Larval Fish Use of Lower Missouri River Scour Basins in Relation to Connectivity

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ABSTRACT

Knowledge of how larval fishes use floodplain habitats is essential to guide efforts to restore ecological integrity of altered large river ecosystems. Assemblage structure, temporal patterns of abundance, density, and taxa richness for larval fishes were examined in twelve lower Missouri River floodplain scour basins created by the "Great Flood of 1993". Study sites were chosen to encompass the full range of lateral connectivity and included three continuously connected, four periodically connected, and five isolated scour basins.

Connectivity was quantified for each scour basin by three components: distance between river and scour (m), duration of connection (d), and an index of water exchange between river and scour. Each study site was sampled on 10 dates at approximately 15-day intervals from April through August 1996. Five random sample locations were chosen within each site on each sampling date. Larval fishes were collected using a boat-towed sled net.

Connectivity strongly influenced taxa richness and assemblage structure of larval fishes in lower Missouri River scour basins, but mean catch-per-unit-effort for all larval taxa combined was not related to connectivity. Differences in larval fish assemblage structure among sites were associated with distance between river and scour, duration of connection, and the exchange index but were not related to morphological differences among scours. Taxa richness increased with increasing connectivity due to addition of larvae of rheophilic taxa that were rare or absent in isolated scours. Increasing connectivity resulted in larval fish assemblages changing from a fauna dominated by gizzard shad and centrarchids in isolated scours to an increasingly more diverse assemblage that included greater abundances of riverine taxa. Higher variability in connectivity was observed among periodically connected scours compared to isolated or continuously connected scours. This resulted in greater variation in larval fish assemblages among periodically connected waterbodies. Increasing connectivity via greater duration or exchange or lower distance from the river will enhance accessibility of scours for rheophilic taxa.

Duration and timing of connection strongly influenced larval fish assemblages among scour basins. Connection with the Missouri River during late summer and early fall enhanced access to all continuously connected scour basins and one periodically connected scour basin for *Hypopthalmichthys* spp., *Hybognathus* spp., *Macrhybopsis* spp., freshwater drum, grass carp, and emerald shiner. Relative importance of floodplain and in-channel, shallow-water habitats for recruitment of larval fishes is not currently known for the lower Missouri River.

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INTRODUCTION

Many fishes in large rivers capitalize on availability of productive floodplain water bodies (e.g. sloughs, side channels, backwaters) for reproduction, nursery, feeding, and refuge from adverse river conditions (Copp 1989, Ward 1989, Bayley and Li 1992). Backwaters and seasonally flooded wetlands often support greater abundance and biomass of fishes than main river channels (Penczak and Zalewski 1974; Sheaffer and Nickum 1986; Amoros and Roux 1988; Neumann et al. 1994) and are considered an essential component responsible for high fish production rates in large, low-gradient rivers (Risotto and Turner 1985, Welcomme 1985, Ward 1989, Bayley 1991). Riverine fishes that spawn in floodplain water bodies depend on predictable seasonal flood flows, termed the "flood pulse" (Junk et al. 1989), to connect these habitats with the main channel when environmental conditions are suitable for spawning (reviewed in Ward 1989; Pinay et al. 1990; Werner 2002). Larvae and young-of-the-year of fishes that spawn in areas other than floodplains (e.g., tributaries or main channel) often use floodplain water bodies for nursery habitat (Junk and Welcomme 1990; Wallus et al. 1990). These fishes rely on the river's flood pulse to connect the main channel with the floodplain at stages in their life history when they migrate, or are transported by currents, into or out of these areas (Halyk and Balon 1983, Poff et al. 1997). So important are over-bank flows and inundation of the floodplain to spawning and nursery of some large river fishes that the " flood recruitment model" has been proposed to describe how some species respond to rises in flow and flooding and how flooding provides them high densities of food for recruitment (Harris and Gehrke 1994).

Timing, duration, and magnitude of flow exchange between the channel and floodplain in relation to reproductive activities of riverine fishes are therefore critical elements determining what fishes capitalize on floodplain waterbodies for spawning and nursery (Galat et al. 1997, Ward et al. 1999). Similarly, these attributes of connectivity also determine successful migration of juvenile fishes back to the river.

