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Fisheries in man-made pools below grade-control structures and in naturally occurring scour holes of unstable streams

C. M. Cooper and S. S. Knight

ABSTRACT: As a part of the ecological research on high-gradient streams in the Yazoo River Basin of Mississippi, four man-made pools below grade-control (low-drop) structures and four naturally occurring scour-hole pools were sampled for fish composition by the rotenone method. Tillatoba and Long Creeks were chosen because of the presence of grade-control structures used as structural management practices for control of channel erosion from head cutting and because the region has been included in a comprehensive land treatment and channel stability project (Demonstration Erosion Control Project (DEC) of the Yazoo Basin). Differences in the fisheries characteristics of the two pool habitats were expected because of differences in their relative stability, bottom substrate, and pool life expectancy. Natural scour holes yielded 0.06 kg/m^3 *of fish from 39 species; 0.018 kg/m*^{3} *were considered harvestable. Twenty-nine species of fish in man-made pools yielded 0.06 kg/m*^{3}*, with 0.025 kg/m*^{3} *being harvestable. Channel catfish (*Ictalurus punctatus*) and carpsucker (*Carpiodes carpio*) were the dominant fish by weight in both pool habitats. Bullheads (*Ictalurus *sp.), sunfish (*Lepomis *sp.), and spotted bass (*Micropterus punctulatus*) were important in natural pools, and bullheads, largemouth bass (*Micropterus salmoides*), and sunfish were dominant in man-made pools. Length frequency distributions indicated that there was better growth of many species and more stable reproducing populations of forage fish in man-made pools, although they yielded somewhat fewer species. While such pools will not support heavy sport fishing pressure, drop structure pools have several advantages over most natural scour holes in their fisheries characteristics. They also offer protection from stream channel degradation while providing additional habitat diversity.*

As agricultural practices have replaced natural vegetation across the United States, many river basins have experienced stream instability and erosion problems. This has been particularly so in regions of gradient change, where streambed controls are limited.

Post-settlement channel degradation from erosion and headcutting has occurred on a massive scale in streams in the upper reaches of Mississippi's Yazoo River Basin. Because of the severity of erosion problems throughout the hill lands forming this drainage, Congress in 1984 directed the U.S. Army Corps of Engineers and the Soil Conservation Service to establish six demonstration watersheds as a means of developing a systematic and universally applicable land and water treatment program. The demonstration erosion control project in the Yazoo Basin illustrates how specific land and channel management strategies can be applied to similar erodible watersheds across the United States.

C. M. Cooper and S. S. Knight are ecologists with the Sedimentation Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Oxford, Mississippi 38655. *This paper is a contribution of the Sedimentation Laboratory, ARS-USDA, Oxford, Mississippi. The authors thank Robert Holley, Terry Welch, John Gathwright, and Frank Wiggers for field assistance and Betty Hall and Winfred Cook for assistance in manuscript preparation.*

The Agricultural Research Service's Sedimentation Laboratory in Oxford, Mississippi, supported the demonstration project by documenting preproject conditions and watershed changes and by evaluating the efficiency of specific management strategies. The primary objectives of the project are to develop means of controlling erosion, sedimentation, and flooding. Evaluating the impact of these management practices on the biota of demonstration watersheds is also of major concern.

In many locations in the upper Yazoo River Basin, streams have cut through unconsolidated to weakly consolidated loess into underlying sands and gravels. This results in 2-m to 4-m high banks in headwater areas and large sand deposits in alluvial reaches. A channel stability measure tested in the project was low, drop grade-control structures. A series of low drop structures were placed in selected streams about 10 years ago to prevent headcutting, a major cause of channel deepening, streambank failure, and large sand and gravel bedload. Low drop-type grade-control structures (Figure 1) of sheet-pile driven steel or concrete generally function best hydraulically where gradient change is 1 m or less. Structure designs include downstream riprap-lined stilling basins (Figure 1) with energy dissipating baffle plates (2, 3). Although low drop structures are designed and positioned to prevent channel degradation, secondary benefits may be derived from improved fisheries associated with their downstream pools.

