FISH UTILIZATION OF RIPARIAN HABITATS CREATED BY EROSION CONTROL STRUCTURES

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INTRODUCTION

Channel incision within a stream has both direct and indirect effects on the adjacent riparian zone. Bed lowering due to channel incision severs the natural floodplain/stream interaction and results in alteration of physical and biological features of the riparian zone. Prior to channel incision, riparian zones typically have well vegetated streambanks with bank heights that enable natural overbank flooding to occur. During channel incision, streambanks undergo a reduction in riparian vegetation caused by bank failure which is initiated by oversteepening and an increase in bank heights due to lowering of the channel bed. These processes result in containment of storm event runoff entirely within the channel. Additionally, lateral inflow over altered streambanks may initiate gully erosion within the adjacent riparian zones and agricultural fields and cause further environmental deterioration. 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).

Field-scale grade control structures (drop pipes) are utilized to control gully erosion occurring adjacent to incised streams undergoing restoration as part of the Demonstration Erosion Control (DEC) project in the Yazoo River basin. Over 2,000 structures were planned for installation or constructed as part of the DEC project (Shields et al. 1995a). A drop pipe consists of a dam with an "L" shaped metal pipe passing through it (Figure 1). Both structural features function in erosion control. The dam causes water to pond, thus reducing the runoff velocity and its sediment transporting capacity. The drain pipe conveys runoff from the field level to the stream level and prevents overbank flow. Additionally, installing this structure results in the replacement of eroding gullies with riparian habitats located at the field level of incised streams (Cooper et al. 1997; Smiley et al. 1997) and small pools located at the outflow of the pipe within the stream channel. Our objectives for this research were to: 1) describe fish communities within drop pipe created habitats by examining species composition, species richness, number of captures, and number of fish captured per unit effort (NPUE), and 2) determine the relationship of pool surface area and depth with fish species richness and NPUE within drop pipe created habitats.

MATERIALS AND METHODS

Habitat Classification

Two types of aquatic habitats which 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 wetland could include a variety of habitat types ranging from ephemeral to permanent wetlands. For the purposes of this paper, field level wetland specifically refers to the intermittent riverine wetland habitat defined by Cooper et al. (1997) and Smiley et al. (1997). In general, these are the largest wetlands created by drop pipe installation. Pool surface area of sampled field level wetlands ranged from 157.08 to 3282.24 m^2; water depth varied from 0.14 to 2.60 m. These wetlands are located on the field level of riparian zones adjacent to incised streams with streambanks that are nearly vertical in many locations and bank heights ranging from 2 to 7 m high (Shields et al. 1994: Cooper and Knight 1991). These bank heights result in the field level wetlands being hydrologically isolated from the stream, as overbank flooding is very uncommon within streams exhibiting this degree of incision (Shields and Cooper 1994). The source of water for these wetlands is precipitation and storm runoff from watersheds that normally include the surrounding agricultural fields.

Stream level pools are small backwater pools located within the channel of the incised stream. In general, these pools consist of a scour hole at the pipe's outflow with a narrow channel leading to the stream. During base level 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 = 0.08 to 91.02 m^2; range of depth = 0.06 to 1.75 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 are usually connected with the adjacent stream.

Fish and Physical Habitat Data Collection Methods

We sampled fish communities and physical habitat from 12 field level wetlands and 38 stream level pools located within Hotophia, Long, and Otoucalofa Creek watersheds. These three watersheds are part of the Yazoo River basin and located in northwestern Mississippi along the bluffline bordering the Mississippi River alluvial plain (Shields et al. 1995b). Fish and habitat data were collected from field level wetlands in May 1996, while 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 this study, selected sites of both habitat types were sampled by electroshocking and seining. We found that seining (15.2 m, mesh size 0.9 cm or 6.1 m, 0.3 mesh size) was the most effective sampling technique for field level wetlands, while 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, we sampled all microhabitats within each site and our mean collecting effort was 3.3 seine pulls. 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, we used only NPUE calculated from sites sampled with the larger seine 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 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% formaldehyde 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 concurrently with fish collecting from all 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 analyses were used to determine differences in mean number of captures and mean NPUE between field level wetlands and stream level pools. However, the means and standard deviations 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. 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 (Halyk and Balon 1983; Connor and McCoy 1979) 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 and the variation in distance of the scour hole from the stream. The watershed effect may occur because all sampled pools were not adjacent to the same stream, but three different streams. Therefore, we examined the watershed effect by comparing species richness and NPUE among stream level pools from Hotophia, Long, and Otoucalofa Creeks using a single factor analysis of variance. We used Pearson's product-moment correlation to determine if a relationship existed between distance of scour hole from stream with 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