As terrestrial-aquatic landscapes become increasingly fragmented, so have the hydrologic connections between their elements (Pringle 2001). Anthropogenic modification of the lower Missouri River, extending from Sioux City, Iowa to the river mouth near St. Louis, Missouri, has disrupted the natural dynamic river-floodplain linkage, as in many of the world's large river ecosystems. The formerly shallow, braided channel of the lower Missouri River was converted to a single, deep, swift navigation channel (Hesse et al. 1989, Hesse and Sheets 1993, Latka et al. 1993), resulting in a 50% reduction in river-floodplain water surface area (Funk and Robinson 1974) and a 39% decrease in area of floodplain wetlands (Hesse et al. 1988). Upstream from Missouri, a series of flood-control dams and reservoirs have altered the pre-impoundment annual hydrograph of the lower Missouri River that created and destroyed flood-plain water bodies. Historically, the lower Missouri River exhibited a bimodal flood pulse in April and June (Galat and Lipkin 2000) with the June flood being the larger of the two pulses and coinciding with spawning of many floodplain-dependent fishes (Galat and Lipkin 2000, Galat et al. 1998). The present annual hydrograph of the lower Missouri River is characterized by a regulated stage increase in early spring that levels off and remains constant through autumn to provide flows for navigation (Galat and Lipkin 2000). Flood height has been truncated and late summer discharge increased. Only about 10% of the original lower Missouri River flood-plain is inundated on average during annual flooding, as high agricultural levees confine the river to a width of 183-335 m (Schmulbach et al. 1992). Loss of side- and off-channel habitats and disruption of the natural synchrony of the river's hydrologic and thermal regimes have resulted in substantial changes in the composition, structure, and function of plant, invertebrate, and fish communities (Hesse et al. 1988, 1989, Schmulbach et al. 1992, Galat and Frazier 1996), as well as declines in harvest of commercial and sport fishes (Whitley and Campbell 1974, Groen and Schmulbach 1978).

The "Great Flood of 1993" in the Midwest U.S. surpassed all previously recorded floods in terms of precipitation amounts, river levels, flood duration, and area of flooding (Parrett et al. 1993, Wahl et al. 1993, Interagency Floodplain Management Review Committee 1994) and

reconnected the lower Missouri River to its ancestral floodplain for the first time in over 20 years. Floods overtopped and breached over 500 flood-control levees along the lower Missouri River between Kansas City and St. Louis (Scientific Assessment and Strategy Team 1994). Increased hydraulic heads and concentrated flow through narrow openings in levee breaks created zones of intense scour downstream and upstream of breaks (Scientific Assessment and Strategy Team 1994) This intense erosion produced over 450 new steep-sided water bodies or "scour basins" (Galat et al. 1997). These scour basins may function as analogs of floodplain water bodies which existed along the lower Missouri River prior to impoundment and channelization (Galat et al. 1997).

Scours can be classified into three categories based on the seasonal predictability of their overland hydrologic connections with the Missouri River (Galat et al. 1998). Continuously connected scours remain connected with the river throughout most of the year, disconnecting only during extreme low-water events. Periodically connected scours connect with the river during periods of high water and may connect and disconnect several times during a given year. In low water years, periodic scours may not connect to the river. Isolated scours remain separated from the river by levees and only connect with the river during catastrophic floods that over-top levees. Although floodplain water bodies can be assigned to discrete categories, scour basin connectivity is a continuous variable that encompasses multiple components, including distance from the river, exchange of water with the river, and duration and frequency of connection (Amoros and Roux 1988; Galat et al. 1997). Overland connectivity is significant for riverine fishes because it provides pathways for active or passive movement of fishes between the river and scours and strongly influences scour limnology (e.g. turbidity, nutrient concentration, algal biomass, temperature, current velocity; Knowlton and Jones 1997).

Post-flood research along the lower Missouri River has focused on assessing differences in density, taxa richness, and assemblage structure of fishes among scour basin types. Catch rates, biomass, and species richness of juvenile and small adult fishes were significantly higher in continuously and periodically connected scours compared to isolated scours (Kubisiak 1997).