Because 19% of all warmwater fishing in freshwater occurs in streams and rivers, management practices should be developed and improved continually for wise use of these resources (4). More information is needed on the ecology and population dynamics of fish in small to medium-sized warmwater streams to solve problems of increasing demands on warmwater fisheries. Man-made pools below grade-control structures potentially may support a larger and more stable fishery than naturally occurring pools because of firm sides and bottoms that provide substrate for food organisms, excellent year-round dissolved oxygen levels, deeper and more stable average depths, and a more permanent nature.

The presence of existing low drop structures allowed an ecological evaluation before major construction efforts began in the Yazoo Basin. The objectives of our study were to examine the potential of man-made pools to improve fisheries resources, to examine the effects of existing grade-control structures on stream fisheries, and to compare the fishes in naturally occurring stream scour

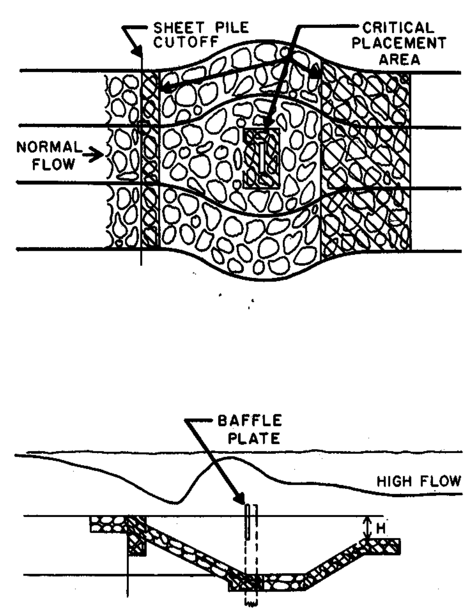

Figure 1. Typical low drop-type grade-control structure, depicting sheet pile cut-off and pool below drop; H = gradient change (modified after Little and Long 1982).

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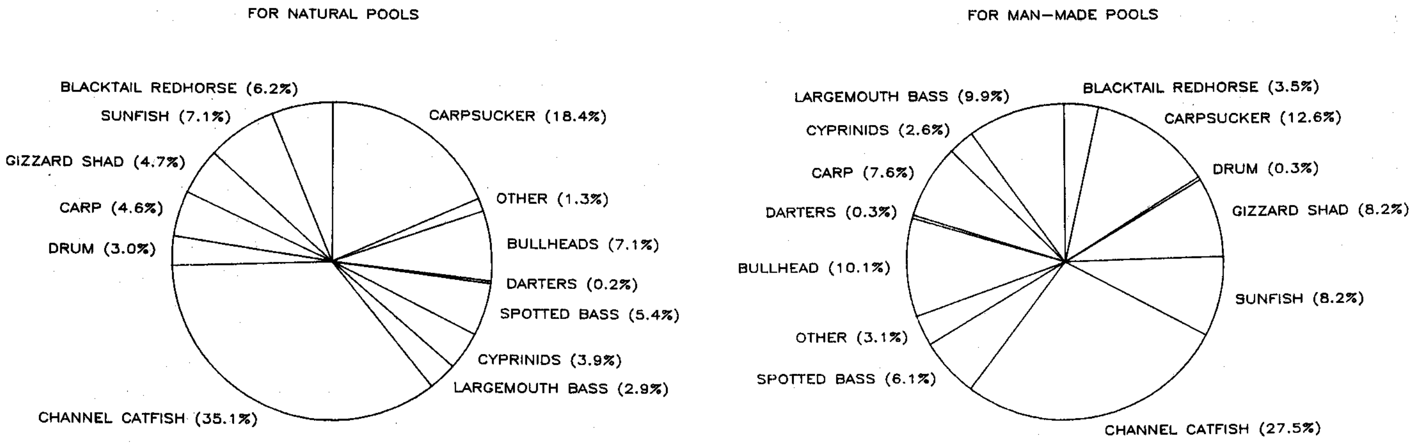

Figure 2. Percent by weight of fish found in natural and man-made pools.

holes with those in man-made pools below grade-control structures.