Fish were not captured in all sampling sites within both habitat types. We captured fish in seven field level wetlands and 26 stream level pools from a total of 12 and 38 sites, respectively. A list of all the 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 3803 captures, while a total of 22 species from 668 captures occurred within stream level pools. Stream level pools exhibited a slightly higher, but not significantly higher ($P = 0.339$), mean species richness than field level wetlands, while field level wetlands exhibited a greater mean number of captures and mean NPUE (Table 2).

We did not detect 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. Additionally, no significant correlation was observed between distance to scour hole from stream with species richness ($r = -0.024$, $P > 0.05$) or NPUE ($r = 0.007$, $P > 0.05$). Regression analyses detected a significant positive relationship between pool surface area and depth with species richness within field level wetlands (Table 3, Figure 2). A significant positive relationship between pool surface area and depth with species richness and NPUE within stream level pools was also detected (Table 3, Figure 2).

DISCUSSION

Fish utilization of both field level wetlands and stream level pools indicates the present potential of aquatic habitat creation by drop pipe installation. Installing these structures 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.

While no significant difference in mean species richness was observed between field level wetlands and stream level pools, total species richness and standard deviation of mean species richness was higher within the stream level pools and may be attributed to differences in degree of isolation between the two habitat types. Both field level wetlands and stream level pools contained individuals of fish species which could be 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*), redfin shiner (*Lythrurus umbratilis*), striped shiner (*Luxilus chrysocephalus*), brook silverside (*Labidestes sicculus*), yazoo shiner (*Notropis rafinesque*), river carpsucker (*Carpoides carpio*), emerald shiner (*Notropis atherinoides*), and bluntface shiner (*Cyprinella camura*)] (Table 1). These species are also present within Hotophia, Long, and Otoucalofa Creeks (Shields et al. 1994, Knight and Cooper 1987) and their presence within stream level pools implies periodic connections with these streams. Total and mean number of captures was higher within the field level wetlands than the stream level pools. The smallest field level wetland sampled was 2.2 times greater in area than the largest stream level pool sampled. This magnitude in size difference enables field level wetlands to support much higher numbers of fish.

Halyk and Balon (1983) used rotenone to sample 19 natural floodplain pools adjacent to a fourth order stream in Ontario, Canada. These floodplain pools exhibited three notable similarities with our field level wetlands and stream level pools: 1) they are aquatic habitats formed within depressional areas; 2) they are located adjacent to streams which are physically influenced by the agricultural land use within the watershed; and 3) they have similar surface areas, which are intermediate in size between surface areas possessed by field level wetlands and stream level pools. It was interesting that total species richness of floodplain pools was 18, similar to the total species richness of stream level pools (22). However, floodplain pools had a higher mean species richness (11.8) and a higher mean number of captures (1435.7) than either field level wetlands and stream level pools. The similarity in total species richness indicates that overall both habitat types are capable of being utilized by a similar number of species from the adjacent stream. However, the higher mean species richness and mean number of captures within floodplain pools indicates that floodplain pools are more frequently used by a greater number of species and individuals than stream level pools. This increase in mean species richness and mean number of captures may be a result of the larger mean physical size exhibited by floodplain pools.

