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Fish Assemblages in Streams Subject to Anthropogenic Disturbances Along The Natchez Trace Parkway, Mississippi, USA

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Abstrak: Kajian terhadap komuniti ikan telah dijalankan selama tiga tahun (Julai 2000 – Jun 2003) di empat batang anak sungai iaitu Sungai Big Bywy, Little Bywy, Middle Bywy dan McCurtain. Sungai-sungai ini terletak di sepanjang Natchez Trace Parkway, di daerah Choctaw Mississippi, USA dan merupakan anak sungai kepada sungai Big Black. Perlombongan lignit dijangka memberikan kesan negatif kepada kualiti air sungai Little Bywy dan Middle Bywy manakala Sungai Big Bywy didapati mempunyai sejarah dalam pelurusan sungai. Sungai McCurtain dipilih sebagai sungai rujukan. Ikan disampel menggunakan unit *electrofishing* mudah-alih (Smith-Root Inc., Washington, USA). Secara relatifnya, kelimpahan ikan tidak menunjukkan perbezaan yang ketara antara kesemua anak sungai ($P > 0.05$), namun kelimpahan ikan pada setiap musim adalah berbeza. Ikan jenis insektivor didapati mendominasikan kesemua anak sungai yang dikaji. Walaupun hasil kajian menunjukkan terdapat perbezaan dari segi struktur spesies, tetapi perlurusan sungai dan perlombongan lignit tidak menunjukkan kesan negatif terhadap komponen fungsi komuniti ikan ini. Ini menujukkan spesies ikan di sungai tersebut bersifat *euryceous fluvial generalist* yang mampu beradaptasi dengan ekosistem anak sungai yang pelbagai.

Kata kunci: Ikan, Perlombongan, Pelurusan Sungai

Abstract: A three-year study (July 2000 – June 2003) of fish assemblages was conducted in four tributaries of the Big Black River: Big Bywy, Little Bywy, Middle Bywy and McCurtain creeks that cross the Natchez Trace Parkway, Choctaw County, Mississippi, USA. Little Bywy and Middle Bywy creeks were within watersheds influenced by the lignite mining. Big Bywy and Middle Bywy creeks were historically impacted by channelisation. McCurtain Creek was chosen as a reference (control) stream. Fish were collected using a portable backpack electrofishing unit (Smith-Root Inc., Washington, USA). Insectivorous fish dominated all of the streams. There were no pronounced differences in relative abundances of fishes among the streams ($P > 0.05$) but fish assemblages fluctuated seasonally. Although there were some differences among streams with regard to individual species, channelisation and lignite mining had no discernable adverse effects on functional components of fish assemblages suggesting that fishes in these systems are euryceous fluvial generalist species adapted to the variable environments of small stream ecosystems.

Keywords: Fish, Mining, Channelisation

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INTRODUCTION

Streams throughout the Mississippi (USA) river basin have been channelised for flood control and drainage purposes. Major channelisation projects have also been conducted on larger streams (Brown *et al*. 2005) with numerous other smaller scale projects conducted at local levels. For example, small streams along the Natchez Trace Parkway were channelised during the early and mid 1900s, but these streams have remained relatively undisturbed since this time. Other streams along the Natchez Trace Parkway have not been modified by channelisation, and have generally retained their natural channel configurations (Rohasliney & Jackson 2008).

Channelisation of stream beds in conjunction with regulation of water flow can set the stage for a complex array of interactive abiotic factors that can influence lotic ecosystem fish assemblages (Jackson 2005). In this regard, anthropogenic disturbances often decrease variability in physical environmental components of stream habitats (Slavik & Bartos 2001). These habitat changes tend to reduce stability and diversity in faunal assemblages by eliminating long-lived and larger species, thereby favoring smaller and opportunistic fish species with shorter life cycles (Shields 1995).

In Mississippi, lignite (i.e., soft coal) is believed to exist in 29 counties and is considered a potential source of localised energy production. In 2000, the North American Coal Company began surface lignite mining operations at its 2247.3-ha Red Hills Mine facility near Ackerman, Mississippi (Mississippi Environment 1999). Lignite from this mine fuels a power plant that produces 440 megawatts of electricity.

Lignite mining has the potential to negatively impact biological functioning in streams. Mining by its nature consumes, diverts and can pollute water resources. The negative impacts of mining activities on fish communities have been reported by numerous investigators. Some studies have shown that acid mine drainage may completely eliminate fish fauna from streams and rivers, or can lead to impaired systems that support only a few acid-tolerant species (Gracia-Criado *et al*. 1999).

The objective of our study was to evaluate impacts, if any, on fish assemblages that could be attributed to historical stream channelisation and the more recent lignite mining operations extant in the Big Black River stream catchments.

