Patterns of Fish Community Structure Associated with Created Wetlands in the Upper White River Watershed

Mark Leao, *Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, Mail Slot 4912, 1200 University Drive, Pine Bluff, AR 71601*

Michael A. Eggleton, *Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, Mail Slot 4912, 1200 University Drive, Pine Bluff, AR 71601*

Edmund R. Buckner, *Department of Agriculture, University of Arkansas at Pine Bluff, Mail Slot 4913, 1200 University Drive, Pine Bluff, AR 71601*

Abstract: Fish communities were sampled from macrotopographical features found in created wetlands of different ages (termed young, old, and reference) designed by the Wetland Reserve Program in three counties in east-central Arkansas. Wetlands were sampled from March–June 2003 using mini modified-fyke nets and experimental gill nets in pool and ditch habitats. A total of 8,952 fishes representing 49 species was collected. Repeated-measures analysis of variance (ANOVA) indicated no significant differences in fish diversity or evenness between different-aged wetlands in pool habitats; a significant pattern of greater fish species richness in pools associated with reference wetlands occurred relative to young and old created wetlands. In ditch habitats, fish diversity and evenness tended to increase significantly through time in reference wetlands compared to created wetlands, whether young or old, though overall means were not significantly different among the three different-aged wetlands. Conversely, fish richness tended to be significantly greater in ditch habitats of young wetlands. Detrended Correspondence Analysis (DCA) suggested fish communities varied along a gradient related to both wetland age and habitat type. Results indicated that rough fish species such as common carp *(Cyprinus carpio),* black bullhead *(Ameiurus melas),* and green sunfish *(Lepomis cyanellus)* were associated with created wetlands regardless of whether young or old. Reference wetlands exhibited a tendency towards greater abundances and varieties of centrarchid and cyprinid fish species such as pugnose minnow *(Opsopoeodus emiliae),* warmouth *(L. gulosus),* weed shiner *(N. texanus),* and cypress minnow *(Hybognathus hayi).* Older-created wetlands were intermediate between fish communities found in young and reference wetlands and contained fish species found in both other wetland types. Overall, DCA results demonstrated a successional trend in created wetlands wherein young wetland fish communities evolved with increasing age towards communities found at reference sites that were considered to be more natural and undisturbed.

Key words: created wetlands, Wetland Reserve Program, fish communities, macrotopography

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Wetlands are extremely valuable resources that provide a number of ecological functions. Wetlands help recharge aquifers and provide flood reduction, act as biological filters by utilizing excess nutrients from fertilizers and removing pesticides from surface waters, reduce erosion and stream sedimentation, and provide habitat and vital breeding grounds for various fish and wildlife species (Walbridge 1993, Leitch et al. 1994). Wetlands also generate revenue from recreational uses such as duck hunting, bird and wildlife watching, and recreational sport fish angling. The commercial fishing industry alone contributed US$1.9 billion to the U.S. gross national product in 1998, and over 95% of the fish and shellfish species harvested by the U.S. fishing industry are wetland-dependent species (Mitsch and Gosselink 2000).

The Lower Mississippi Alluvial Valley (LMAV) contains one of the most ambitious wetland creation efforts in the world (King and Keeland 1999). As of 2002, over 67,585 ha in the LMAV have been converted to wetlands. Landowners and the U.S. government have invested over $400 million in the last eight years on wetland creation aimed at environmental rehabilitation in the LMAV (King and Keeland 1999). In 1990, the U.S. Department of Agriculture (USDA) in conjunction with the Natural Resources Conservation Service (NRCS) established the Wetlands Reserve Program (WRP). With the WRP, natural resource professionals and landowners have an opportunity to reclaim former wetlands that were drained and leveled for agriculture back to functional wetlands. The goal of the WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre of land enrolled in the program. To meet this goal, the WRP focuses on wetland plans that include construction of an undulating landscape with a diverse hydroperiod that will support a variety of habitat zones such as scrub/shrub, wooded, submerged, emergent, and floating leaf communities.