However, catch rates and species richness of larval fishes were not significantly different among continuously connected scours formed by water entering the floodplain (entrance scours) compared to continuously connected scours created by water exiting the floodplain (exit scours, Tibbs and Galat 1997). The study described herein adds to our knowledge of the importance of lower Missouri River floodplain water bodies to fishes by examining larval fish use of scours along the entire continuum of scour basin connectivity. Objectives of this study were to: 1) quantify degree of connectivity for continuously connected, periodically connected, and isolated lower Missouri River scour basins, 2) compare water temperature and transparency among scour basins and between scours and the river relative to connectivity, and 3) compare composition, density, taxa richness, and timing of scour basin use for larval fishes among sites and in relation to scour morphology and components of connectivity. Understanding how connectivity affects use of floodplain water bodies by larval fishes will help guide future decisions regarding restoration and management of aquatic resources in large river floodplains.

STUDY AREA

Twelve scour basins created during the 1993 flood were selected for study. Study sites were chosen to represent varying degrees of connectivity with the lower Missouri River and included three continuously connected, four periodically connected, and five isolated scours located between river kilometers 529 and 257 (Figure 1). This section of the lower Missouri River contained the highest number of levee failures and scour basins that resulted from the 1993 flood (Galat et al. 1997). A single letter abbreviation for each scour type (C=continuous, P=periodic, and I=isolated) will hereafter prefix river km when individual sites are discussed (Table 1).

Bathymetric surveys of scours were conducted by the Natural Resources Conservation Service (NRCS) during November 1996. Scour surface areas ranged from 2.2-26.6 ha when bank-full, with mean depths of 1.0-5.2 m (Kubisiak 1997; Table 1).

Continuous scours were adjacent to the river, periodic scours ranged from 0-230 m from the river, and isolated scours were 500 to > 3200 m from the river (Kubisiak 1997; Table 1).