Study methods

We determined the fish composition of four grade-control stilling basins and four natural pools by rotenone sampling during the summer of 1985 on Long Creek and the North Fork of Tillatoba Creek in Panola and Tallahatchie Counties in north central Mississippi. Both creeks have deeply encised channels that flow through loess hills and drain into rivers in the Yazoo Basin. The near-surface geology of the region includes silts and clays of the Wilcox and Claiborne groups, both Eocene in age, overlain by loess and fluvial sands and gravels in Loess or Bluff Hills subprovinces. Surface acreage of the pools ranged from 13 m^2 to 950 m^2, with a total volume of 1,074 m^3 for natural pools and 1,329 m^3 for man-made pools.

Because natural scour holes occur at random and are transient, we did not have paired samples; however, we selected pools of each type so that shape and size was similar. Depths ranged from less than 1 m to 3 m. Average base flow ranged from 0.001 cms to 0.14 cms. The bottom substrate of natural pools was typically sand and gravel on clay. Sides of the natural pools were steep and consisted of clay; some had sand bars on one side or end. The bottom of the stilling basins consisted of limestone rock riprap partially covered by sand and gravel. Sides of the man-made pools were lined by limestone rock riprap covered with periphyton.

We blocked each pool with 3 mm^2 mesh seines; we placed nets below all sites and above those sites where fish could move upstream. We dispensed rotenone initially from upstream in a quantity necessary to obtain a pool concentration of 1 to 2 mg/liter; additional rotenone was dispensed as needed. We placed potassium premanganate crystals downstream of each pool to neutralize outflowing rotenone.

We began collections about the same time each day. Temperatures varied little. After collection, large fish were weighed and measured on site. All other fish were preserved and processed in the laboratory. We removed scales from some "game" species to determine age. Game species included those typically caught for sport, such as largemouth bass, bluegill, and channel catfish. Because chi square analysis indicated significant differences in fish distribution both between and within each pool type, we combined catches by pool type.

Results and discussion

We collected a total of 3,504 fish representing 39 species from natural pools and 3,401 fish representing 29 species from man-made pools during the summer of 1985. Channel catfish (*Ictalurus punctatus*) and redfin shiners (*Notropis umbratilis*) dominated the natural scour holes; each comprised 15.9% of the catch. They were followed in abundance by bluntnose minnows (*Pimephales notatus*) (7.9%). In man-made pools bluntnose minnows (20.6%) dominated, followed by Redfin darters (*Etheostoma whipplei*) (13.8%) and green sunfish (*Lepomis cyanellus*) (13.6%).

Channel catfish and carpsuckers, (*Carpiodes carpio*) made up the greatest proportion of the catch by weight from both pool types (Figure 2). Other abundant groups in natural pools were bullheads, (*Ictalurus* sp.), sunfish (*Lepomis* sp.), and spotted bass (*Micropterus punctulatus*). In man-made pools additional commonly occurring taxa were bullheads, largemouth bass (*M. salmoides*), sunfish, gizzard shad (*Dorosoma cepedianum*) and spotted bass.

Man-made pools yielded 76 kg of fish compared to 62 kg from natural pools (Table 1). On a per-volume basis, both pools were equal in total fish production. However, natural pools contained 11 kg of fish characterized as predatory and 51 kg classified as prey species. On the other hand, man-made pools produced 23 kg of predatory fish and 52 kg of prey fish. Man-made pools yielded 13 kg more harvestable-size fish as defined by Swingle (5). On a per volume basis, natural pools yielded 0.001 kg/m^3 of harvestable fish compared with 0.025 kg/m^3 from man-made pools.

The percent by weight (E value) of the total catch for largemouth bass, spotted bass, and bluegill, the most common game species, was 2.9, 5.4, and 1.3, respectively, for natural pools and 9.8, 6.0, and 2.4, respectively, for man-made pools (Table 2). The combined weight for the three species from natural pools was 9.6%; from man-made pools it was 18.3%. The ratio of for-

Table 1. Total weights of fish collected by rotenone sampling natural and man-made pools below grade-control structures on Long Creek and the North Fork of Tillatoba Creek in north central Mississippi.

