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Fish Richness and Abundance in Created Riparian Habitats and Channelized Northern Mississippi Streams

Fish Richness and Abundance in Created Riparian Habitats of Channelized Northern Mississippi Streams

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ABSTRACT

Streamside habitats in Mississippi have been impacted by agricultural practices and channel incision. One contributing process to the degradation of riparian habitats adjacent to deeply incised streams is the development of gully erosion. Gully erosion is initiated by storm runoff flowing over high unstable streambanks which result from channel incision. Field-scale grade control structures (drop-pipes) are used to control gully erosion and often result in the creation of small field-level wetlands and stream-level pools. Fish and habitat data were collected from selected field-level wetlands and stream-level pools located in hill lands of Mississippi from May to September 1996. Field-level wetlands contained a total of eight species from 3809 captures; 22 species from 668 captures occurred within stream-level pools. Regression analysis indicated that pool area and depth were associated positively with species richness and numbers per unit effort within field-level wetlands and stream-level pools. Our results suggest that altering the drop-pipe installation design to facilitate the creation of larger and deeper field-level wetlands and stream-level pools will provide even greater benefits for fish and other wildlife.

INTRODUCTION

Streams and rivers of the southeastern United States are recognized as one of 233 regional habitat types which need to be protected to assist with the conservation of global biodiversity (Olson and Dinerstein, 1998). Unfortunately, many streams and rivers within the southeastern United States have been impacted by channel incision (Shields et al., 1998). Riparian zones within northwestern Mississippi most often consist of narrow vegetative corridors lacking riparian wetlands and other aquatic habitats which can serve as important habitats for stream fishes. Agricultural practices and channel incision have contributed to the degradation of riparian habitats within this region since the 1830's. The initial reduction of riparian zone width and vegetation occurred as land immediately adjacent to these waterways was cleared and developed for agriculture. Channel incision was initiated by federal

channelization projects conducted between 1930 and 1960 (Shields et al., 1995a). During channel incision, a further reduction of riparian vegetation accompanied the process of bank failure, which was initiated by over-steepening and an increase in streambank heights (Simon and Hupp, 1987). Physical degradation of riparian zones continued with the development of gully erosion, which was initiated by storm runoff flowing over high unstable streambanks formed by channel incision.

Within stream ecosystems, protection and restoration of riparian zones should be one of the highest biological priorities because of the complex physical and biotic interactions which occur at this land-water interface (Dickson and Warren, 1994). Despite this importance, most restoration projects within incised streams fail to consider riparian zone restoration and focus on the creation of in-stream habitat (Brookes et al., 1996). Additionally, past research on restoration efforts of incised streams in northwestern Mississippi has only examined the responses of stream fish communities to alterations of in-stream habitats (Cooper and Knight, 1987; Shields et al., 1995; Shields et al., 1995b; Shields et al., 1997; Shields et al., 1998). Field-scale grade control structures (drop-pipes) (Fig. 1) are the most common erosion control devices installed as part of the Demonstration Erosion Control (DEC) project in the Yazoo River basin and are used to control gully erosion occurring adjacent to incised streams (Shields et al., 1995a). Installing drop-pipes results in replacement of eroding gullies with riparian habitats located at the field-level of incised streams and small pools located within the stream channel. Cooper et al.

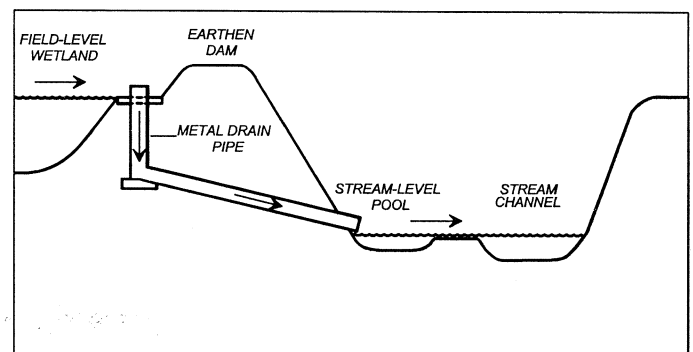


Figure 1. Cross section of drop-pipe structure and created habitat types.

