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CONSEQUENCES OF STREAM IMPOUNDMENT ON FISH COMMUNITIES IN A SMALL NORTH AMERICAN DRAINAGE

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ABSTRACT

We examined impoundment associated fish community changes in the Kinkaid Creek drainage of southern Illinois by comparing collections made in 1998 and 1999 with a pre-impoundment survey conducted in 1958. We also analyzed other historical pre- and post-impoundment collections made during the past 60+ years. A dramatic change in fish community structure occurred with the pre-impoundment community dominated by cyprinids and the post-impoundment community now dominated by centrarchids. In addition, a 50% increase in the number of fish species known from the Kinkaid Creek drainage has occurred, with 35% of all species known from Illinois now present in the drainage. This increase in species richness coincides with the extirpation of six native species. Possible explanations for the changes in the species assemblage and increased species richness include the introduction and dispersal of non-native fish species and habitat alteration. Finally, we contend that processes, such as habitat alteration, must be considered when analyzing the pattern of increased species richness caused by non-native species seen in North American drainages. Copyright © 2001 John Wiley & Sons, Ltd.

KEY WORDS: community structure; freshwater fishes; habitat alteration; impoundment; introduced fishes

INTRODUCTION

Dam building and its subsequent impoundment of flowing waters has been occurring in the United States for over 150 years. Between 1930 and 1975, over 10000 dams were constructed on rivers and creeks of all sizes in the United States (Reisner, 1986). Owing mainly to the lack of suitable sites and shifts in federal funding priorities, the construction of new dams on large, commercially navigable rivers has significantly declined since that time. However, the impoundment of smaller rivers and creeks has continued unabated. With the increased recognition of native aquatic biodiversity (Master, 1990; Lydeard and Mayden, 1995), rigorous examination of the effects of habitat altering activities, such as river and creek impoundment, is needed.

Dams are frequently implicated as causes of population decline and extirpation of freshwater fishes (Miller *et al*., 1989; Allan and Flecker, 1993; Page *et al*., 1997). The following study was conducted to ascertain the effects of impoundment on the fish fauna of a small creek in southern Illinois. Our goals were to (1) duplicate, as closely as possible, the sampling methodology of the pre-impoundment fish survey (Stegman, 1959), and determine if and how changes in fish species richness and community structure have occurred; and (2) compare Stegman's (1959) faunal list and the results of our sampling efforts with total species lists compiled from other historical collections made in the drainage, both pre- and post-impoundment, to determine if drainage wide changes in richness have occurred.

The Kinkaid Creek basin drains 135 km^2 of the Shawnee Hills region of extreme southwestern Illinois (Figure 1). The main channel of Kinkaid Creek is approximately 35.4 km long, and is a third order stream at its confluence with the Big Muddy River. Given its hilly nature, the majority of land in the Kinkaid Creek basin has been spared from clearing and is forested. With the exception of some regions to the

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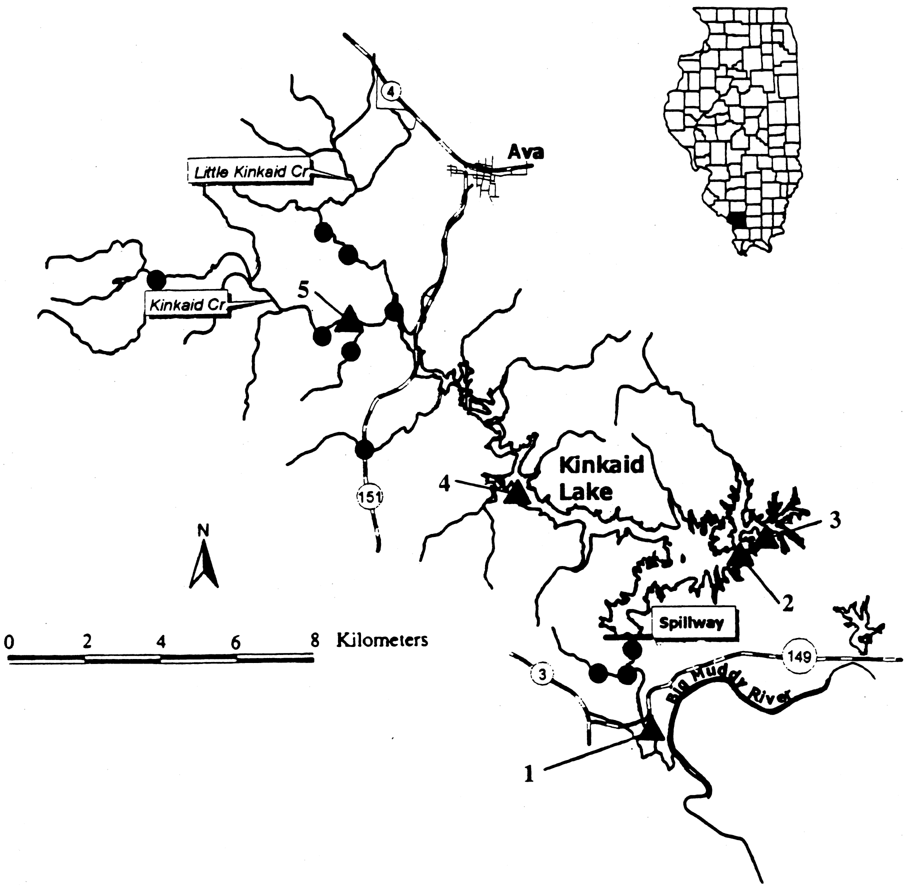