When examining species-area relationships, an increase in area almost always results in an increase in species richness (Connor and McCoy 1979). Based on the theory of island biogeography, Taylor (1997) predicted that isolated pools should exhibit a steeper slope of the regression line than connected pools when examining species-volume (or area) relationships. Taylor examined species-volume relationships between connected and isolated stream pools in Oklahoma and did not detect a significant difference in slope values between isolated pools and connected pools. However, he did observe that isolated pools exhibited a slightly higher slope and a lower R^2 value than connected pools. We found the same trend in slope and R^2 values when comparing the species-area relationships between field level wetlands (isolated) and stream level pools (connected) (Table 3). The similarity in species-area relationships between these natural and created habitats may be a subtle indicator of habitat quality within drop pipe created habitats.

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 the 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 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. The creation of stream level pools results in an additional pool type within incised streams which can be utilized by stream fishes. Creation of additional pool types is important because incised streams are lacking in pool habitats (Shields et al. 1994). Additionally, because these created habitats are located adjacent to the main channel they may provide fish refugia from storm events. Refugium is important because harsher environmental conditions occur within incised streams than nonincised streams during storm events since all flow is contained within channel (Matthews 1986).

In conclusion, these environmental improvements occurred as a result of standard installation practices which focus on erosion control without consideration of habitat creation. The potential restoration benefits of drop pipe installation have yet to be realized and our results suggest that altering the installation design to facilitate the creation of larger and deeper field level wetlands and stream level pools will provide greater benefits to fish and other wildlife. Additionally, increasing the connectivity of the stream level pools to adjacent streams to facilitate greater movement of fishes between the stream level pools and stream may greatly benefit the stream fish community.

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Table 1. Species list, overall relative abundance, total number of captures, and frequency of occurrence within seven field level wetlands and 26 stream level pools.

Field level wetland fish species	Percent	Number	Frequency
Lepomis cyanellus (green sunfish)	46.9	1782	6
Gambusia affinis (western mosquitofish)	22.5	856	1
Notemigonus crysoleucas (golden shiner)	20.0	762	5
Lepomis macrochirus (bluegill)	8.1	307	3
Pomoxis nigromaculatus (black crappie)	1.0	39	1
Ameiurus natalis (yellow bullhead)	0.7	25	1
Ameiurus melas (black bullhead)	0.4	16	3
Micropterus salmoides (largemouth bass)	0.3	10	1
Lepomis hybrid (hybrid sunfish)	0.2	6	1
Stream level pool fish species			
Lepomis cyanellus (green sunfish)	31.6	211	19
Lepomis macrochirus (bluegill)	16.9	113	12
Gambusia affinis (western mosquitofish)	9.0	60	9
Notemigonus crysoleucas (golden shiner)	8.4	56	10
Erimyzon oblongus (creek chubsucker)	7.5	50	10
Semotilus atromaculatus (creek chub)	6.4	43	11
Fundulus olivaceus (blackspotted topminnow)	6.1	41	13
Lepomis megalotis (longear sunfish)	2.5	17	6
Micropterus punctulatus (spotted bass)	2.2	15	6
Dorosoma cepedianum (gizzard shad)	1.9	13	3
Ameiurus natalis (yellow bullhead)	1.5	10	5
Pimephales notatus (bluntnose minnow)	1.2	8	3
Lythrurus umbratilis (redfin shiner)	1.0	7	2
Luxilus chrysocephalus (striped shiner)	0.7	5	2
Labidestes sicculus (brook silverside)	0.6	4	1
Notropis rafineque (yazoo shiner)	0.6	4	1
Carpiodes carpio (river carpsucker)	0.3	2	2
Notropis atherinoides (emerald shiner)	0.3	2	1
Cyprinella camura (bluntface shiner)	0.3	2	1
Pomoxis nigromaculatus (black crappie)	0.3	2	1
Aphredoderus sayanus (pirate perch)	0.1	1	1
Lepomis gulosus (warmouth)	0.1	1	1
Lepomis hybrid (hybrid sunfish)	0.1	1	1

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

Habitat type	species richness	number of captures	NPUE
Field level wetland	3.1 (1.4)	543.3 (533.2)	185.7 (201.5)
Stream level pool	4.6 (3.1)	25.7 (30.8)	3.9 (2.8)