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(1997) and Smiley et al. (1997) documented that fish occupy field-level wetlands, but no prior research has focused on fish communities of both field-level wetlands and stream-level pools and their associations with selected physical habitat characteristics. Therefore, our objectives for this research were to: 1) describe fish communities associated with aquatic habitats created by drop-pipe installation; 2) determine the relationship of pool surface area and depth with number of fish species (species richness) and numbers per unit effort (NPUE) within drop-pipe created habitats; and 3) evaluate the effectiveness of these structures in habitat creation to assist with restoration efforts within incised streams.

METHODS AND MATERIALS

Habitat Classification

Two types of aquatic habitats that may result from drop-pipe installation are field-level wetlands and stream-level pools. According to prior habitat classification of drop-pipe created habitats, field-level wetlands could include a variety of habitat types ranging from ephemeral to permanent wetlands. In this paper, we focus specifically on the intermittent riverine wetland habitat defined by Cooper et al. (1997) and Smiley et al. (1997). These are permanently inundated unconsolidated bottom wetlands surrounded by agricultural fields and located immediately adjacent to incised streams with streambanks that are nearly vertical in many locations and bank heights that range from 2- to 7-m high (Cooper and Knight, 1991; Shields et al., 1994). These bank heights result in the field-level wetlands being hydrologically isolated from the stream, as overbank flooding is rare (Shields and Cooper, 1994). The source of water for these wetlands is precipitation and storm runoff from watersheds that normally include the agricultural fields. Field-level wetlands are the largest wetlands created by drop-pipe installation. Pool surface area of sampled field-level wetlands ranged from 157.1 to 3282.2 m²; water depth varied from 0.1 to 2.6 m.

Stream-level pools are small backwater pools located within the channel of the incised stream which are created by outflow from the drainpipe. In general, these pools consist of a scour hole at the pipe's outflow with a narrow channel leading to the stream. During stream base flow conditions, we found variation in the location of the scour hole to range from 0 (immediately adjacent) to 63 m from the stream. Stream-level pools are much smaller than field-level wetlands (range of surface area = 0.1 to 91.0 m²; range of depth = 0.06 to 1.8 m). Stream-level pools do not exhibit the same degree of isolation as the field-level wetlands because they are located within the stream channel. During moderate runoff events these pools usually are connected with the adjacent stream.

Fish and Physical Habitat Data Collection Methods

Fish communities and physical habitats were sampled from 12 field-level wetlands and 36 stream-level pools located within Hotophia, Long, and Otoucalofa creek watersheds. These three

watersheds are part of the Yazoo River basin and are located in northwestern Mississippi along the bluffline bordering the Mississippi River alluvial plain (Shields et al., 1995c) (Fig. 2). Fish and habitat data were collected from field-level wetlands in May 1996; stream-level pools were sampled from June to September 1996. The discrepancy in number of sites sampled between field-level wetlands and stream-level pools is indicative of the availability of sites, not sampling effort. Prior to initiating this study, selected sites of both habitat types were sampled by electroshocking and seining. Seining (15.2 m, mesh size 0.9 cm or 6.1 m, mesh size 0.3 cm) was the most effective sampling technique for field-level wetlands and electroshocking was the most effective within stream-level pools. Sampling the entire habitat within field-level wetlands was impractical due to their large size and depth. However, all microhabitats within each site were sampled and the mean collecting effort was 3.1 seine hauls (SE = 0.52). The smaller seine was only used at one site where an excessive amount of woody debris made sampling with the larger seine ineffective. Due to potential differences in capture efficiency of the two seines, only NPUE calculated from sites sampled with the larger seine were used in the regression analyses. Stream-level pools were sampled with a Coffelt BP-4 backpack-mounted electroshocker and our mean sampling effort was 5.6 minutes (SE = 0.72) of electroshocking. The small size of these pools enabled us to sample each pool completely.

All identifiable fish were enumerated and released at the site of capture. Fish unidentifiable in the field were preserved in 10% formalin solution and returned to the laboratory for subsequent identification and enumeration. Pool surface area was obtained by first determining the shape of each pool (circle, rectangle, square, or triangle) and then physical dimensions (length, width, height) necessary to calculate surface area were measured using a tape measure. Maximum pool depths were measured to the nearest centimeter using either a meter stick or a 2.7 meter pole, which was marked in increments of centimeters. Measurements of surface area and maximum pool depths were obtained at the time of fish collection.