Figure 1. Map of Kinkaid Creek drainage in southwestern Illinois. Numbered solid triangles denote Stegman's (1959) original five sampling sites that were re-sampled in 1999. Site numbers correspond with those of Stegman. Solid circles denote additional sites that were quantitatively sampled in 1998 and 1999

north and northeast, most of the basin has remained under United States Forest Service or Illinois Department of Natural Resources ownership since the late 1960s. In 1970, an earthen dam was placed across Kinkaid Creek approximately 5.3 km upstream of its mouth to form the 1400-ha Kinkaid Lake for recreational purposes. Average lake depth is 8.8 m, and when water surface level is higher than 128 m above sea level, excess water runs over a concrete spillway, down a naturally occurring limestone bluff, and into a 0.4 ha receiving pool that opens into the downstream section of Kinkaid Creek. To determine its potential as a 'fisheries resource', an intensive survey of the Kinkaid Creek basin fish fauna was conducted (Stegman, 1959). Stegman sampled a total of five sites during the spring and summer of 1958, using a variety of collecting methods, including minnow seines, hoop and fyke nets, electroshocking, and sodium cyanide. In Stegman's (1959) study, each site was sampled for fishes three separate times.

MATERIALS AND METHODS

We sampled each of Stegman's (1959) five sites on three separate dates. The sampling dates were 2–3 March, 12–13 May, and 15–16 June 1999. Sampling sites were numbered 1–5, following Stegman (1959) (Figure 1). Site 1 was located approximately 3.2 stream km downstream of the dam, sites 2 and 3 were on an eastern arm of the reservoir, site 4 was on the reservoir halfway between the upstream confluence of Kinkaid Creek with the reservoir and the dam, and site 5 was on Kinkaid Creek approximately 1.5 km upstream of its confluence with the reservoir (Figure 1). We duplicated the collection methods of Stegman

(1959) as closely as possible at each site; however, given changes in habitat since impoundment, different methods were employed at sites 2, 3, and 4. We sampled sites 1, 2, 3, and 4 with a 240-V boat-mounted electrofisher for 0.5 h per sample. We also set two 12.7-mm mesh baited hoop nets overnight at site 1. Site 5 was sampled with a 3.1×1.2-m, 6.4-mm mesh minnow seine for one half-hour and a Smith-Root Model 12 DC backpack electrofisher for 0.5 h per sample. Given permit restrictions on sampling techniques, we could not duplicate Stegman's (1959) one-time use of sodium cyanide at sites 2–5. We identified and counted fishes collected at each site. Voucher specimens of each species were preserved in the field with 10% formalin and deposited in the Illinois Natural History Survey (INHS) Fish Collection.

We sampled ten additional sites in the Kinkaid Creek drainage (Figure 1) from one to three times in 1998 and 1999 using a 3.1×1.2-m, 6.4-mm mesh or a 3.1×1.8-m, 3.2-mm mesh minnow seine. One of these sites, a large pool at the base of the Kinkaid Lake spillway, was extensively sampled using a 2.4-m diameter, 6.4-mm mesh cast net and a fishing rod and reel.

We compiled historical records of fishes known from the Kinkaid Creek drainage, other than those collected by Stegman (1959), by searching the fish collections of INHS, Southern Illinois University at Carbondale, and the University of Michigan Museum of Zoology.