Study Area

The Natchez Trace Parkway (Fig. 1) transects Mississippi from its northeast corner, southwesterly to the city of Natchez on the Mississippi River. Administered as a national park, parkway lands are managed and protected for aesthetic qualities as well as ecological integrity. Within the park, streams supposedly have minimum anthropogenic impacts and subsequently are considered to provide undisturbed and relatively stable environments for aquatic organisms (Rohasliney 2005).

Our study examined the following four tributaries of the Big Black River: Middle Bywy Creek (33°25’24”N 89°15’59”W); Little Bywy Creek (33°24’25”N

89°16’33”W); Big Bywy Creek (33°26’57”N 89°14’09”W); and McCurtain Creek (33°21’33”N 89°20’11”W). These stream sites cross the parkway in the vicinity of Jeff Busby (Little Mountain) State Park, Choctaw County, Mississippi, USA, and are located between the towns of Mathiston and French Camp (Fig. 1). Little Bywy and Middle Bywy creeks were subject to mining activities in their headwater reaches. Specifically, mining near the parkway occurred 3.22 km upstream of the Little Bywy Creek study area and 4.83 km upstream of the Middle Bywy Creek study area. Big Bywy and Middle Bywy creeks have also been subjected to channelisation. McCurtain Creek was used as a reference site. Characterisation of all the study sites is provided in Table 1, using criteria developed by Barbour *et al*. (1999) and Plafkin *et al*. (1989).

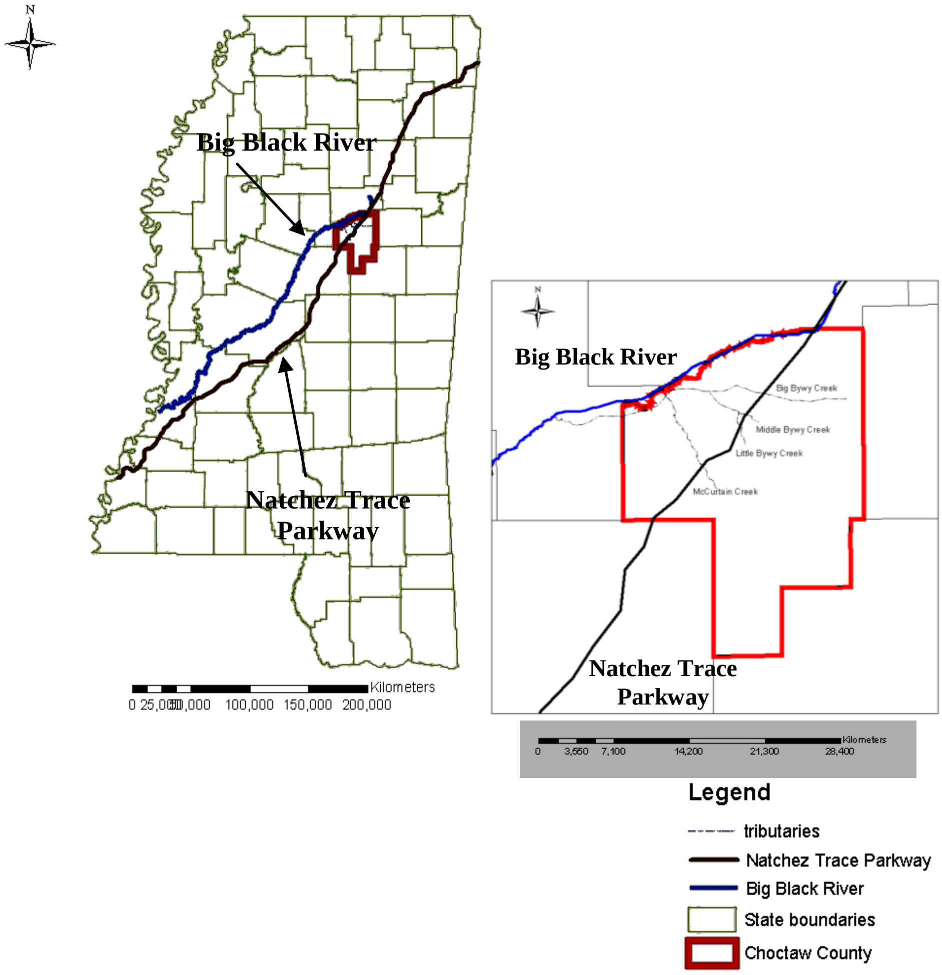

Figure 1: Map of the Natchez Trace Parkway, Choctaw County, Mississippi, USA with an insert depicting the location of Big Bywy, McCurtain, Middle Bywy and Little Bywy creeks.