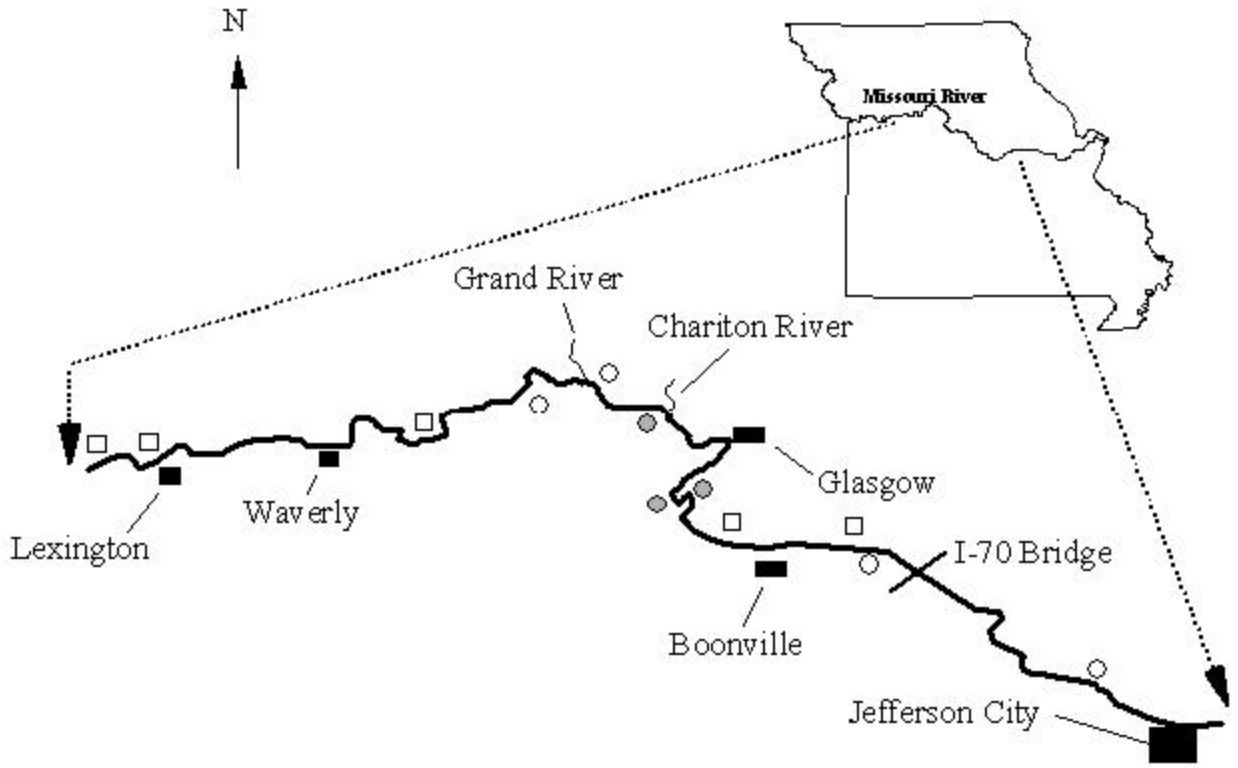

Figure 1. Locations of 12 scour basins selected as study sites and selected landmarks along about 272 km of the lower Missouri River. Open squares indicate isolated scours, open circles indicate periodically connected scours, and filled circles indicate continuously connected scours.

Table 1. Locations, selected morphometric characteristics, distance from river (m), estimated river stage of connection (m above mean sea level), and location of nearest gauge for continuously connected, periodically connected, and isolated scour basins selected as study sites. River km is distance above the confluence of the Missouri and Mississippi Rivers.

Site	River km	Category	Area (ha)	Mean depth (m)	Shoreline development	Distance	Connection stage	Gauge
C345	345.1	Continuously connected	6.3	2.8	1.60	0	182.66	Glasgow
C351	351.4	Continuously connected	2.3	1.0	1.81	0	182.66	Glasgow
C387	387.3	Continuously connected	26.6	1.7	1.99	0	182.66	Glasgow
P257	257.3	Periodically connected	3.7	1.7	1.59	10	177.84	Boonville
P303	302.5	Periodically connected	6.0	3.4	2.48	230	177.94	Boonville
P397	396.5	Periodically connected	3.9	2.1	2.05	0	183.06	Glasgow
P421	420.7	Periodically connected	3.8	5.5	1.60	200	203.54	Waverly
I305	305.4	Isolated	2.2	4.8	1.25	600	182.42	Boonville
I330	329.8	Isolated	18.7	4.4	3.72	3260	181.30	Boonville
I442	441.7	Isolated	3.4	5.2	2.40	2700	205.59	Waverly
I513	512.5	Isolated	3.5	3.8	1.55	500	205.59	Waverly
I529	528.5	Isolated	10.6	1.3	3.41	500	205.59	Waverly

Elevations of connection (m above mean sea level) between scours and the Missouri River were determined from NRCS basin surveys. River stage data for estimating connection stage for each site were taken from the gauge most accurately representing stage for the reach of river where each scour was located. Gauge selection was based on proximity of gauge to scour and absence of major tributaries between site and gauge. At several times during the sampling season, scours were visited as they were connecting or disconnecting from the river. River stages that coincided with observed connection or disconnection were used to refine estimates of connection stages.

METHODS

Connectivity

Connectivity between scour basins and the river was quantified by three components: distance between river and scour, duration of connection, and water exchange between river and scour. Distances (m) between the river and each scour were obtained from Kubisiak (1997) and are shown in Table 1. Duration of connection (d) was estimated for each scour by counting the number of days that the Missouri River was at or above connection stage for that site (Table 1) during the time interval that larval fishes were collected from all scour basins (22 April to 31 August 1996). Exchange was quantified using an index (Table 2) assigned based on the proportion of the scour axis that had detectable current (velocity $\geq$0.01 m/s using a Global Water Flow Probe or General Oceanics 2030R current meter suspended in a wire hoop). Current velocities were measured at the back of the scour, at ¾, ½, and ¼ the length of the scour axis, and at the scour-river interface. Current velocity was measured while standing in the scour when possible. In deeper water, current was measured from a boat anchored from both bow and stern. Sites were assigned an exchange value for the date of each sampling visit (Table 3). Exchange index values ranged from 0 (no surface connection with the river) to 7 (river-flow through entire scour). Exchange index values for dates not sampled were assigned using estimates of river stage thresholds that separated levels of the exchange index for each site. Threshold stages for

Table 2. Descriptions of exchange index values applied to lower Missouri River scour basins. Scour axis refers to a line from the center of the river-scour interface to the farthest point landward within the basin.