Pre-impoundment land use was assessed by visually interpreting aerial photos to delineate watershed boundaries and cover types. Data was then digitized in ARC/INFO (1998) (Version 7.2). Post-impoundment land use was taken from Landsat TM imagery used to construct the Land Cover of Illinois (1996) GIS database.

RESULTS

We collected a total of 898 fishes, representing 39 species, and one hybrid in our duplication of Stegman's (1959) sampling efforts (Table I). Although our total number of species collected closely matches Stegman's number (38, plus one hybrid), faunal compositions were different. Thirteen of Stegman's 38 species (34%) and one hybrid were not collected in our sampling, 13 of our 39 species (36%) and one hybrid were not collected in Stegman's pre-impoundment survey (Table II).

Members of the family Centrarchidae dominated our total sample, comprising 54.4% of the total number of fishes collected. *Lepomis macrochirus* was the most abundant species, accounting for 32.7% of the total sample. Six other families comprised at least 1% of the total sample (Figure 2). Families that individually accounted for less than 1% of the total sample included Fundulidae (0.8%), Amiidae (0.3%), Poeciliidae (0.3%), Moronidae (0.3%), Lepisosteidae (0.2%), and Esocidae (0.1%). Numbers of each species collected at each site are given in Table I.

We combined sites 2, 3, and 4 when examining relative abundances at individual sites because of the homogenous nature of the lentic habitat found in the reservoir. The fish fauna within the reservoir was dominated by centrarchids, which accounted for 78.6% of all fishes collected. The remaining fauna consisted of six families (Figure 3(B)). Upstream of the reservoir at site 5, cyprinids accounted for 71.4% of the total sample, while the remaining fauna consisted of six families (Figure 3(C)). Downstream of the reservoir, at site 1, centrarchids again dominated the fauna accounting for 38.1% of the total sample, while the remaining sample consisted of nine families (Figure 3(A)).

According to historical records, a total of 48 species of fishes and one hybrid were collected from the Kinkaid Creek drainage prior to impoundment (Table II). Since impoundment of the creek, a total of 74 species and two hybrids have been collected, including 65 species and two hybrids in the 1998–1999 sampling period alone (Table II). Six species have not been collected in the drainage since Kinkaid Creek's impoundment; *Carpiodes carpio*, *Notropis atherinoides*, *Pimephales promelas*, *Percopsis omiscomaycus*, *Micropterus punctulatus*, and *Percina maculata*. Thirty-two species collected after impoundment of Kinkaid Creek were not collected prior to the construction of the dam (Table II). Of these 32 species, 11 are considered to be the result of intentional or unintentional introductions of species not native to the Kinkaid Creek drainage (Table II).

Table I. Numbers of species and individuals collected from Stegman's (1959) five sites during 1999 sampling of Kinkaid Creek

Species name	Number of individuals by site			
	1	2–4	5	Total
Lepistoseus oculatus Winchell	1			1
Amia calva Linnaeus	3			3
Dorosoma cepedianum (Lesueur)	15	82	4	101
Campostoma anomalum (Rafinesque)			6	6
Cyprinella lutrensis (Baird and Girard)			13	13
Cyprinus carpio Linnaeus	3	4		7
Ericymba buccata Cope			2	2
Lythrurus umbratilis (Girard)			14	14
Notemigonus crysoleucus (Mitchill)		1		1
Notropis ludibundus (Girard)			14	14
Pimephales notatus (Rafinesque)		2	115	117
Semotilus atromaculatus (Mitchill)			18	18
Catostomus commersoni (Lacepède)			7	7
Ictiobus bubalus (Rafinesque)	4			4
I. cyprinellus (Valenciennes)	8			8
I. niger (Rafinesque)	2			2
Minytrema melanops (Rafinesque)		9		9
Moxostoma erythrurum (Rafinesque)			6	6
Ameirus natalis (Lesueur)		2	1	3
Ictalurus punctatus (Rafinesque)		7		7
Esox americanus Gmelin	1			1
Fundulus notatus (Rafinesque)	4		2	6
F. olivaceus (Storer)			2	2
Gambusia affinis (Baird and Girard)			3	3
Labidesthes sicculus (Cope)	7	3		10
Menidia beryllina (Cope)	1	4		5
Morone chrysops (Rafinesque)		2		2
M. mississippiensis Jordan and Eigenmann	1			1
Lepomis cyanellus Rafinesque		1		1
L. cyanellus × *L. macrochirus*			4	4
L. gulosus (Cuvier)		7		7
L. macrochirus Rafinesque	13	283	2	298
L. megalotis (Rafinesque)	10	33	12	55
L. microlophus (Günther)		52		52
Micropterus salmoides (Lacepède)	4	62		66
Pomoxis annularis Rafinesque	4	4		8
Etheostoma flabellare Rafinesque			3	3
E. nigrum Rafinesque			15	15
E. spectabile (Agassiz)			5	5
Percina caprodes Rafinesque		4	7	11
Total	81	562	255	898