Recent Arkansas WRP wetland plans have been developed to reflect the complexities of natural wetland ecosystems. These complex ecosystems are driven by the diversity of topographic relief and their corresponding hydroperiod (e.g., timing, depth, duration, and inundation of a flooding event). Many fish, amphibian, reptile, and plant species are dependent on hydroperiod diversity to successfully reproduce (Schneider and Sharitz 1988, Tockner et al. 2000). The duration and timing of inundation regulate the response of fish fauna to flooding (King et al. 2003). Habitat diversity also is an important factor related to fish species composition allowing for more niche specialization (Diana 1995), which may lead to increased species richness and diversity. The age of a wetland also plays a significant role in fish distributional patterns. For instance, fish community composition is influenced by water depth, water clarity, productivity, food web interactions, and fish movement, which are all factors that change with aging habitats (Matthews 1998).

As of 1990, Arkansas had already lost over 70% of its naturally occurring wetlands and 80% of its bottomland hardwood forests (Dahl 1990). Most of Arkansas' wetlands were drained for agriculture, pasture land, and timber production from the 1950s to the late 1970s (National Research Council 1982, Hefner and Brown 1985). No studies have been conducted in Arkansas to evaluate the success of converting agricultural lands to functional wetland complexes capable of supporting rich and diverse fish communities. Therefore, the objectives of this study were to: 1) evaluate fish communities among different-aged wetlands created by the WRP in Arkansas and compare these to natural (i.e., reference) wetlands, and 2) evaluate fish communities among different macrotopographic habitats (i.e., ditches and pools) within different-aged wetlands created by the WRP. Macrotopography refers to elevational changes greater than 15 cm.

Methods

Fish Collections

Data for this study were collected during 2003. The study was originally designed to be four months in duration (March–June); however, only three months of data were included in the analysis due to site inaccessibility during May flooding. Fish communities were sampled on wetland macrotopography (i.e., pools and ditches) from five different WRP tracts and a newly-created wildlife management area (WMA) with similar management goals as the WRP tracts.

Study sites were located in Jackson, Prairie, and White counties in east-central Arkansas. Study sites were privately and publicly owned, and ranged in size from 75 to 6,880 ha. The WRP tracts were placed into two groups that discriminated wetland age. The first group (termed 'young') consisted of newly-created sites that were one–two years in age. The second group (termed 'old') was made up of sites that were three–five years in age. "Reference" sites composed a third group that were considered to be relatively natural and undisturbed wetlands. For each wetland age group, the same three pools and three ditches were sampled once per month from March through June 2003.

The reference site selection criteria included accessibility, proximity to the WRP tracts being sampled, age, hydroperiod, and their relatively undisturbed nature. The WRP tracts criteria included proximity to each other, proximity to reference sites, habitat types available, accessibility, hydroperiod, and age. At each sampling site, two modified mini-fyke nets were set along with an experimental gill net at midnight and left for 12 hours. Captured fishes were identified, measured, and enumerated in the field with survivors released. Fishes not easily identified in the field were preserved in 10% buffered formalin, returned to the laboratory, and identified and measured at a later time.

The modified mini-fyke nets had a mesh size of 3.0 mm, with a lead of 4.5 m long by 0.6 m high. The frame was constructed of two rectangles 0.6 x 1.2 m made of 7.9-mm black oil-tempered spring steel. The cab was made of two 7.9-mm thick spring steel hoops that were 0.6 m in diameter. The whole net was coated in latex green dip to prevent weathering. A similar net is used by the Long Term Resource Monitoring Program on the upper Mississippi River for sampling riverine backwater habitats (Gutreuter et al. 1995). The experimental monofilament gill nets were 38.1 m in length and 2.4 m in depth. The nets contained five equal-area panels (2.4 m x 7.6 m) of different mesh sizes. Panel mesh sizes were 2.5-cm, 3.8-cm, 5.1-cm, 6.4-cm, and 7.6-cm square mesh.