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

Habitat type	x	y	Intercept	Slope	R^2	P
Field level wetland	area	species richness	-1.465	0.592	0.459	0.016
	depth	species richness	-0.127	1.673	0.531	0.011
	area	NPUE	-4.312	1.783	0.360	0.051
	depth	NPUE	-0.152	4.849	0.386	0.055
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

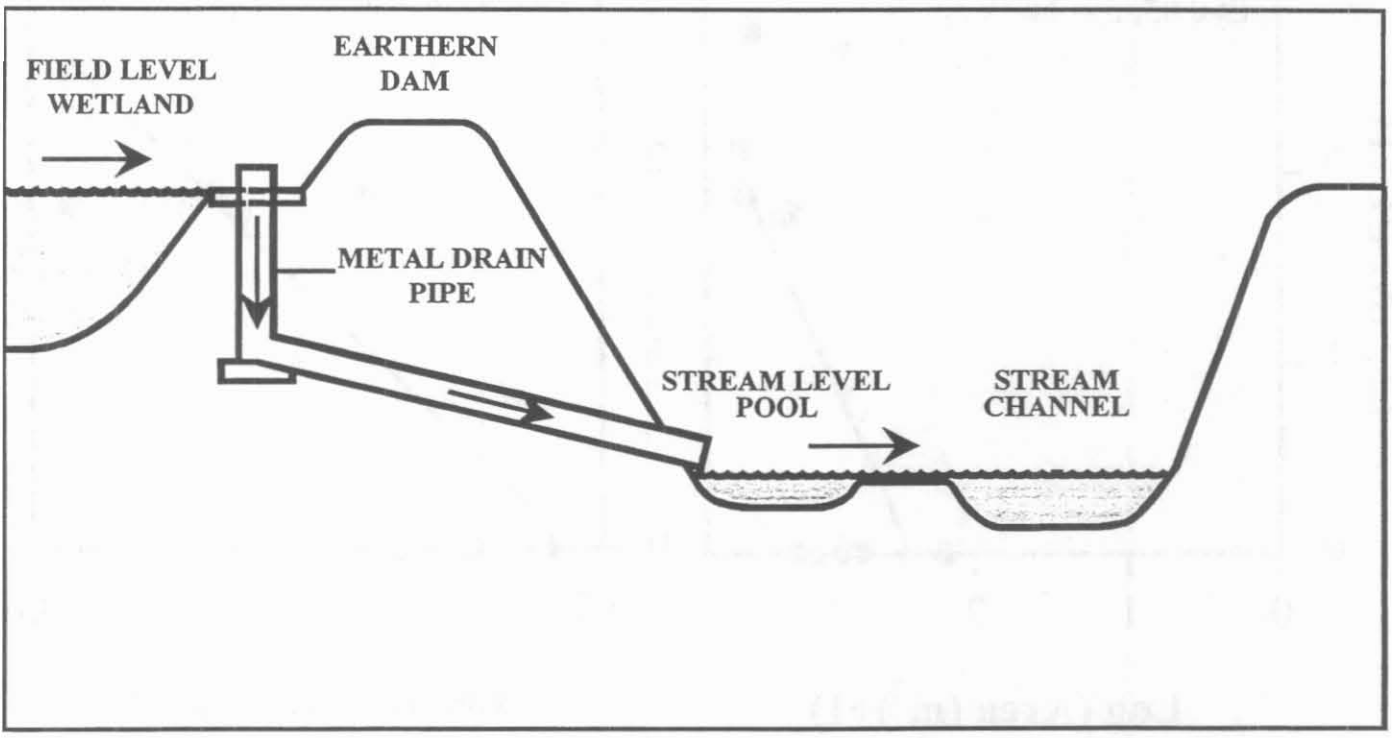

Figure 1. Cross section of drop pipe structure and created habitat types.