Exchange Value	Description
0	No surface connection with the river
1	Connected with no current detectable
2	Connected with current detectable only within first 1/4 of scour axis
3	Connected with current detectable between 1/4 and 1/2 length of scour axis
4	Connected with current detectable between 1/2 and 3/4 length of scour axis
5	Connected with current detectable at greater than 3/4 length of scour axis
6	Connected with chute-like flow through entire scour, but flow confined to scour basin
7	Connected with flow through entire scour and across floodplain outside of scour basin

sites paired with the Glasgow, Missouri gauge (continuously connected sites and site P397) were obtained from Kubisiak (1997). Threshold river stages for sites P257, P303, and P421 were estimated by pairing observed exchange index values with river stage for the same date using gauges indicated in Table 1. Some thresholds were observed and the appropriate stage was assigned. When thresholds were not observed, it was necessary to interpolate threshold stages as the mean of the highest and lowest stages where adjacent index values were observed. Each site was assigned an exchange index value for all dates from 22 April to 31 August 1996 using estimated threshold stages and river stage data.

Larval fish sampling

Each study site was sampled on ten dates at approximately fifteen day intervals beginning in early April 1996 before any larvae were anticipated to be present and ending in late August

Table 3. Start and end dates of sample periods for twelve lower Missouri River scour basins during 1996. Larval fish sampling, exchange index estimation, and temperature and secchi depth measurements were conducted on one date at each site during each sample period.

Sample period	Start date	End date
1	06 April	16 April
2	22 April	03 May
3	13 May	19 May
4	29 May	04 June
5	15 June	21 June
6	01 July	06 July
7	14 July	19 July
8	30 July	02 August
9	10 August	14 August
10	24 August	27 August

1996 (Table 3). The order in which sites were sampled within each sampling period was chosen randomly, but blocked by their category of connectivity to avoid sampling all sites of one type in sequence.

Five locations were sampled at each study site on each collection date. Sampling locations in scours were chosen randomly and independently of specific habitats within a site. A 30 m^2 grid was drawn over a bathymetric map of each site. Five grid intersections within the inundated area of the scour at the time of sampling were randomly chosen as starting locations for each sample and a random direction for towing sampling gear was then selected for each starting point.

Larval fishes were collected using a sled net (25 cm tall, 54 cm wide, 1.4 m long, 500 µm mesh) based on Topp (1967) and Yocum and Tesar (1980) and similar to that used by Tibbs and

Galat (1997). The sled was designed to float in the upper 0.5 m of the water column in areas deeper than the sled. Runners on the bottom of the sled's frame allowed the sled to ride over the substrate in shallow water. This allowed the use of the same sampling device in both near-shore and open-water areas. This sampling design may have underrepresented fishes whose larvae are primarily benthic (e.g., Acipenseriformes).

Each sample consisted of a two-minute sled net tow 30 m behind a boat at a speed of approximately 1.0 m/s. Towing the net behind the boat subjected samples to possible biases due to propeller wash. However, Gallagher and Conner (1983) found no significant differences in fish catches for pushed icthyoplankton nets compared to boat-towed icthyoplankton nets in several lower Mississippi River habitats. When a sample began at or near the shoreline in an area inaccessible by boat, the sled was carried by hand as close to the randomly selected starting location as the length of the tow rope allowed. A flow meter (General Oceanics Model #2030R) suspended in the mouth of the net was used to determine the distance of each tow. Tow distance was multiplied by area of the net opening to calculate tow volume. Tows sampled an average water volume of 19.2 m^3 ± 0.2 SE. Mean tow volumes ranged from 18.2 m^3 for site P421 to 20.6 m^3 for site C387.

Water temperature (°C) and water transparency (cm) were measured in conjunction with each larval fish sample. Temperature was measured at a depth of about 0.2 m below the surface with a YSI Inc. Model 57 oxygen meter. A secchi disk was used to estimate water transparency.