Table 1: Characterisation of four sites sampled for fish based on Rapid Bioassessment Protocols (RBP) developed by Barbour *et al*. 1999.

Site	Characteristics
Big Bywy (BB)	Unstable substrates primarily composed of sand with old dredge spoils from historical channelisation present along both banks. About 25% of the channel substrate was gravel with minimal amounts of large woody debris. The average channel width was 22 ± 5 m, and the average water discharge was 7.3 ± 0.7 m^3/s. The average water depth was 1.4 ± 0.2 m.
McCurtain Creek (MC)	More diverse in-channel habitat features with numerous pools, riffles and runs. The channel was sinuous and meandering. The substrate was predominantly fine sediments, while 25% of the stream bottom was comprised of gravel and cobble. This stream had the narrowest channels at 12 ± 5 m, and an average water discharge of 4.5 ± 0.3 m^3/s. The average water depth was 1.9 ± 0.05 m.
Middle Bywy (MB)	Substrates were primarily clay, packed mud and small gravel. Fine sediments imbedded 20% of the substrates. The channel was straight and characterised by shallow runs and pools. The average channel width was 20 ± 10 m and the water discharge was 7.1 ± 0.4 m^3/s. The average water depth was 1.0 ± 0.3 m.
Little Bywy (LB)	Substrates were primarily sand, mud and clay. The channel was sinuous and meandering with riffles, runs and pools of varying depth. On average, this stream had deeper water that the other three streams, and contained moderate amounts of large woody debris. The channel width was 14 ± 2 m and the water discharge was 3.3 ± 0.3 m^3/s. The average water depth was 1.8 ± 0.2 m.

MATERIALS AND METHODS

Water quality data and fish sampling were collected concurrently between 0800 and 1700 during the period of August 2000 to June 2003 at the Little Bywy and Middle Bywy creeks (N = 216 samples/stream). Likewise, samples were collected from January 2002 to June 2003 (N = 108 samples/stream) at the Big Bywy and McCurtain creeks. Dissolved oxygen (DO) (mg/l), conductivity (µS/cm) and temperature (°C) were measured *in situ* with YSI Model 85 (Yellow Springs, OH, USA) and YSI Model 30 meters (Yellow Springs, OH, USA). Alkalinity (mg/l) and pH were measured *in situ* using Hach chemical analyses procedures (Hach Company 1999). Precipitation data (January 2001 to June 2003) for Ackerman, Mississippi were supplied by the Mississippi State University Climatology Laboratory. Current velocity (m/s) was recorded at 6 randomly determined locations in each stream once every month (August 2000 to June 2003) in Little Bywy and Middle Bywy creeks (N = 198 samples/stream); January 2002 to June 2003 in Big Bywy and McCurtain creeks (N = 108 samples/stream), with a digital flow meter positioned 5–10 cm below the surface water. Water discharge (m^3/s) was calculated from velocity data using equations from Needham and Needham (1969).

Fish were collected with a Model 15-A (600–700 V; 60 Hz) portable backpack electrofishing unit (Smith-Root Inc., Washington, USA). The time period of fish collection was once per season (i.e., spring, summer, fall, winter) from July 2000 to May 2003 in the Little Bywy and Middle Bywy creeks (N = 92 samples/stream), and from January 2002 to May 2003 in the Big Bywy and McCurtain creeks (N = 72 samples/stream). Seasonal sampling allowed adequate time for fish assemblage recovery and redistribution between sampling events (Mitton & McDonald 1994). There was concern that more frequent sampling would not give fishes the opportunity to recover, and the data collected would not be reflective of actual abundance and distribution patterns (Mitton & McDonald 1994).

Electrofishing was conducted by a two-person team. On each sampling date, six electrofishing runs were conducted upstream from the study stream's intersection with the Natchez Trace Parkway bridge, while another six were conducted downstream from the bridge (N = 12 samples/date). Each electrofishing run consisted of a 10-minute shock period. One person carried and operated the electrofishing unit, while the other person netted shocked fish. If present at the study sites, riffle, run and pool habitats were sampled during each electrofishing run. All captured fish were placed immediately into a bucket containing water from the stream and retained alive until completion of the respective 10-minute electrofishing run. Fish were then removed from the bucket, identified to species, individually measured (total length, mm), weighed (g), enumerated (collectively and by species) and released back into the stream location from which they had been captured. Voucher specimens were retained for lab verification using keys developed by Ross (2001). These voucher specimens were preserved in 10%-buffered formalin, labeled and stored in the Mississippi State University Forest and Wildlife Research Center Fishery Laboratory. Guild assessments were conducted as per Goldstein and Simon (1999).