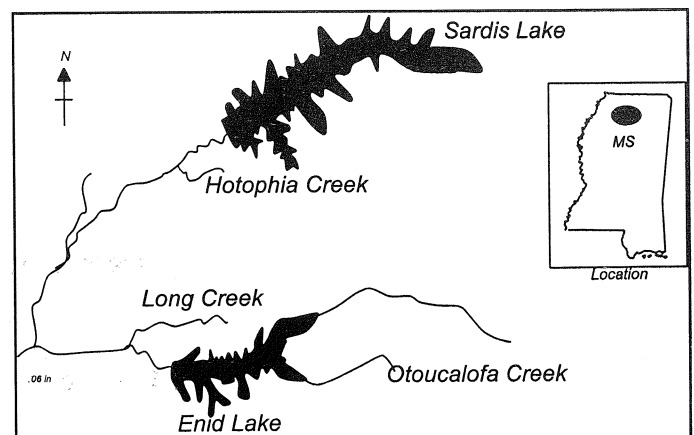


Figure 2. Location of study sites.

Statistical Analysis

A t-test was used to compare species richness between field-level wetlands and stream-level pools. Species richness values were $\log(x+1)$ transformed prior to analysis to meet the assumptions of normality and equal variance (Zar, 1984). Due to differences in capture efficiency between sampling techniques, no statistical comparisons were made for mean number of captures and mean NPUE between field-level wetlands and stream-level pools. However, the means and standard errors were calculated and reported for comparison. A simple regression analysis was used to examine the relationship of surface area and depth with species richness and NPUE. This analysis was preferred to multiple regression because of the occurrence of high multicollinearity between surface area and depth within both field-level wetlands ($r = 0.808$, $P < 0.005$) and stream-level pools ($r = 0.733$, $P < 0.00001$) (Zar, 1984). In all regression analyses, both the independent and dependent variables were $\log(x+1)$ transformed prior to analysis (Zar, 1984). The logarithmic transformation of both axes is the most common model utilized to examine species-area relationships (Connor and McCoy, 1979; Halyk and Balon, 1983) and was used to meet the assumptions of normality and equal variance (Zar, 1984).

In addition to surface area and depth, species richness and NPUE within stream-level pools may be influenced by a watershed effect resulting from sampling stream-level pools adjacent to different streams. Variation in distance of the scour hole from the stream may also affect species richness and NPUE within stream-level pools. A single factor analysis of variance was used to test for a watershed effect by comparing species richness and NPUE among stream-level pools from Hotophia, Long, and Otoucalofa Creeks. Pearson's product-moment correlation was used to determine the relationship between distance of scour hole to stream and species richness and NPUE. All statistical tests were conducted using SigmaStat 2.0 for Windows (Jandel Corporation, 1995) statistical software package. Significant results were identified at the $P < 0.05$ level.

RESULTS

Fishes were captured in eight of 12 field-level wetlands and 26 of 36 stream-level pools. A list of all species captured, relative abundance, total number of captures, and frequency of occurrences is provided in Table 1. The four most abundant species captured within both habitat types were green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), western mosquitofish (*Gambusia affinis*), and golden shiner (*Notemigonus crysoleucas*). Total species richness of field-level wetlands was eight from 3809 captures; a total of 22 species from 668 captures occurred within stream-level pools. Stream-level pools exhibited a slightly higher, but not significantly higher ($P = 0.229$), mean species richness than field-level wetlands. Field-level wetlands exhibited a greater mean number of captures and mean NPUE (Table 2).

Regression analyses revealed a significant positive relationship between pool surface area and depth with species richness and NPUE within both field-level wetlands and stream-level pools (Table 3). A watershed effect on species richness ($F_{2,23} = 0.674$, $P > 0.05$) or NPUE ($F_{2,21} = 0.437$, $P > 0.05$) within stream-level pools was not detected. Additionally, no significant correlation was observed between distance to scour hole from stream with species richness ($r = -0.024$, $P > 0.05$) or NPUE ($r = 0.007$, $P > 0.05$).

DISCUSSION

Fish use of both field-level wetlands and stream-level pools indicates the potential of aquatic habitat creation by drop-pipe installation. Installation of this structure can result in the development of habitats characterized by either permanent inundation (field-level wetlands) or periodic connections with an adjacent waterbody (stream-level pools). It is necessary for created habitats to possess at least one of these physical characteristics to maintain water quality levels suitable for the physiological requirements of fishes.

