnus*)	2	0	2
Flathead catfish (*Pylodictis olivaris*)	4	9	13
Channel catfish (*Ictalurus punctatus*)	3	2	5
Blue catfish (*Ictalurus furcatus*)	24	12	36
Goldeye (*Hiodon alosoides*)	1	2	3
Freshwater drum *Aplodinotus grunniens*)	2	75	77
Total	***99***	***118***	***217***

Table 3.-Fish species collected using conventional (trotlines, trammel nets, and hoop nets) during sampling of the Price Towhead bendway weir.

Species	Number	Total Length (cm)
Trotlines		
Blue catfish (*Ictalurus furcatus*)	1	58.2
Trammel Nets		
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	1	79.2
Paddlefish (*Polyodon spathula*)	1	23.3
Gizzard shad (*Dorosoma cepedianum*)	1	19.0
Carp (*Cyprinus carpio*)	1	65.3
Hoop Nets		
Flathead catfish (*Pylodictis olivaris*)	4	24.2, 24.8, 36.6, 40.8
Channel catfish (*Ictalurus punctatus*)	1	68.8
Blue catfish (*Ictalurus furcatus*)	2	38.1, 44.0