Analyses of riparian zone characteristics of each stream were conducted using digital data from 1:250,000-scale topographic maps (US Department of the Interior 1990) and aerial photographs provided by the Mississippi Automated Resource Information System (MARIS). These data were integrated for analysis with Geographical Information System (GIS) software (ArcMap 3.1). Calculations were based on GIS analyses of 200-m-wide buffers for both stream banks. Land use was defined as cropland, grassland or forestland (type specific). Ground truthing was conducted on sites during summer 2003 to confirm the remote sensing and GIS data.

DATA ANALYSES

Relative abundances of fishes within guilds (insectivores, detritivores, carnivores, omnivores, herbivores, planktivores) (Goldstein & Simon 1999) were compared among the streams. In addition, physicochemical parameters and relative abundances of fish were compared across seasons. Logarithmic transformations were performed when it was necessary to address requirements of normal distributions for parametric statistics (e.g., analyses of variance (ANOVA)) (Zar 1974). Significant differences among streams were investigated using a non-parametric least significant difference (LSD) multiple range test. $P < 0.05$ was used for accepting or rejecting the null hypotheses.

Ordination techniques were used to analyse patterns of macroinvertebrate assemblages to determine their relationships with suites of stream habitat variables (all streams considered collectively) (ter Braak 1986). Canonical correspondence analysis (CCA) was used to identify relationships between two suites of variables by finding linear combinations of variables in a first set that were most highly correlated with those in a second set (ter Braak 1986). After derivation of canonical vectors, correlations of the original variables with these vectors (loadings) were examined. The resulting canonical structure served as a basis for biological interpretations. A Monte Carlo test was used to assess the probability (based on 1000 permutations) that such a distribution pattern could occur by chance. Significance was assessed at $P < 0.05$. Analyses were conducted with PC-Ord (McCune & Mefford 1997), SAS Version 8.2 (SAS Institute Inc. 2002) and Analytical Software (2000) routines. Fish assemblages in the streams were categorised using the Index of Biological Integrity (IBI) as developed by Karr et al. (1986).

RESULTS

Seasonal differences (all streams considered collectively) were detected for DO ($F_{3,\ 15} = 4.91$, $P < 0.005$), temperature ($F_{3,\ 15} = 262.4$, $P < 0.0001$), and water discharge ($F_{3,\ 15} = 3.42$, $P < 0.05$). Average DO concentration during spring (7.3 mg/l) was greater than during fall (6.3 mg/l), but was not significantly different than that of winter (6.8 mg/l) and summer (6.7 mg/l). This pattern reflects increased biological oxygen demand associated with the autumnal influx of allochthonous organic material into the stream. Average temperature ranged from 21.94°C during the summer to 3.28°C during the winter. Average water discharge for the streams ranged from 4.1 m^3/s during the fall to 7.1 m^3/s during the winter ($P < 0.05$), and this difference in discharge was related to seasonal patterns of rainfall (Table 2).

The only parameter that displayed significant differences among streams was pH ($F_{3,\ 21} = 3.62$, $P < 0.05$). Mean pH (6.7) was greater in Big Bywy Creek than in McCurtain Creek (6.2), but did not differ significantly from that of Middle Bywy (6.5) and Little Bywy (6.5) creeks. These pH values indicated that all of the streams were well-buffered (Giller & Malmqvist 1998) (Table 2). Riparian and floodplain characteristics of the creeks are shown in Figure 2.

Table 2: Physicochemical parameters (measured as mean ± standard error) for the Big Bywy (BB), McCurtain (MC), Middle Bywy (MB) and Little Bywy (LB) creeks along the Natchez Trace Parkway, Mississippi, USA.

Site	Water surface (m)	Estimated stream depth (m)	Large woody debris (m^2/km^2)	Temperature (°C)	pH	DO (mg/l)	Cond (μS/cm)	Alkalinity (mg/l)	Velocity (m/s)
BB	9.6 ± 0.1	0.4 ± 0.1	26.8 ± 1.2	13.8 ± 1.7	6.7 ± 0.1	6.7 ± 0.1	64.7 ± 3.1	26.6 ± 2.0	2.7 ± 0.3
MC	5.3 ± 0.1	0.5 ± 0.1	277.2 ± 5.6	12.8 ± 1.7	6.2 ± 0.1	6.9 ± 0.2	70.8 ± 2.0	37.1 ± 2.1	2.0 ± 0.1
MB	8.3 ± 0.1	0.5 ± 0.1	61.7 ± 2.2	14.5 ± 1.2	6.5 ± 0.2	6.7 ± 0.1	60.9 ± 2.7	33.5 ± 0.1	2.7 ± 0.1
LB	5.2 ± 0.1	0.7 ± 0.1	71.0 ± 0.9	14.8 ± 1.3	6.5 ± 0.1	6.9 ± 0.1	60.2 ± 3.6	33.8 ± 2.5	2.3 ± 0.1

Notes: DO = dissolved oxygen; Cond = conductivity. Water surface measurements were taken based on a wetted channel.