	Total Weight of Fish	
Measurement	*Natural Pools*	*Man-Made Pools*
Total weight (kg)	61.9	75.8
Predator weight (kg)	10.6	23.4
Prey weight (kg)	51.3	52.4
Harvestable weight (kg)	19.6	32.7
Volume (m^3)	1074	1329
Total weight/volume (kg/m^3)	0.06	0.06
Harvestable weight/volume (kg/m^3)	0.001	0.025

age fish to carnivorous fish (F/C ratio) was 4.8 for natural pools and 2.2 for man-made pools. Both of these values were within the F/C ratio range of balanced lakes (1.5 to 10). However, the F/C ratio for man-made pools indicated some slight crowding of predators (5).

Total weight of harvestable fish expressed as a percentage (A_t value) is a common measure of stock assessment. An A_t value between 33% and 90% is acceptable for successful fishing (5). The A_t value was 31.6% for natural pools and 43.1% for man-made pools. Proportional stock density (PSD), the proportion of quality-size fish in a stock expressed as a percentage, is also a good indicator of fishing quality. PSD for spotted bass was 50% for natural pools and 64% for man-made pools. The PSD range required for sustained quality fishing is 45% to 65%. The 64% for man-made pools also indicated the availability of a large fish stock (*1*).

Length frequency distributions indicate the interaction of reproductive rates, growth, and mortality rates on the age groups of fish present in a system and can help identify problems, such as year class failure, low recruitment, or slow growth (*1*). The length frequency histograms for largemouth bass, spotted bass, and channel catfish showed better growth in man-made pools because a greater proportion of the catch was in the larger length classes (Figure 3). This growth pattern resulted from the greater stability of man-made pools. Fish may reproduce and remain in these pools where they feed on a stable forage base. Distributions of shad, bluegill, and longear sunfish produced a strong forage base for predatory fish in both pool types (Figure 3). The distribution of shad was similar in both pools; however, the distribution of bluegill was more evenly scattered over the range of length classes in natural pools, indicating a possible reproductive cycle failure. Bluegill may simply have migrated into natural pools, not reproduced in them. Bluegill in artifical pools showed a more healthy distribution, with a strong year class (age 1+) at 7 to 8 cm (TL) and a gradual decline in other length classes over time (Figure 3). Longear sunfish showed better growth in natural pools (Figure 3). This was expected because they are typically considered stream-dwelling species and are adapted to the constant filling and scouring of natural pools.