Analysis of digitized data from aerial photos taken in 1965 revealed that 62.8% of the Kinkaid Creek drainage was classified as wooded, and 37.2% was classified as either agricultural, grassland, or urban. After deleting that portion of the drainage now impounded (classified as open water), landcover data from 1991–1995 Landsat TM imagery had 63.1% of the drainage scored as wooded and 36.9% as either agricultural, grassland, or urban.

Table II. Pre- and post-impoundment presence of fishes in the Kinkaid Creek drainage in southern Illinois

Species	Pre-impoundment (* denotes those recorded by Stegman)	Post-impoundment (* denotes those collected from Stegman's five sites in 1999)
Polyodon spathula (Walbaum)		X
Lepisosteus oculatus Winchell	X	X*
L. osseus (Linnaeus)	X*	X
L. platostomus Rafinesque	X*	X
Amia calva Linnaeus	X*	X*
Alosa chrysochloris (Rafinesque)		X
Dorosoma cepedianum (Lesueur)	X*	X*
D. petenense (Günther) **S**		X
Campostoma anomalum (Rafinesque)	X*	X*
Ctenopharyngodon idella (Valenciennes) **I**		X
Cyprinella lutrensis (Baird and Girard)	X*	X*
C. whipplei Girard		X
Cyprinus carpio Linnaeus	X*	X*
Ericymba buccata Cope	X	X
Hybognathus nuchalis Agassiz		X
Hypopthalmichthys molitrix (Valenciennes) **I**		X
H. nobilis (Richardson) **I**	X	X
Lythrurus fumeus (Evermann)		X
L. umbratilis (Girard)		X
Luxilus chrysocephalus Rafinesque	X	X
L. zonatus (Agassiz) **I**	X*	X*
Notemigonus crysoleucus (Mitchill)		X
Notropis atherinoides Rafinesque **E**		X
N. ludibundus (Girard)	X	X*
N. rubellus (Agassiz) **I**	X*	
N. volucellus (Cope)	X*	X*
Opsopoeodus emiliae Hay		X
Phenacobius mirabilis (Girard)		X
Pimephales notatus (Rafinesque)		X
P. promelas Rafinesque **E**	X*	X
P. vigilax (Baird and Girard)	X*	X*
Semotilus atromaculatus (Mitchill)	X	
Carpiodes carpio (Rafinesque) **E**		X
Catostomus commersoni (Lacépède)	X*	X*
Erimyzon oblongus (Mitchill)	X*	
Ictiobus bubalus (Rafinesque)	X*	X*
I. cyprinellus (Valenciennes)	X*	X
I. niger (Rafinesque)		X*
Minytrema melanops (Rafinesque)		X*
Moxostoma erythrurum (Rafinesque)		X*
Ameiurus melas (Rafinesque)	X*	X*
A. natalis (Lesueur)	X*	X*
Ictalurus punctatus (Rafinesque)	X*	X*
Noturus gyrinus (Mitchill)	X	X*
Esox americanus Gmelin		X*
E. masquinongy Mitchill **S**		X
Percopsis omiscomaycus (Walbaum) **E**	X	
Aphredoderus sayanus (Gilliams)	X*	X
Fundulus notatus (Rafinesque)	X*	X*
F. olivaceus (Storer)	X	X*
Gambusia affinis (Baird and Girard)		X*
Labidesthes sicculus (Cope)		X*
Menidia beryllina (Cope) **I**		X*
Morone chrysops (Rafinesque)		X*

Table II. (Continued)