Data Analysis

Several measures of fish community structure were calculated for each wetland sampled using PC ORD (McCune and Mefford 1999). Community measures included fish species richness (S), fish community evenness (E), and fish community diversity (D). Species richness was reported as the number of different species collected for a particular sample at a given site. Evenness referred to the distribution of individuals among species in a community and was a measure of equitability (Ney 1999). Fish community diversity was estimated using Simpson's Diversity Index, which expresses the probability of any two individuals drawn at random from an infinitely large community belonging to different species (Magurran 1988). Simpson's Index values were reported as 1-D, referred to as D', whereby greater values reflected greater diversity.

Detrended correspondence analysis (DCA; Hill and Gauch 1980) was performed to assess patterns in fish communities relative to wetland age and habitat type. DCA is a multivariate indirect gradient analysis that uses reciprocal weighted-averaging to analyze species x sample data matrices, whereby site scores are generated for each individual sample based on the fish species collected there. The site scores generated by DCA are unitless but not arbitrary measures of community structure. Distances between samples in multivariate space are interpreted as actual differences in community structure. Individual sites located close in ordination space have similar fish communities, whereas sites far apart have different fish communities. In our study, one replicate sample from one site was dominated by orangespotted sunfish *(Lepomis humilis).* This sample was discarded from the analysis due to its disproportionate influence on the overall analysis because it distorted what we believed was an ecologically relevant gradient in wetland fish communities.

Repeated-measures analyses of variance (ANOVA) were used to compare each of the statistical measures of fish community structure (S, E, and D') among wetlands of different ages. The effects assessed in each ANOVA were wetland age (i.e., young, old, or reference), time (i.e., collection months March, April, and June), and the wetland age-time interaction. Analyses were conducted separately by wetland macrotopographic habitat (i.e., pools and ditches). When wetland age-time interactions were nonsignificant, then slopes of the fish community-time relationships for each wetland age were judged to be equivalent (i.e., parallel). Thus, differences between individual means (i.e., S, E, and D') were tested using least-squares means as a post-hoc mean separation test (Zar 1999). In cases where the wetland age-time interactions were significant, then slopes of the individual fish community-time relationships were tested against each other using orthogonal linear contrasts. All statistical tests were analyzed using the PROC MIXED procedure in SAS (SAS 1988) using a first-order autoregressive correlation structure. In the case of DCA axis scores (as measures of fish community structure), standard two-way factorial ANOVA procedures were conducted separately on axis-1 and axis-2 scores in SigmaStat (SPSS 1992–1997). Within these analyses, Tukey multiple comparison tests were used as a post-hoc mean separation test. Significance for all analyses was declared at an alpha level of 0.05.

Results

A total of 8,952 fishes, representing 49 species, was collected during three months of sampling (Table 1). Repeated-measures ANOVA results on fish species richness indicated no significant wetland age-time interaction in ditch ($P = 0.883$) or pool ($P = 0.258$) habitats. In ditch habitats, least-squares means indicated that young wetlands had on average significantly greater richness than both old ($P = 0.040$) and reference ($P = 0.033$) wetlands. However, in pool habitats, least-squares means indicated that richness was significantly greater in reference wetlands relative to young wetlands ($P = 0.013$), but not compared to old wetlands ($P = 0.168$); species richness did not vary between old and young wetlands ($P = 0.208$).

Repeated-measures ANOVA on D' values exhibited significant wetland age-time interaction in ditch habitats ($P = 0.008$); pool habitats contained no effects of wetland age, time, or wetland age-time interaction ($P > 0.050$). In ditch habitats, fish diversity increased through time in reference wetlands and decreased through time in both young and old wetlands. Expectedly, fish diversity-time slopes differed significantly between reference and old wetlands ($P = 0.047$) and between reference and young wetlands ($P = 0.002$); fish diversity-time slopes of old and young wetlands did not differ significantly ($P = 0.255$).