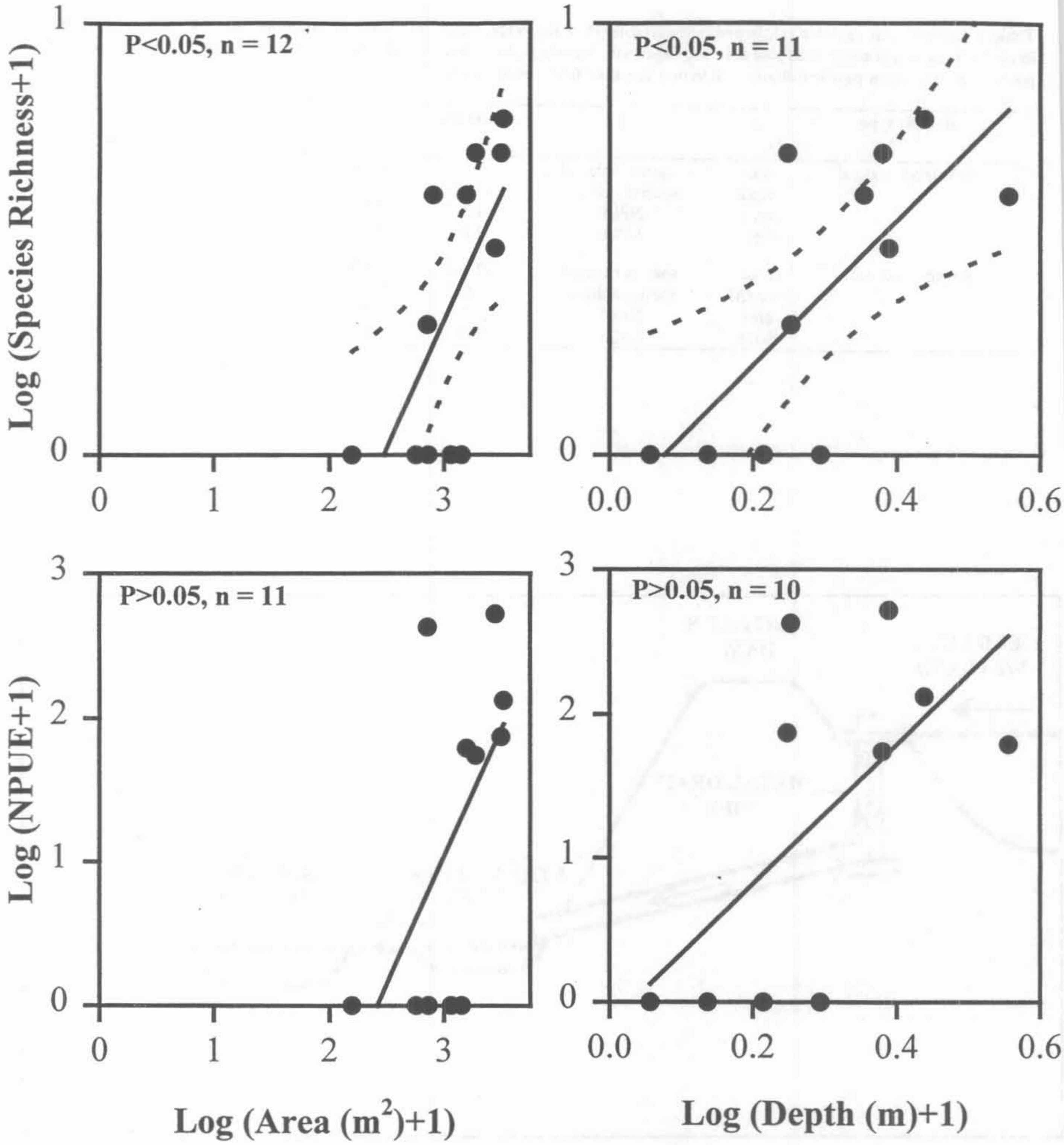

Figure 2. Regression plots of species richness and NPUE against area and depth within field level wetlands created by drop pipe installation. The solid line is the regression line, while the dotted line represents the 95% confidence intervals.