Species	Pre-impoundment (* denotes those recorded by Stegman)	Post-impoundment (* denotes those collected from Stegman's five sites in 1999)
M. mississippiensis Jordan and Evermann		X*
M. saxatilis (Walbaum) **S**		X
M. chrysops × *M. saxatilis*		X
Centrarchus macropterus (Lacépède)		X
Lepomis cyanellus Rafinesque	X*	X*
L. gulosus (Cuvier)	X*	X*
L. humilis (Girard)	X*	X
L. macrochirus Rafinesque	X*	X*
L megalotis (Rafinesque)	X*	X*
L. microlophus (Günther)		X*
L. cyanellus × *L. macrochirus*		X*
Micropterus dolomieu Lacépède **I**		X
M. punctulatus (Rafinesque) **E**	**X***	
M. salmoides (Lacépède)		X*
Pomoxis annularis Rafinesque	X*	X*
P. nigromaculatus (Lesueur)	X*	X
Etheostoma asprigene (Forbes)		X
E. chlorosoma (Hay)	X	X
E. flabellare Rafinesque	X*	X*
E. gracile (Girard)	X*	X*
E. nigrum Rafinesque	X*	X*
E. proeliare (Hay)	X*	
E. spectabile (Agassiz)		X
Percina caprodes Rafinesque		X
P. maculata (Girard) **E**		X
P. shumardi (Girard)		X
Stizostedion vitreum (Mitchill) **S**		X
Aplodinotus grunniens Rafinesque		X
Total no. of species (hybrids not counted)	48 (38*)	74 (39*)

E = extirpated, **I** = not native to the Big Muddy River drainage and unintentionally introduced, **S** = stocked for fisheries purposes.

DISCUSSION

Land use practices within a watershed can have significant impacts on its aquatic ecosystems by increasing siltation and nutrient loads (Wichert and Regier, 1998). Our analysis of pre- and post-impoundment aerial imagery shows that land use practices within the Kinkaid Creek drainage has remained relatively unchanged. Therefore, because the adjacent terrestrial habitat has remained stabile, we assume that biotic changes in the Kinkaid Creek drainage are attributable to alterations to the creek. The impoundment of a flowing riverine system can significantly alter several attributes of an ecosystem. Besides the obvious changes in water depth and flow regimes within newly formed reservoirs, downstream effects include changes in channel morphology, water sediment loads, water chemical properties, thermal conditions, and flow regimes (Baxter, 1977; Ward and Stanford, 1987). Studies of fish communities in impounded systems have focused on changes across the entire basin (Eley *et al.*, 1981; Rogner and Brinton, 1982), upstream (Erman, 1973) and downstream (Hoyt and Robison, 1980; Young, 1980; De Jalon *et al.*, 1994) of dams, and within the reservoir (Hashagen, 1973; Kapasa and Cowx, 1991). The results of these studies have documented either little change in overall fish species richness (Rogner and Brinton, 1982), substantial reductions in richness (Eley *et al.*, 1981; Kapasa and Cowx, 1991), or large shifts in dominant species within assemblages (Erman, 1973; Martinez *et al.*, 1994). The results of our study add to this variation by documenting a substantial increase in basin-wide richness, in addition to changes in relative abundances and species assemblages.

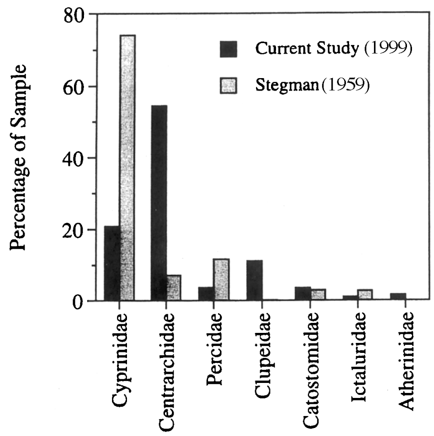

Figure 2. Percent abundances of families of fishes collected by Stegman (1959) and current study (1999) at all five sampling sites

Prior to the impoundment of Kinkaid Creek, nine different sites had been sampled by several workers within the relatively small Kinkaid Creek drainage. Most of these sites were sampled repeatedly using a variety of techniques, including sodium cyanide poisoning. We cannot totally disprove the pre-impoundment absence of all 32 species that have been collected only since 1970 (Table II), as a few of the newly recorded species (e.g., *Luxilus chrysocephalus*, *Cyprinella whipplei*) typically inhabit creeks and small rivers, and their habitat preferences do not correlate with observed post-impoundment habitat changes in the Kinkaid Creek drainage. However, we feel the pre-impoundment collecting efforts in the basin gives an accurate estimate of pre-impoundment richness, and strongly supports the post-impoundment increase described below. The extensive collecting efforts conducted in the basin between 1998 and 1999 for the current study (15 total sites, most of which were sampled repeatedly), likewise, give an accurate estimate of post-impoundment species richness. As non-qualitative or unknown sampling techniques were used at many pre- and post-impoundment sites, we are limited to using these two data sets to address changes in basin-wide species richness.