With respect to fish community evenness (E), identical results were obtained as with fish community diversity. In pool habitats, no significant effects of wetland age, time, or wetland age-time interaction were observed ($P > 0.05$). Conversely, in ditch habitats, fish community evenness-time relationships were not parallel ($P = 0.001$), with evenness increasing through time in reference wetlands and decreasing through time in both young and old wetlands. Fish community evenness-time slopes differed significantly between reference and old wetlands ($P = 0.005$) and reference and young wetlands ($P < 0.001$), whereas slopes of old and young wetlands did not differ significantly ($P = 0.396$).

DCA ordinations suggested fish community compositional changes among both wetland age (Fig. 1) and habitat type (Fig. 2). Reference wetlands tended to have greater axis-1 scores, whereas young wetlands tended to have lower axis-1 scores (Fig. 1). Older wetlands contained intermediate axis-1 scores. Fish communities in reference wetlands tended to have greater abundances of centrarchid and cyprinid fish species such as bluegill *(L. macrochirus)*, warmouth *(L. gulosus),* pugnose minnow *(Opsopoeodus emiliae),* weed shiner *(N. texanus),* and cypress minnow *(Hybognathus hayi).* Young wetlands were associated more with rough fish species such as common carp *(Cyprinus carpio),* black bullhead *(Ameiurus melas),* and green sunfish *(L. cyanellus),* though a weak association may have existed with orangespotted sunfish. Older created wetlands exhibited fish communities intermediate between young and reference wetlands. Fish community differences also were evident between pool and ditch habitats. Fish communities in pools tended to have greater abundances of sunfish species and cyprinids, whereas ditch habitats contained more rough fishes as described before (Fig. 2).

Analysis of variance results on DCA axis-1 site scores (as measures of fish com-

Table 1. Species found and total number collected for each wetland age group. X's indicate absence of species.

Common names	Scientific names	Young	Old	Reference
Shortnose gar	*Lepisosteus platostomus*	10	22	11
Longnose gar	*Lepisosteus osseus*	2	X	6
Spotted gar	*Lepisosteus oculatus*	19	7	35
Gizzard shad	*Dorosoma cepedianum*	976	986	129
Threadfin shad	*Dorosoma petenense*	2	X	X
Black crappie	*Pomoxis nigromaculatus*	360	67	25
White crappie	*Pomoxis annularis*	13	4	X
Pirate perch	*Aphredoderus sayanus*	40	17	5
Inland silverside	*Menidia beryllina*	72	0	9
Black bullhead	*Ameiurus melas*	631	231	67
Yellow bullhead	*Ameiurus natalis*	12	16	3
Logperch	*Percina caprodes*	2	X	8
Bowfin	*Amia calva*	17	24	12
Chain pickerel	*Esox niger*	2	X	2
Common carp	*Cyprinus carpio*	2977	141	23
Smallmouth buffalo	*Ictiobus bubalus*	15	6	12
Bigmouth buffalo	*Ictiobus cyprinellus*	X	2	15
Spotted sucker	*Minytrema melanops*	X	X	7
Freshwater drum	*Aplodinotus grunniens*	1	10	1
Channel catfish	*Ictalurus punctatus*	1	2	4
Tadpole madtom	*Noturus gyrinus*	1	X	2
Largemouth bass	*Micropterus salmoides*	7	16	3
White bass	*Morone chrysops*	3	9	4
Yellow bass	*Morone mississippiensis*	7	X	3
Swamp darter	*Etheostoma fusiforme*	5	6	18
Quillback	*Carpiodes cyprinus*	2	X	1
Warmouth	*Lepomis gulosus*	33	21	120
Longear sunfish	*Lepomis megalotis*	X	1	1
Spotted sunfish	*Lepomis punctatus*	X	1	4
Orangespotted sunfish	*Lepomis humilis*	29	74	593
Bluegill	*Lepomis macrochirus*	13	50	31
Redbreast sunfish	*Lepomis auritus*	X	X	1
Bantam sunfish	*Lepomis symmetricus*	9	X	X
Green sunfish	*Lepomis cyanellus*	408	22	2
Dollar sunfish	*Lepomis marginatus*	1	6	1
Redear sunfish	*Lepomis microlophus*	X	1	X
Flier	*Centrarchus macropterus*	40	2	5
Banded pygmy sunfish	*Elassoma zonatum*	X	X	6
Mosquito fish	*Gambusia affinis*	19	16	8
Golden shiner	*Notemigonus crysoleucas*	17	95	1
Blackspotted topminnow	*Fundulus olivaceus*	X	X	7
Blackstripe topminnow	*Fundulus notatus*	X	X	1
Pugnose minnow	*Notropis emiliae*	2	X	106
Weed shiner	*Notropis texanus*	X	X	20
Cypress minnow	*Hybognathus hayi*	X	9	21
Redfin shiner	*Lythrurus umbratilis*	X	X	4
White perch	*Morone americana*	1	X	X
Striped bass	*Morone saxatilis*	X	1	X
Starhead topminnow	*Fundulus dispar*	X	1	X
Totals		5,749	1,866	1,337