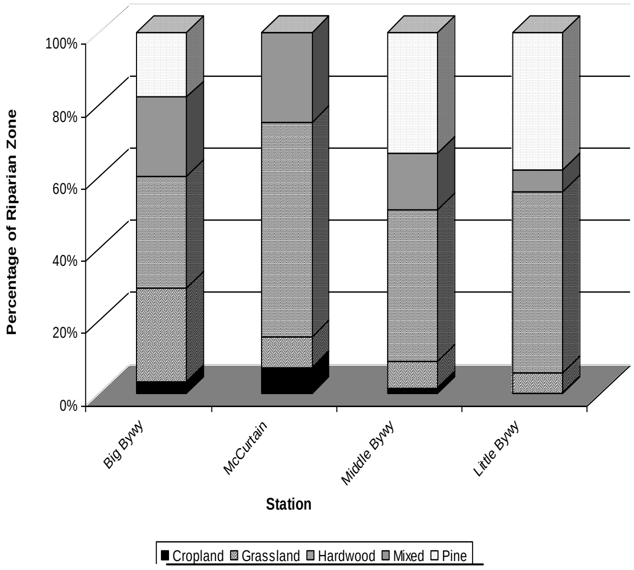

Figure 2: Percent land use composition in 2003 for 200-m buffers along Big Bywy, McCurtain, Middle Bywy and Little Bywy creeks on the Natchez Trace Parkway property, Mississippi, USA (2003).

There were 4111 fish collected during this study, representing 11 families, 25 genera and 47 species (Table 3). The most common fishes captured were bluegill (*Lepomis macrochirus*), longear sunfish (*Lepomis megalotis*), emerald shiner (*Notropis atherinoides*) and blackspotted topminnow (*Fundulus olivaceous*). There were no significant differences among streams ($F_{3,\ 35} = 1.65$, $P > 0.2$) with respect to overall (all species combined) fish abundances (Table 3). However, the relative abundance of fishes differed significantly across seasons ($F_{3,\ 35} = 4.68$, $P < 0.01$) with spring having a higher relative abundance of fishes (20.3 ± 1.9 fish/10 minutes) than other seasons (Fig. 3).

Table 3: Total numbers of fish captured from Big Bywy (BB), McCurtain (MC), Middle Bywy (MB), and Little Bywy (LB) creeks along the Natchez Trace Parkway, Mississippi, USA.

Family	Species	Local name	BB	MC	MB	LB
Aphredoderidae	*Aphredoderus sayanus*	Pirate perch	+	+	+	+
Atherinidae	*Labidesthes sicculus*	Brook silverside	-	-	-	+
Catostomidae	*Erimyzon oblongus*	Creek chub-sucker	+	+	+	+
	Moxostoma poecilurum	Blacktail redhorse	+	+	+	+
Centrarchidae	*Lepomis cyanellus*	Green sunfish	+	-	+	+
	Lepomis gulosus	Warmouth	+	+	+	+
	Lepomis macrochirus	Bluegill	+	+	+	+
	Lepomis megalotis	Longear sunfish	+	+	+	+
	Lepomis microlophus	Redear sunfish	-	-	+	-
	Micropterus punctulatus	Spotted bass	+	+	+	+
	Micropterus salmoides	Largemouth bass	-	-	-	+
Cyprinidae	*Cyprinella camura*	Bluntface shiner	+	+	+	+
	Cyprinella venusta	Blacktail shiner	+	+	-	+
	Hybognathus nuchalis	Mississippi silvery minnow	+	-	-	-
	Hybognathus hayi	Cypress minnow	-	-	-	+
	Luxilus chrysocephalus	Striped shiner	+	+	+	+
	Lythrurus roseipinnis	Cherryfin shiner	+	+	+	+
	Lythrurus umbratilis	Redfin shiner	-	+	+	+
	Nocomis leptocephalus	Bluehead chub	-	-	-	+
	Notemigonus crysoleucas	Golden shiner	-	-	+	-
	Notropis atherinoides	Emerald shiner	+	+	+	+
	Notropis sabinae	Sabine shiner	+	+	+	+
	Notropis texanus	Weed shiner	+	+	+	+
	Semotilus atromaculatus	Creek chub	+	+	+	+
	Pimephales notatus	Bluntnose minnow	+	+	+	+
	Pimephales vigilax	Bullhead minnow	+	+	+	+
Esocidae	*Esox niger*	Chain pickerel	+	+	+	+
Fundulidae	*Fundulus notatus*	Blackstripe topminnow	-	-	+	+