Species richness in the basin has increased by 50% since Kinkaid Creek was impounded in 1970. The 74 species collected in the basin since 1970 represent 35% of the total Illinois fish fauna (Burr, 1991; Laird and Page, 1996). This is especially noteworthy, given the Kinkaid Creek subdrainage of the Big Muddy River drainage encompasses only 135 km^2. When examined at a larger scale, the Kinkaid Creek subdrainage contains 70% of the fish fauna of the Big Muddy River drainage, while accounting for only 2% of the 6182 km^2 of land drained by the Big Muddy drainage (Burr and Warren, 1993). We propose that the majority of the increase in richness is a result of three actions: (1) the intentional and unintentional introduction of species not native to the Big Muddy River drainage; (2) range expansions of species introduced into other regions of Illinois or the lower midwest; and (3) habitat alteration that has created conditions more favorable to certain species.

Introduction of alien species

Kinkaid Lake was built for recreational purposes, one of which was for the establishment of a sportfish fishery. To meet this goal, three species not native to the Big Muddy River drainage have been stocked into Kinkaid Lake, *Dorosoma petenense*, *Esox masquinongy*, and *Morone saxatilis*. Prior to impoundment, *Stizostedion vitreum* was collected on only two occasions from the Big Muddy River drainage, and was never collected from Kinkaid Creek. Since 1971, over 23 million *S. vitreum* have been stocked into Kinkaid Lake. While there is no official record of *Micropterus dolomieu* being stocked in Kinkaid Lake, the single individual collected by us from below the lake spillway was most likely introduced in the lake by an unscrupulous angler. Prior to our record, *M. dolomieu* had never been recorded from the Big Muddy River drainage (Burr and Warren, 1993).

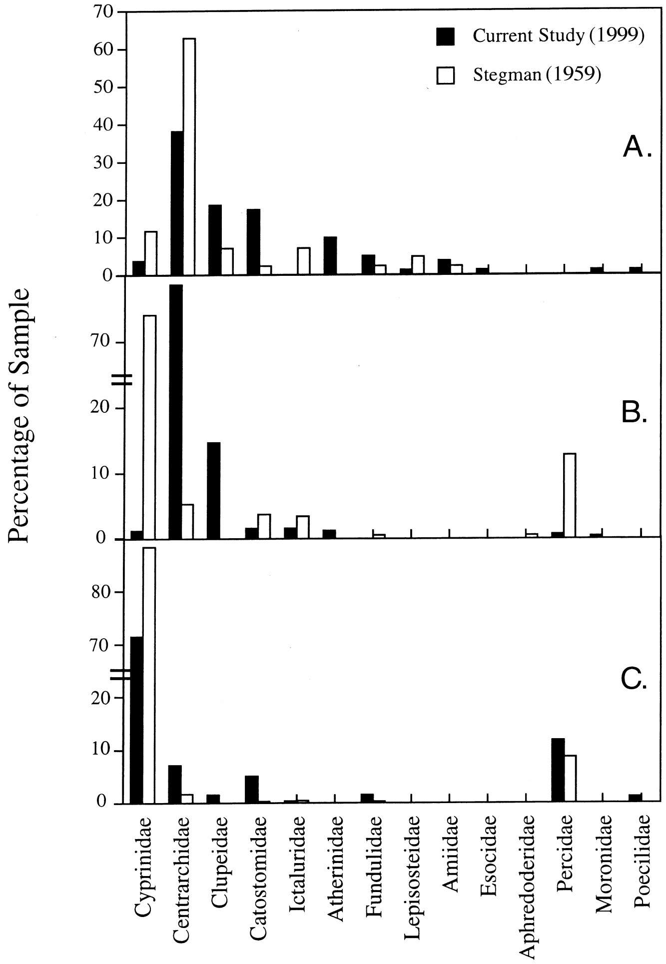

Figure 3. Percent abundances of families of fishes collected by Stegman (1959) and current study (1999) at: (A) site 1, downstream of Kinkaid Lake, (B) sites 2, 3, and 4, now within Kinkaid Lake, and (C) site 5, upstream of Kinkaid Lake