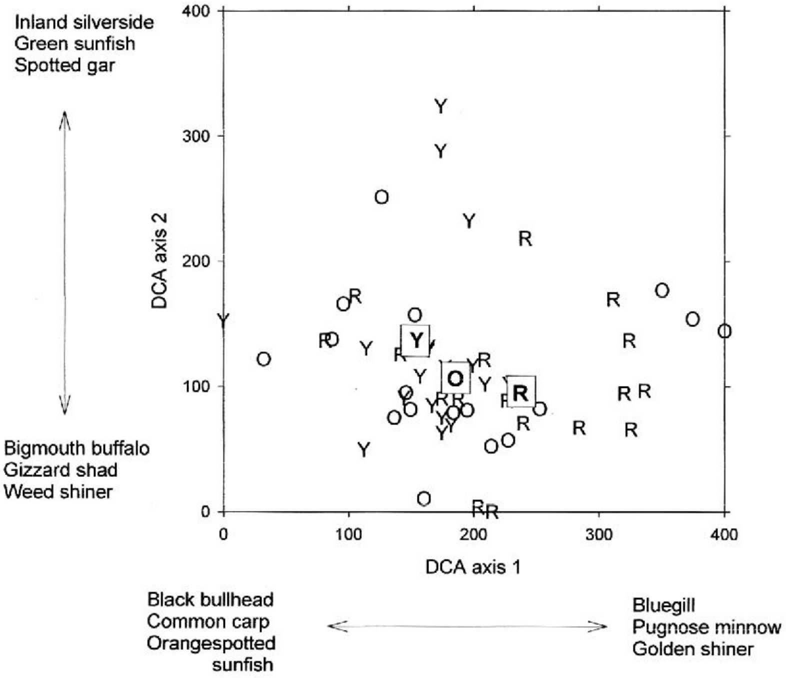

Figure 1. Detrended Correspondence Analysis (DCA) ordination illustrating the differences in ordination space occupied by young (Y), old (O), and reference (R) wetlands. The grand mean axis-1 and axis-2 scores for each age group are denoted by the boxed labels. Species labeled for axis-1 and axis-2 represented species with the greatest axis correlations, and are indicative of species-wetland age associations.

munity structure) exhibited significant differences between both habitat types (*P* = 0.03) and wetland ages (*P* = 0.006) with no significant wetland age x habitat interaction (*P* = 0.74). Tukey Multiple Comparison tests showed these differences to exist between young and reference wetlands (*P* = 0.023), and also between ditches and pools (*P* = 0.006). No significant differences were found for any effects using DCA axis-2 site scores (*P* = 0.10–0.31).