(continued on next page)

Table 3: *(continued)*

Family	Species	Local name	BB	MC	MB	LB
	Fundulus olivaceous	Blackspotted topminnow	+	+	+	+
Ictaluridae	*Ameiurus natalis*	Yellow bullhead	+	+	+	+
	Ameiurus melas	Black bullhead	-	-	-	+
	Ictalurus punctatus	Channel catfish	-	+	+	+
	Noturus hildebrandi	Least madtom	-	-	+	-
	Noturus miurus	Brindled madtom	+	+	-	+
	Noturus phaeus	Brown madtom	+	+	+	+
	Noturus stigmosus	Northern madtom	-	-	-	+
Percidae	*Ammocrypta vivax*	Scaly sand darter	+	+	+	+
	Etheostoma whipplei	Redfin darter	+	+	+	+
	Etheostoma swaini	Gulf darter	+	+	+	+
	Etheostoma stigmaeum	Speckled darter	-	+	+	+
	Etheostoma chlorosoma	Bluntnose darter	+	+	+	+
	Etheostoma lynceum	Brighteye darter	+	+	+	+
	Etheostoma nigrum	Johnny darter	-	-	-	+
	Percina sciera	Dusky darter	+	+	+	+
	Percina caprodes	Logperch	-	-	-	+
Petromyzontidae	*Ichthyomyzon gagei*	Southern brook lamprey	-	+	-	+
Poeciliidae	*Gambusia affinis*	Western mosquitofish	-	-	+	+
		Total number collected	932	814	1312	1053
		Number of species collected	30	32	36	43

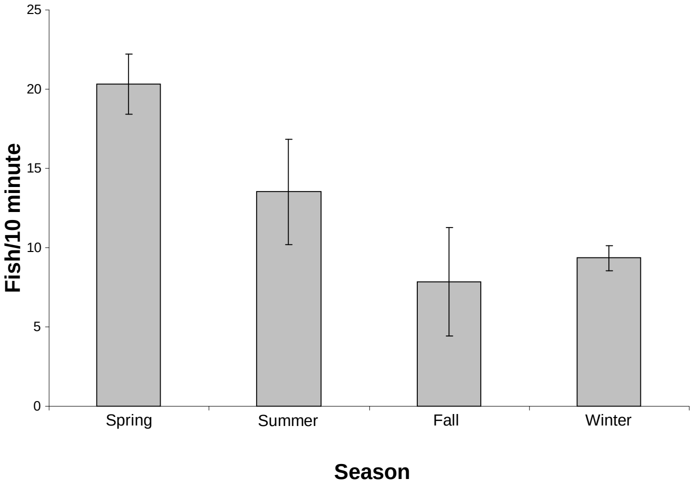

Figure 3: Seasonal abundances of fishes collected in the Big Bywy, McCurtain, Middle Bywy and Little Bywy creeks.

The CCA eigenvalue of the first axis was 0.21 ($P > 0.05$) and the eigenvalue of the second axis was 0.13 ($P > 0.05$) (Table 4). Consequently, no clear relationship was detected between fish abundances and the environmental variables addressed in this study, with the exception of water discharge (Table 4). Herbivorous fishes were the least abundant fishes collected (0.5 ± 0.3 fish/10 minutes) ($F_{6,\ 21} = 28.7$, $P < 0.001$). The greater relative abundance of insectivorous fishes may have been due to high abundance of species from the Centrarchidae (sunfishes), Cyprinidae (minnows) and Percidae (darters) families (Fig. 4). Application of the IBI to the stream fish assemblages resulted in a “fair to good” score for Big Bywy, McCurtain, and Middle Bywy creeks, and a “good” score for Little Bywy Creek.

Table 4: Canonical correspondence analysis (CCA) of fish abundance and environmental variables, including correlations, eigenvalues and variances for the first three axes. Correlations between fish taxa and environmental variables, and *P*-values of a Monte Carlo test are shown for the significant axes.