The unintentional introduction of fishes through the release of unused bait may explain the presence of two cyprinids, *Luxilus zonatus* and *Notropis rubellus*, in Kinkaid Creek. Prior to our collection of single specimens of both species, neither was known to occur in southern Illinois (Smith, 1979; Pflieger, 1997). Given that interstate transport and the sale of bait is at best loosely controlled (Meronek *et al*., 1995), and that several fish species are frequently observed in single lots of bait (CAT, personal observation), it seems likely that both species were released into Kinkaid Lake by unaware anglers. The inland silverside, *Menidia beryllina*, is native to the Atlantic and Gulf coast of the United States and the lower Mississippi River, and has been introduced into several Illinois reservoirs as forage for sportfish (Laird and Page, 1996). One of these reservoirs is Baldwin Lake, located in southwestern Illinois. An examination of Kinkaid Lake stocking records indicates that *D. petenense* stocked into Kinkaid Lake frequently came from Baldwin Lake. It seems reasonable to assume that small numbers of *M. beryllina* could easily have been introduced into Kinkaid Lake with shipments of *D. petenense*.

Range expansion of other alien species

The silver carp, *Hypophthalmichthys molitrix*, and bighead carp, *H. nobilis* are native to Asia, and were introduced into Arkansas in the early 1970s (Laird and Page, 1996). Since then, they have dispersed up the Mississippi River into Illinois. The presence of these two species in lower Kinkaid Creek is most likely the result of their continued expansion into southern Illinois via the Big Muddy River. The grass carp, *Ctenopharyngodon idella*, is also native to Asia, and was introduced into Arkansas in the early 1960s. It was first collected in Illinois in 1971, and now occurs sporadically across the state (Laird and Page, 1996). Its post-impoundment collection in lower Kinkaid Creek is the result of this statewide expansion.

Habitat alteration

The impoundment of Kinkaid Creek has not only transformed a 14-km reach of the stream into a deep lentic pool, but through reduced flow, has made the 4-km portion of the creek between the lake spillway and its confluence with the Big Muddy River inhabitable by species commonly found in big or medium-sized rivers and their associated backwaters, low gradient creeks, and/or other lentic habitats. Very little, if any, water flows over the spillway when lake water level is below 128 m above sea level. This results in barely detectable flow in lower Kinkaid Creek. Stegman (1959) reported that flow in lower Kinkaid Creek ceased at flood stages on the Big Muddy River; however, we assume that, as a free flowing stream, water moved much more rapidly through the middle and lower reaches of Kinkaid Creek at normal to low stages on the Big Muddy River. Thus, Kinkaid Creek now has slower flow rates throughout a much longer portion of the year. Sixteen species collected since the impoundment of Kinkaid Creek (Table I) prefer large rivers, lakes, backwater habitats with minimal flow, and low gradient creeks (Smith, 1979; Page and Burr, 1991); *Polyodon spathula*, *Lepisosteus oculatus*, *Alosa chrysochloris*, *Opsopoeodus emiliae*, *Ictiobus bubalus*, *I. cyprinellus*, *I. niger*, *Esox americanus*, *Labidesthes sicculus*, *Gambusia affinis*, *Morone chrysops*, *M. mississippiensis*, *Centrarchus macropterus*, *Lepomis microlophus*, *Etheostoma asprigene*, and *Aplodinotus grunniens*. We speculate that these species have colonized the lower reaches of Kinkaid Creek via the Big Muddy River.

Extirpation of native species

The impoundment of Kinkaid Creek has created habitat more favorable to some species and conditions unsuitable to others. Six species have not been collected in the Kinkaid Creek drainage since 1970; *Carpiodes carpio*, *Notropis atherinoides*, *Pimephales promelas*, *Percopsis omiscomaycus*, *Micropterus punctulatus*, and *Percina maculata*. Most of these species require permanently flowing habitats (Smith, 1979; Page and Burr, 1991); however, two species, *Pimephales promelas* and *Percopsis omiscomaycus*, are known to inhabit lakes. We can only speculate that their absence is owing to the higher concentrations of predatory sportfishes now found in the basin. *Carpiodes carpio* and/or *Percina maculata* have also been reported as extirpated from drainages in Arkansas (Dewey and Moen, 1978), Illinois (Rogner and Brinton, 1982), and Oklahoma (Eley *et al*., 1981) after impoundment.