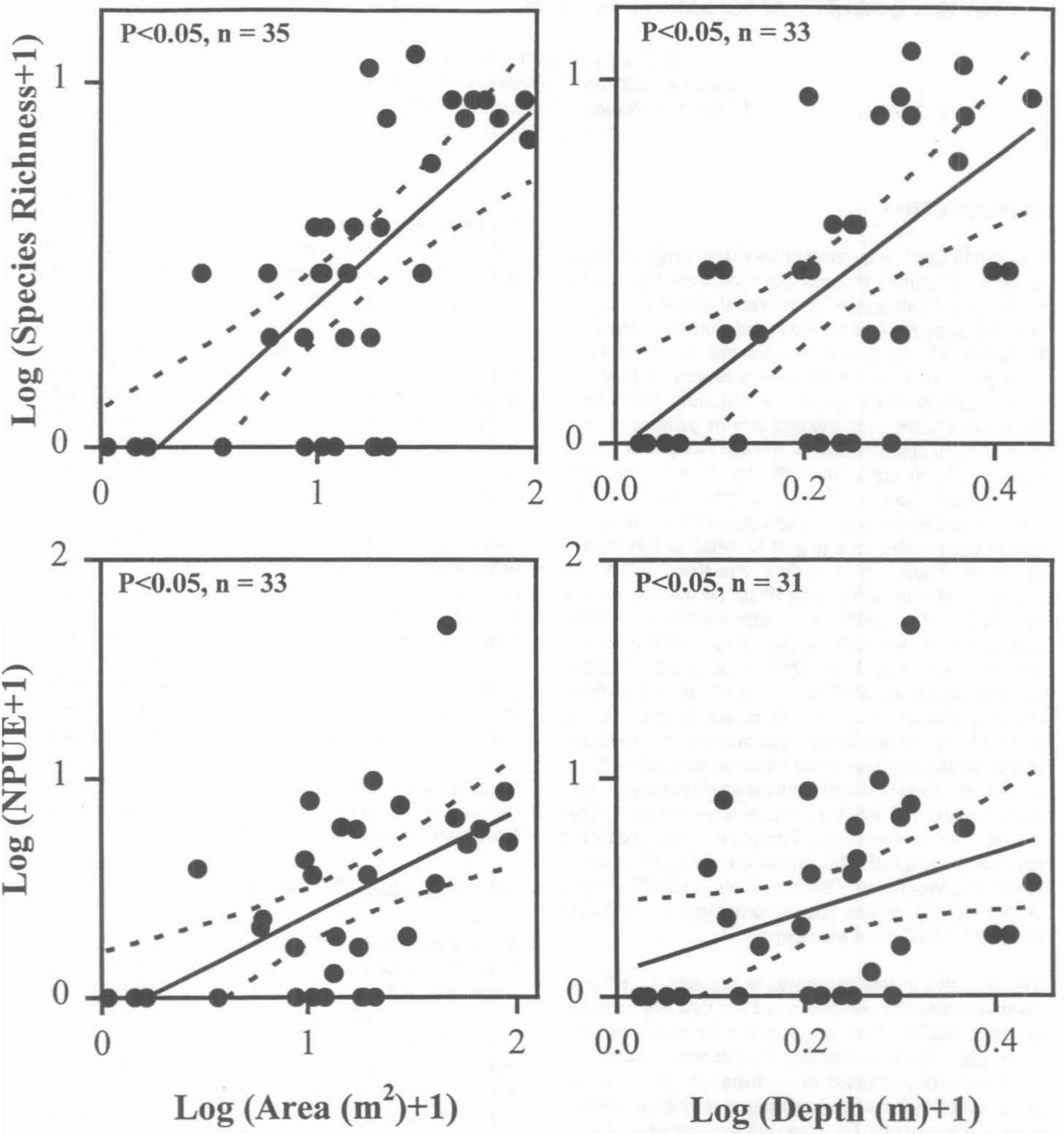

Figure 3. Regression plots of species richness and NPUE against area and depth within stream level pools created by drop pipe installation. The solid line is the regression line, while the dotted line represents the 95% confidence intervals.