Discussion

Pools in young wetlands were significantly lower in species richness than pools from reference wetlands. In contrast, ditches in young wetlands tended to have greater species richness compared to ditches in reference wetlands, though the effect was weak due to low statistical power. In pool habitats, this observation is logical in the sense that reference pools were present longer and more fish species had oppor-

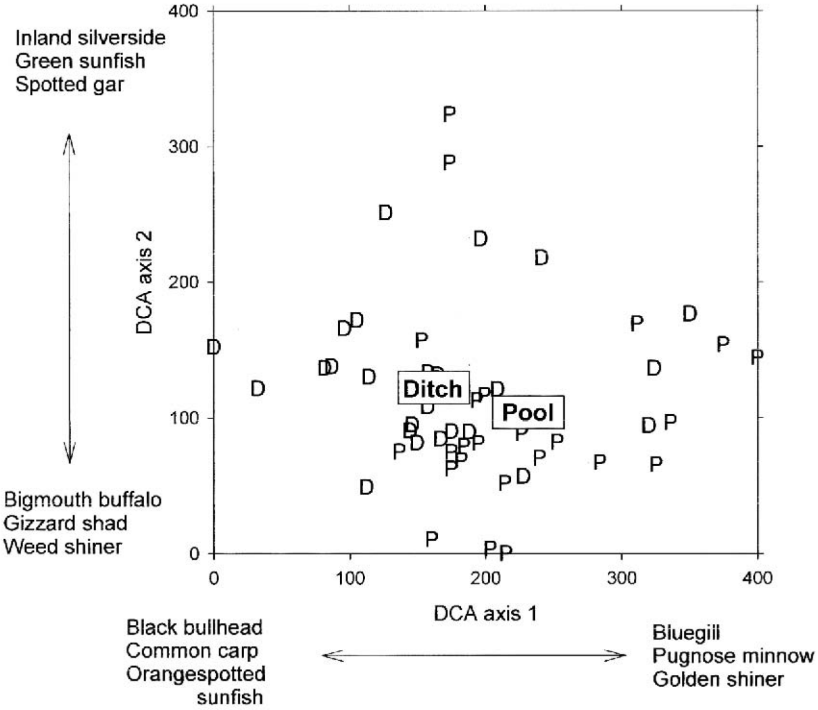

Figure 2. Detrended Correspondence Analysis (DCA) ordination illustrating the differences in ordination space occupied by ditches (D) and pools (P). The grand mean axis-1 and axis-2 scores for each habitat type are denoted by the boxed labels. Species labeled for axis-1 and axis-2 represented species with the greatest axis correlations, and are indicative of species-habitat associations.

tunities to colonize these habitats. In addition, diversity of habitats allows for more niche specialization in fishes (Matthews 1998) in that reference pools have had more time for habitat complexity and diversity to develop than young wetland pools.

Fish species richness in floodplain pools results from species additions by spring invasions, and species subtractions by local extinctions during summer months (Halyk and Balon 1983). Fish species primarily colonize these pools during flood events when pools are connected to main river channels. Some of the young wetland sites had not yet been exposed to a flooding event prior to May 2003, so colonization by fishes had been limited. For example, some young wetlands that had very few or no fishes collected in March or April had several species present by June. Theiling et al. (1999) also reported large changes in fish communities in young wetlands immediately following a flood event. As more immigrants appear in a habitat, generalist fish species are typically replaced with specialist fish species that are better competitors and able to persist on a smaller niche breadth, thus increasing fish community richness (Diana 1995). In the case of the young ditches having greater richness than the reference ditches, this could be due to the extremely abundant number of fishes caught in the young ditches in June after a large flooding event in May.

Similarities in fish evenness and diversity across different-aged wetlands and different macrotopographical habitats indicated that created wetlands were capable of supporting diverse fish communities, comparable to natural wetlands, in a very short period of time. In similar studies, Langston and Kent (1997) and Williams and Zedler (1999) found fish colonization to be rapid in constructed wetlands. However, the results of this effort do not suggest that fish community composition was the same across different-aged wetlands or habitats. On the contrary, DCA showed that fish communities were significantly different among different-aged wetlands (suggested by DCA axis-1 scores). Differences in DCA axis-1 scores indicated a predictable shift in species composition with increasing wetland age (Fig. 1). Specifically, the transition from a rough fish-dominated community to one typified by centrarchids and small-bodied cyprinids corresponded with the increasing wetland age. Similarly, differences in DCA axis-1 scores suggested there were significant changes in fish communities between pools and ditches (Fig. 2). This again underscores the role that habitat diversity and complexity may play in wetland fish communities.