Variable	Axis 1	Axis 2	Axis 3
Water temperature (°C)	0.140	–0.150	0.490
Dissolved oxygen (mg/l)	0.070	–0.130	–0.430
pH	0.030	0.330	–0.130
Conductivity (µS/cm)	–0.210	0.270	–0.050
Alkalinity (mg/l)	–0.250	0.400	–0.290
Velocity (m/s)	–0.390	–0.140	0.090
Water discharge (m^3/s)	–0.470	0.020	0.030
Eigenvalue	0.210	0.130	0.090
Cumulative % explained	20.900	13.000	8.700
Correlation taxa-environmental variables	0.880	0.950	0.930

Monte Carlo Test

Axis	Taxa-environmental variables	*P* value
1	0.88	0.10
2	0.95	0.08
3	0.93	0.20

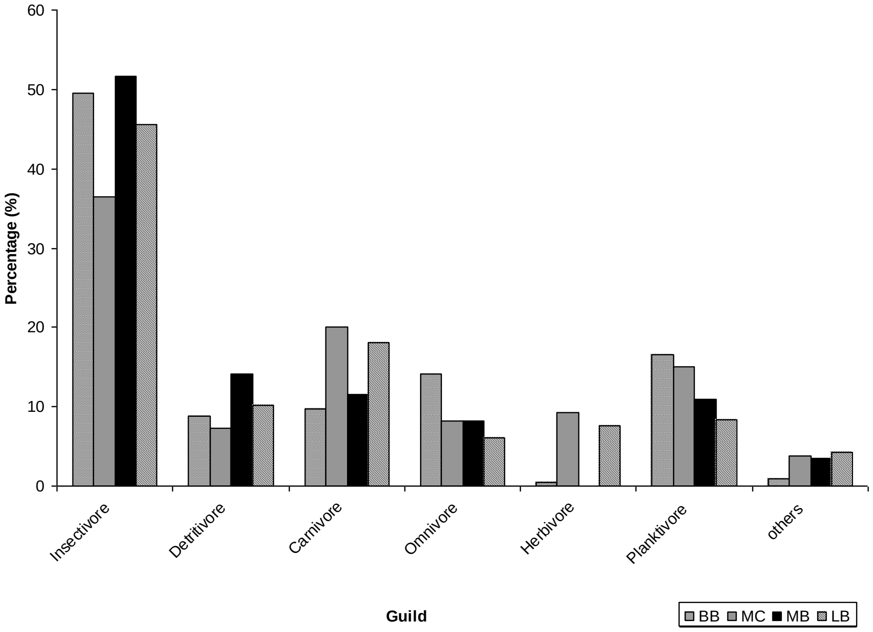

Figure 4: Percentage of fishes by guild in the Big Bywy (BB), McCurtain (MC), Middle Bywy (MB) and Little Bywy (LB) creeks along the Natchez Trace Parkway, Mississippi, USA. Guild assignments are based on Goldstein and Simon (1999).

DISCUSSION

Water quality in the four Big Black River tributaries addressed by this study was not affected by lignite mining and historical channelisation. The higher pH values recorded in Big Bywy Creek could be attributed to soil pH as reflected in the adjacent riparian zone vegetation types. In this regard, the riparian zone of Big Bywy Creek had the lowest percentage of vegetation types (pine, mixed hardwood and pine, and hardwood, all combined, 70.9%) typically found in soils with lower pH values.

Although the negative impacts of stream channelisation are well documented in the literature, the historically channelised streams that we sampled in our study had apparently experienced significant recovery since originally being channelised. In addition to recovery of in-channel features (e.g., meanders, riffle-pool series), the riparian zone forests were well-established on both sides of study area stream banks. This vegetation provided shade, woody debris and inputs of allochthonous organic materials that serve as the energetic foundation for biological production in small stream ecosystems (Vannote *et al*. 1980; Platts & Nelson 1989).

Insectivorous, fishes that are consider fairly tolerant, euryceous fluvial generalists (Cloutman 1997) can establish and maintain viable populations and dynamic assemblage structures in variable physicochemical environments. Over time and in conjunction with the recovery and maturation of nearby riparian forests, in-channel stream features increased in complexity due to scour and fill processes as well as from inputs of woody debris. Such stream habitat heterogeneity has a positive influence on fish assemblages (Brown & Matthews 1995).

Fishes in all the streams we studied along the Natchez Trace Parkway were predominately insectivorous fishes from the families Centrarchidae, Cyprinidae and Percidae. Rohasliney and Jackson (2008) found that benthic macroinvertebrate assemblages in these streams were diverse and that the abundance of benthic macroinvertebrates suggested an adequate forage base for insectivorous fishes. Without such a forage base, Plafkin *et al*. (1989) state that omnivorous fishes will dominate. Therefore, such a shift from insectivorous to omnivorous fishes reflects a degrading or degraded stream environment and is why low metrics for the IBI (Karr *et al*. 1986) are assigned for streams with numerous omnivores.