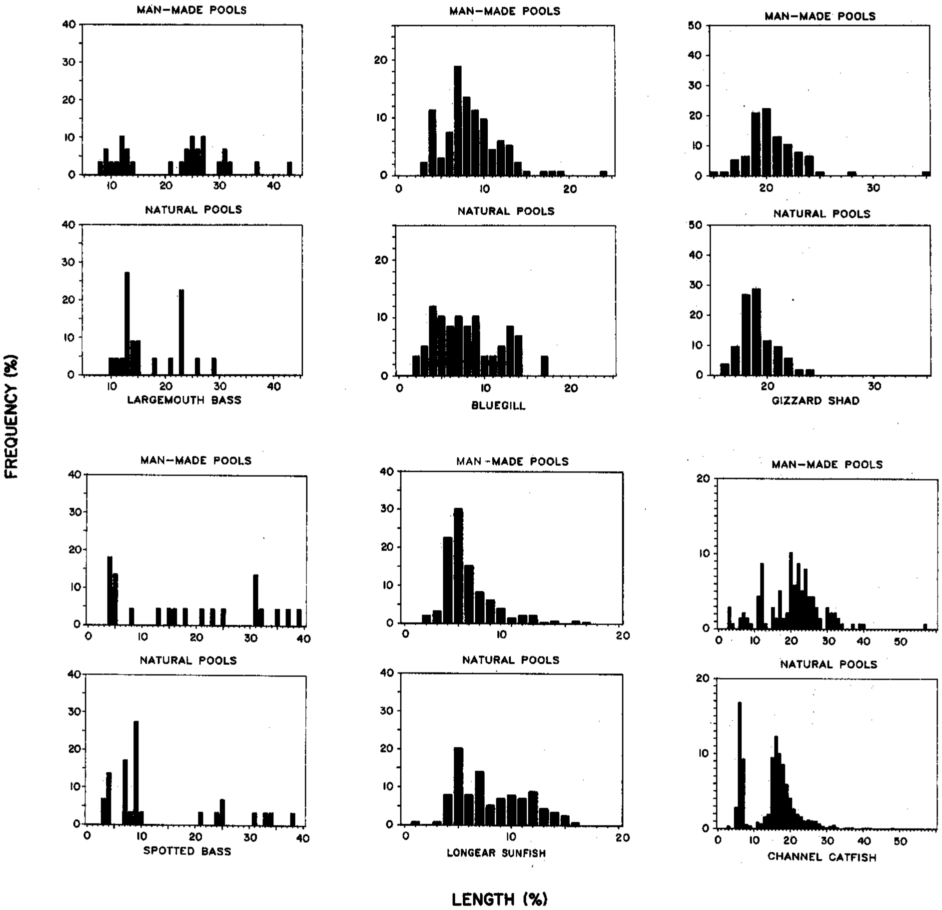

Figure 3. Length frequency distributions for prevalent species of fish found in natural and man-made pools.

Table 2. Fisheries characteristics from rotenone sampling conducted in natural pools and man-made pools below grade control structures on Long Creek and the North Fork of Tillabota Creek in north central Mississippi.

	Natural Pools		Man-Made Pools	
Species	*PSD**	*E-Value†*	*PSD*	*E-Value*
Gizzard Shad (*Dorosoma cepedianum*)	0	4.7	3	8.1
Freshwater Drum (*Aplodinotus grunniens*)	0	3.0	0	0.3
Channel Catfish (*Ictalurus punctatus*)	15	35.1	5	27.3
Bluegill (*Lepomis macrochirus*)	0	2.9	33	9.8
Largemouth Bass (*Micropterus salmoides*)	8	1.3	7	2.4
Yellow Bullhead (*Ictalurus natalis*)	8	3.5	13	8.0
Longear (*Lepomis megalotis*)	7	3.1	6	1.9
Spotted Bass (*Micropterus punctulatus*)	50	5.4	64	6.0
Green Sunfish (*Lepomis cyanellus*)	16	2.5	17	3.8
Black Bullhead (*Ictalurus melas*)	‡	‡	17	2.1

*PSD = proportional stock density
†E-value = percent by weight of the total catch
‡Black bullheads were not caught in large enough numbers in the natural scour holes to be considered in calculating PSD's or E-values.

Lack of reproductive success and poor size distribution of many species in natural pools probably resulted from the instability of scour holes. These pools may be subjected to several fill and scour cycles per year; each cycle would destroy periphyton, invertebrate and detritus food sources, and vital reproductive habitat. Although low drop pools were subject to these same stresses, pool stability and hydraulics favored minimal damage and improved the habitat for fish.

The four natural pools sampled contained 10 species not encountered in the man-made pools. These 10 species could be divided into two groups. One group was composed of four shiners and minnows that prefer more current than was available in the deeper man-made pools. The other group of six species included miscellaneous darters and other fish that may occur in either stream or pool habitat. Over the long term, species diversity may be slightly less in man-made pools, but the nature of high-gradient streams makes it improbable that existence of these pools would reduce overall stream diversity.

Because low drop structures generally are placed just above stream headcuts, no significant negative upstream impacts occur. Our observations showed that fish migrated upstream past low drop structures during high flows.

Summary

The man-made pools below grade-control structures were similar to natural scour holes in terms of the total number and weight of fish as well as weight per volume. However, examination of individual components and several commonly used indices of fisheries quality revealed greater potential of man-made pools as fisheries resources. There was greater species diversity in the natural pools, but there was increased growth of game fish and a larger percentage of harvestable-size fish in man-made pools. Stronger year classes for several important species in grade-control structure pools, as demonstrated by length frequency distributions, showed greater stability of reproductive habitat.

Although too small to maintain a sustained fishery similar to that of farm ponds, man-made pools do provide additional fisheries habitat in degraded streams. Thus, grade-control structures are stream management techniques that can provide improved fisheries resources in addition to controlling channel degradation problems.

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