The total numbers of fish collected per wetland age group (Table 1) were considerably different. Total numbers of fish were much greater in young wetlands than old or reference sites. This was due to extremely high abundances of juvenile generalist species such as common carp, gizzard shad *(Dorosoma cepedianum),* black bullhead, and green sunfish that were collected in June after the sites had been connected to main channels during May flooding. The presence of juveniles and/or spawning adults suggested that these habitats likely served as important nursery areas for many riverine fishes (Guillory 1979).

All of the wetlands were connected to adjacent rivers and streams during the May flood period, but only the young wetlands contained large abundances of juveniles during June sampling. This may in part be attributed to the lack of an established fish community containing adult predators that directly influence fish communities through predation in young wetlands. The impact of predation may exclude certain fish species, thereby leading to mutually exclusive distributions and strong differences in community composition (Jackson et al. 2001). The young wetlands appeared to be unexploited resources that became rapidly populated during flood periods. However, once fishes had dispersed to a wetland, the likelihood of establishing self-sustaining populations depends on the number of colonists and the extent to which ecological requirements are met (Baber et al. 2002).

Fish communities in wetlands are strongly related to water quality, and differences in populations may be attributed to water quality differences found in constructed and natural wetlands (Streever and Crisman 1993). Water quality in wetlands may differ greatly with respect to levels of turbidity, nutrients, amounts of decaying organic matter, water temperatures, and dissolved oxygen (DO) (Mitsch and Gosselink 2000). Consequently, after spring floodwaters recede, only adapted fish species are able to tolerate seasonally extreme environmental conditions found in some wetlands. Specifically, high mortality of entrapped fish species intolerant of thermal and dissolved oxygen extremes can occur when conditions are especially harsh during summer months. Thus, these wetlands tend to have resident fishes that are tolerant of poor water quality and high temperatures, but also contain transient riverine species during certain periods of the year that utilize these habitats seasonally for foraging, spawning, and nursery areas.

The objectives of the NRCS for the selected tracts used in this study were focused on creating habitat and food for waterfowl, shorebirds, wading birds, amphibians and reptiles. The moist soil and shallow water areas on these tracts were managed to produce the greatest variety of foods by the manipulation of the timing and rate of water drawdown. Several studies have indicated that large numbers of common carp, which were found in large numbers in young wetlands, have destructive effects on submerged macrophytes and other waterfowl food through their feeding activities (Crivelli 1983). However, predators introduced through flooding events, such as largemouth bass *(Micropterus salmoides)* and gar species (*Lepisosteus* spp.) that prefer soft fin-rayed prey, may keep carp populations under control (Metzker and Mitsch 1997). Our results showed decreasing carp populations as wetland age increased (Table 1). Thus, time as opposed to active management, may be needed to reduce common carp populations, and in effect, increase waterfowl food in these wetlands.

Though fish production and creation of diverse fish communities was not the primary objective on any of the WRP tracts, inclusion of macrotopographic considerations during the wetland design phase provided the foundation for wetland fish communities that are similar in diversity to much older reference sites. The fish communities on these tracts provide a viable source of food for waterfowl, shorebirds, and wading birds. In addition, the fishes found on the studied WRP tracts provide recreational value through angling opportunities and also provide recruitment sources for fish populations found in the White River.

Recommendations for future studies include increasing sample size and also duration so as to include late summer/fall periods that better assess fish communities during periods of extreme environmental conditions. Continued monitoring of these sites will also allow us to examine fish community trends over longer periods of time.

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