Changes in species assemblages

Our duplication of Stegman's (1959) quantitative sampling at five sites in the Kinkaid Creek basin permits an examination of shifts in species abundances at those sites. A comparison of total fishes collected from all five sites reveals that the most notable change has been the 53.3 percentage point decrease in percent cyprinid abundance, and the 47.4 percentage point increase in percent centrarchid abundance (Figure 2). Other noticeable changes include a 7.9 percentage point decrease in percent percid abundance and an 11 percentage point increase in percent clupeid abundance (Figure 2). Faunal changes at sites 2, 3, and 4, now under Kinkaid Lake, strongly affect the above noted changes in the total sample. Cyprinids and percids dominated Stegman's (1959) collections at sites 2, 3, and 4, accounting for 74% and 12.7%, respectively (Figure 3(B)), of the total number of fishes collected at those sites. Almost 50% of all fishes collected during our sampling were centrarchids from Kinkaid Lake, while clupeids from Kinkaid Lake accounted for 9% of our total sample (Table I). This shift in dominant species within the reservoir is predictable given three factors: (1) the loss of shallow, flowing habitat favored by percids (Page, 1983) and the increase in shallow, quiet shoreline habitat favored by centrarchids for spawning (Smith, 1979); (2) the intentional stocking of over 435000 *Micropterus salmoides* since 1988; and (3) the increase in abundance of piscivorous sportfishes and the relative susceptibility of cyprinids to such predators (Chapleau *et al*., 1997; Findlay *et al*., 2000).

Upstream of the reservoir (site 5), a 16.9 percentage point decrease in percent cyprinid abundance and a 5.4 percentage point increase in percent centrarchid abundance was recorded (Figure 3(C)). The biological significance remains questionable at this site given the relatively limited decrease in cyprinids compared to the reservoir sites, and the fact that centrarchids still account for less than 10% of the total sample at site 5. Declines in the relative abundances of cyprinids upstream of a reservoir were also reported by Erman (1973) and Wilde and Ostrand (1999). Species diversity at site 5 has changed little since impoundment, Stegman (1959) collected 19 species and we collected 21. Only one of Stegman's (1959) species from site 5 not collected during 1998–1999, *Percina maculata*, is believed to be extirpated from the drainage. Other species not collected at site 5 were collected at other upstream sampling sites in 1999. Winston *et al*. (1991) and Wilde and Ostrand (1999) reported the elimination of several cyprinids upstream of impoundments, we did not document any such extirpations. With the exception of 12 individuals of *Lepomis megalotis*, all species collected during 1998–1999, and not by Stegman, occurred in small numbers and were native to the drainage before impoundment.

We believe that a change in flow regime throughout a larger portion of the year may account for some of the observable changes in the downstream species assemblage. At site 1, Stegman (1959) collected 12 species, while we collected 16 (Table I); only six species are represented in both studies. We also report increases in clupeids, catostomids, and atherinids (Figure 3(A)). Species representing these families at site 1 prefer either big river or slow to non-flowing habitats (Smith, 1979; Page and Burr, 1991). We cannot explain the 40% reduction in centrarchids at this site.

Our results correspond to the pattern of increased fish species richness in North American drainages associated with species invasions recently described by Gido and Brown (1999). In their study, Gido and Brown (1999) attempt to correlate number of alien species with the number of endangered or extirpated species. Their analysis implies that competition and predation are the major factors influencing patterns of species richness. Our data suggests that habitat alteration may cause the extirpation of native species, while at the same time, creating habitat for invading species. Habitat alteration thus represents one of the processes that must be considered when analyzing the pattern of species richness noted by Gido and Brown.

We realize the purpose of Gido and Brown (1999) was to describe pattern, not to address issues related to conservation. However, considering the current imperilment of native freshwater fishes (Warren and Burr, 1994), we believe it is unwise to interpret a pattern of increased species richness as a correlate of overall drainage health and/or stability. Although we were unable to distinguish between the effects of habitat alteration and alien species invasions on native species extirpations in our data set, recently published data indicates that invasions of alien fish species, and the subsequent increase in species richness, can alter abundances and interactions of native species (Vander Zanden *et al*., 1999). From a conservation standpoint, it is unacceptable to infer that introduced species have the same value as native species, and we do not feel that the successful introduction of any number of alien species justifies the loss of a single native species.

The impoundment of Kinkaid Creek has caused significant changes in the fish fauna of that basin. It is debatable whether these changes can be viewed as positive or negative. However, from a conservation perspective, the potential loss of any native species should receive serious consideration. With over 30% of North American freshwater fishes at risk of serious population decline or extinction (Williams *et al*., 1989; Master, 1990) the long-term effects of impoundments must be taken into account if our society is to continue building such structures.

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