Comparisons among created habitats reveal that fish communities within field-level wetlands are characterized by low total species richness and high numerical abundance, while stream-level pools typically exhibit a higher total species richness and reduced numerical abundance. Variation in total species richness between field-level wetlands and stream-level pools may be attributed to differences in degree of isolation from the active stream channel between the two habitat types. Both field-level wetlands and stream-level pools contained individuals of fish species commonly found in both lentic and lotic systems (bluegill, green sunfish). Stream-level pools contained individuals of 10 species typically found only in streams [creek chubsucker (*Erimyzon oblongus*), creek chub (*Semotilus atromaculatus*), bluntnose minnow (*Pimephales notatus*), redbfin shiner (*Lythrurus umbratilis*), striped shiner (*Luxilus chrysocephalus*), brook silverside (*Labidesthes sicculus*), Yazoo shiner (*Notropis rafinesquei*), river carpsucker (*Carpodes carpio*), emerald shiner (*Notropis atherinoides*), and bluntnose shiner (*Cyprinella camura*)] (Table 1). These species are also present within Hotophia, Long, and Otoucalofa creeks (Knight and Cooper, 1987; Shields et al., 1994) and their presence within stream-level pools implies periodic connections with these streams. Additionally, variability in fish abundance among created habitats may be a result of pool size as the smallest field-level wetland sampled was 1.7 times greater in surface area than the largest stream-level pool sampled.

The creation of aquatic habitats within impacted riparian zones is an important step towards mitigating the detrimental effects of channel incision and gully erosion. The degree of isolation of field-level wetlands may prevent this habitat type from directly contributing to recovery of the adjacent incised stream fish community. However, fish communities within field-level wetlands may contribute to the stream corridor ecosystem by serving as a food resource for other riparian

Table 1. Species list, overall relative abundance (percent), total number of captures (number), and frequency of occurrence (frequency) for each created habitat type within eight field-level wetlands and 26 stream-level pools.

Species	Percent	Number	Frequency
<u>Field-level wetland fish species</u>			
<i>Lepomis cyanellus</i> (green sunfish)	46.9	1788	7
<i>Gambusia affinis</i> (western mosquitofish)	22.5	856	1
<i>Notemigonus crysoleucas</i> (golden shiner)	20.0	762	5
<i>Lepomis macrochirus</i> (bluegill)	8.1	307	3
<i>Pomoxis nigromaculatus</i> (black crappie)	1.0	39	1
<i>Ameiurus natalis</i> (yellow bullhead)	0.7	25	1
<i>Ameiurus melas</i> (black bullhead)	0.4	16	3
<i>Micropterus salmoides</i> (largemouth bass)	0.3	10	1
<i>Lepomis</i> hybrid (hybrid sunfish)	0.2	6	1
<u>Stream-level pool fish species</u>			
<i>Lepomis cyanellus</i> (green sunfish)	31.6	211	19
<i>Lepomis macrochirus</i> (bluegill)	16.9	113	12
<i>Gambusia affinis</i> (western mosquitofish)	9.0	60	9
<i>Notemigonus crysoleucas</i> (golden shiner)	8.4	56	10
<i>Erimyzon oblongus</i> (creek chubsucker)	7.5	50	10
<i>Semotilus atromaculatus</i> (creek chub)	6.4	43	11
<i>Fundulus olivaceus</i> (blackspotted topminnow)	6.1	41	13
<i>Lepomis megalotis</i> (longear sunfish)	2.5	17	6
<i>Micropterus punctulatus</i> (spotted bass)	2.2	15	6
<i>Dorosoma cepedianum</i> (gizzard shad)	1.9	13	3
<i>Ameiurus natalis</i> (yellow bullhead)	1.5	10	5
<i>Pimephales notatus</i> (bluntnose minnow)	1.2	8	3
<i>Lythrurus umbratilis</i> (redfin shiner)	1.0	7	2
<i>Luxilus chrysocephalus</i> (striped shiner)	0.7	5	2
<i>Labidesthes sicculus</i> (brook silverside)	0.6	4	1
<i>Notropis rafinesquei</i> (Yazoo shiner)	0.6	4	1
<i>Carpiodes carpio</i> (river carpsucker)	0.3	2	2
<i>Notropis atherinoides</i> (emerald shiner)	0.3	2	1
<i>Cyprinella camura</i> (bluntnose shiner)	0.3	2	1
<i>Pomoxis nigromaculatus</i> (black crappie)	0.3	2	1
<i>Aphredoderus sayanus</i> (pirate perch)	0.1	1	1
<i>Lepomis gulosus</i> (warmouth)	0.1	1	1
<i>Lepomis</i> hybrid (hybrid sunfish)	0.1	1	1