The IBI (Karr *et al*. 1986) scores for all of the streams we studied indicated that the fish assemblages were in fair to good condition (Big Bywy, McCurtain and Middle Bywy creeks) or good condition (Little Bywy Creek). Using criteria for assessments of incised stream channel recovery processes (Schumm *et al*. 1984; Simon 1989), we concluded that all of the streams addressed in our study were experiencing restoration of natural stream features. Correspondingly, the fish assemblages in all of the streams were categorised as in intermediate-colonising stages (Shields *et al*. 1998), which reflects streams that are either approaching stability or in the advanced stages of recovery from previous perturbations. Such streams favor small, short-lived and opportunistic species (e.g., minnows), and also support a few larger fishes including basses and sunfishes. Such intermediate-colonising, fish assemblages are characterised by fishes with rapid maturation processes, high reproductive rates and strong dispersal capability (Schlosser 1987). These fishes are also resilient to highly variable environmental conditions (Schlosser 1985, 1990; Matthews 1986).

The fish assemblages in the streams we studied showed no indication of having been impacted by run-off from lignite mining. The Mississippi Lignite Mining Company (MLMC) adheres strictly to the State of Mississippi Surface Coal Mining Regulations provided by the Mississippi Department of Environmental Quality in order to minimise pollution to the nearby streams. For example, to prevent potentially toxic materials from mixing with air and water, surface water from mine drainage is captured in retention ponds. These ponds are treated and monitored as needed and when water quality meets discharge standards, the water is released back into the streams. Depending on the situation, the water is retained for one to two days.

Acid mine drainage is not a problem with this mine because the coal deposits are not associated with pyrite bands and the sulphur content is very low. Data obtained from the mine's analytical report (Mississippi Lignite Mining Company Permit Renewal 2001) indicated that coal seams contain no more than 0.88% of pyritic sulphur and have pH values ranging from 4.1 to 6.2. The mining company is also responsible for on-site treatment of sewage water from the mine.

The counts of coliform bacteria in discharged water are low because the mine adheres closely to regulations (Mississippi Lignite Mining Company 2001).

The only environmental variable that seemed to influence fish assemblages in the streams that we studied was water discharge. Discharge affects the distribution and abundance of food for fishes in streams because of its influence on transport of materials via drift (Poff & Allan 1995) and renewal of nutrients that can influence instream primary production (periphyton) and ultimately secondary production of functional groups of benthic macroinvertebrates that utilise this periphyton (e.g., scrapers, Junk *et al*. 1989; Allan 1995).

The natural flow regimes of Mississippi streams have strong seasonal and inter-annual variations. Changes in the magnitude, timing and frequency of river flow events can have significant geomorphic influences that may indirectly affect fish assemblage structure and dynamics (Paller 2002). Although our study did not examine the influence of microhabitat parameters, we noted a greater abundance of rheophilic species in the channelised streams, reinforcing the importance of flowing-water habitats. The unchannelised streams tended to have more pool environments that favor species such as Southern Brook Lamprey (*I. gagei*), Brook silverside (*L. sicculus*), Cypress minnow (*H. hayi*) and Johnny darter (*E. nigrum*) (Ross 2001). Largemouth bass (*M. salmoides*) were collected only in Little Bywy Creek, and seemed to be positively associated with the abundance of Brook silverside, which is an important forage fish for largemouth bass. However, Bluehead chub (*N. leptocephalus*) and logperch (*P. caprodes*), which tend to favor slightly fast currents, were also was found in Little Bywy Creek. We attribute this finding to both species needing spawning pits with very slow currents during their reproductive season.

The presence of several species of darters (e.g., *A. vivax*; *Etheostoma* spp.; *Percina* spp.), which as a group tend to be intolerant to degraded stream environments, suggest that all four streams are not impacted currently by anthropogenic disturbances or are evolving through advanced stages of recovery from former perturbations. These findings underscore (1) potentials for stream protection when strict environmental regulations addressing mining operations are codified, employed, and enforced; and (2) the capacity for small streams to recover naturally from the negative impacts of channelisation when safeguarded from repeated channel maintenance activities over a two- to three-decade period.

The findings of this study suggest that human activities such as mining and channelisation may not negatively influence the fish assemblages in the long run if channel restoration or rehabilitation is focusing on improving aquatic habitat with some enhancement of channel stability for the degraded streams. It is our believe that rehabilitated fish habitat may increase fish diversity. Based on our understanding of stream processes, channelisation and mining influences, it is possible to forecast probable changes in fish community composition and guild. Even though fish recovery rate of habitat degradation in the tropical country may not be the same from the temperate country, it is still a very important information to serve as a baseline study for the area. Therefore, Malaysian rivers which have undergone serious degradation due to human activities may need a very serious attention from all agencies in restoring the river's ecological integrity.

Government agencies may take more responsiblility for protecting water resources and restore degraded streams and riparian (streamside) vegetation corridors typically across the Malaysia Peninsular. By focusing on sustainability, Malaysian people can be ensured that their streams and rivers are healthy for future generations to enjoy.

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