Table 2. Mean species richness, mean number of captures, and mean NPUE within eight field-level wetlands and 26 stream-level pools. Numbers in parentheses are standard errors.

Habitat type	Species richness	Number of captures	NPUE
Field-level wetland	2.9 (0.5)	528.9 (187.0)	162.9 (69.8)
Stream-level pool	4.6 (0.6)	25.7 (6.0)	3.9 (0.6)

Table 3. Regression analyses of species richness and NPUE on pool area and depth for field-level wetlands and stream-level pools created by drop-pipe installation. Independent variable (x), dependent variable (y), Y intercept, slope, coefficient of determination (R^2), and significance levels. P values less than 0.05 are significant.

Habitat type	x	y	Intercept	Slope	R^2	P
Field-level wetland	area	species richness	-1.323	0.554	0.449	0.017
	depth	species richness	-0.846	0.642	0.534	0.011
	area	NPUE	-3.789	1.646	0.337	0.048
	depth	NPUE	-2.499	1.981	0.428	0.029
Stream-level pool	area	species richness	-0.143	0.540	0.468	<0.001
	depth	species richness	-0.022	2.031	0.368	<0.001
	area	NPUE	-0.102	0.476	0.316	<0.001
	depth	NPUE	0.112	1.369	0.134	0.043

vertebrate species (Halyk and Balon, 1983), such as snapping turtles (*Chelydra serpentina*), raccoons (*Procyon lotor*), and wading birds (Family Ardeidae) which utilize field-level wetlands (Cooper et al., 1997).

Stream-level pools, in contrast, have potential to directly benefit stream fish communities impacted by channel incision and gully erosion. Incised streams exhibit decreased habitat quality and are lacking in pool habitats (Shields et al., 1998). Natural pools within incised streams are transient habitat features which undergo several fill and scour cycles annually due to shifting sand beds resulting from increased sedimentation loads (Cooper and Knight, 1987). Restoration structures that facilitate the development of pool habitats can benefit fish communities within incised streams. Currently, common restoration structures utilized by the DEC project within the Yazoo River Basin result in creation of variably-sized pools within the stream channel (Cooper and Knight, 1987; Shields et al., 1998). Drop-pipe installation that results in the creation of backwater habitats (stream-level pools) also increases habitat diversity as this habitat type is lacking within incised streams. In addition, stream-level pools may provide refugia during flooding events because they are located adjacent to the main channel, not within it. Refugia are important for fish communities within incised streams as these ecosystems experience harsher environmental conditions than non-incised streams because all flood waters are contained within the enlarged stream channel during storm events (Matthews, 1986).

In conclusion, potential restoration benefits of drop-pipe installation have yet to be realized because these environmental improvements occurred as a result of standard installation practices which focus on erosion control without consideration of habitat creation. These results and others (Cooper et al., 1997; Smiley et al., 1997) suggest that consideration of habitat creation during drop-pipe installation will benefit not only fish communities, but all vertebrate species inhabiting riparian

zones of deeply incised streams. Specifically, modifications to the installation design that result in increased pool size of both created habitat types would benefit fish communities. During low flow conditions, some stream-level pools were isolated from the stream because the narrow channel connecting the stream-level pool to the adjacent stream dried up. Therefore, modifications which would improve connectivity of created stream-level pools with the adjacent stream, such as enlarging the narrow channel, may result in increased fish usage of stream-level pools. Furthermore, many field- and stream-level pools possessed little or no canopy cover. Replanting native riparian vegetation would provide increased canopy cover and leaf input that would benefit fish communities within the created habitats. Future research is needed to evaluate the benefits of the latter two recommendations and to explore the ecological impacts of other potential modifications to the drop-pipe installation design.

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