Laboratory procedures

Larval fish samples were preserved in 5% buffered formalin. At a minimum of three days post-collection, larvae were sorted from debris in samples, counted, and placed in 70% ethanol until they could be identified. Larvae were identified to lowest possible taxonomic group using Conner (1979), Snyder (1979), Auer (1982), Fuiman et al. (1983), Holland-Bartels et al. (1990), Wallus et al. (1990), and Kay et al. (1994). Voucher specimens were verified by the Colorado State University Larval Fish Laboratory, Ft. Collins, CO (Darrel Snyder, personal communica-

tion).

Data analysis

Water temperature and secchi depth

Daily river temperatures (°C) were obtained from the water treatment plant in Lexington, Missouri (river km 510.8). Mean differences in water temperature between each scour and the Missouri River on all sampling dates from April to August were assessed using paired t-tests. Experiment-wise error within each the three scour category comparisons was controlled by using Bonferroni adjusted P-values ($P \leq 0.05/N$). Similarly corrected paired t-tests were also employed to assess site-river temperature differences for sites that were connected to the river within the previous 7 days ($P<0.05/N$) and for sites that were not connected to the river within the previous 7 days ($P<0.05/N$).

River secchi depth (cm) was measured adjacent to periodically connected and continuously connected sites on all sampling dates when a connection was present. Additional river secchi depth data for dates during April-August 1996 were obtained from a gill netting study conducted at 10 of the 12 scour basins sampled in this study (Hooker, unpublished data). Site-river differences in secchi depth were calculated for all sampling dates for continuously connected sites and for periodically connected sites on all sampling dates that a given site was connected. River secchi depths measured within 2 d of sampling dates for isolated and disconnected periodic sites were used to calculate site-river differences in secchi depth on sampling dates when sites were not connected. Mean differences in secchi depth (cm) between each site and the river on all sampling dates were assessed using paired t-tests ($P<0.05$). Paired t-tests were also employed to assess site-river secchi depth differences for sites that were connected to the river within the previous 7 d ($P<0.05$) and for sites that were not connected to the river within the previous 7 d ($P<0.05$).

Larval fishes

Mean catch per unit effort (CPUE, number/100 m^3) for all larval taxa combined was calcu-

lated for each sample period and for the entire study interval (6 April-27 August 1996) for each site. Taxa richness (number of taxa collected) was also determined for each site. It was not necessary to adjust taxa richness data for rarefaction due to similar sampling effort among sites (James and Rathbun 1981). Spearman's rank correlations were used to assess relations between both mean CPUE for all larval taxa combined and taxa richness by site and variables describing site morphology (area (ha), mean depth (m), and shoreline development) and connectivity (distance from river (m), duration of connection (d), and mean exchange) ($P<0.05$). Total number of individuals of each taxon collected was determined for each sample period and for the entire study for each site to characterize larval fish assemblage structure.

Use of scour basins by individual taxa over the entire study interval was related to site morphology and components of connectivity. Also, links between timing of scour use by larval taxa and connectivity were examined. Mean CPUE (number/100 m^3) for each taxon represented by >5 individuals during the study was calculated for each sample period and for the entire study interval (6 April-27 August 1996) for each site. Spearman's rank correlations were used to assess whether site means for CPUE by taxa over the entire study were associated with variables describing site morphology [area (ha), mean depth (m), and shoreline development] and connectivity [distance from river (m), duration of connection (d), and mean exchange] ($P<0.05$). For taxa that were rare or absent in isolated scours, correlation analyses were performed both with and without data from isolated scours.

Detrended correspondence analysis (DCA) was employed to ordinate site means for CPUE by taxa (number/100 m^3) over the entire study. Only taxa represented by >5 individuals during the study were included in this analysis. Ordinations were performed using PC-ORD 4 (McCune and Medford 1999). DCA generated a set of x- and y-coordinates, or axis scores, for each site such that scours with similar larval fish assemblages plotted closer together than scours with dissimilar larval fish assemblages (Gauch 1982) based on mean CPUEs over the entire study. Ordination reduces a large matrix of species frequency- or density-by-site or -sample measurements to a much more manageable set of coordinates that can then be analyzed in

relation to environmental gradients of interest (terBraak 1987). Spearman's rank correlations were used to assess whether DCA axis scores for sites were associated with scour location (river km) and variables describing site morphology [area (ha), mean depth (m), and shoreline development] and connectivity [distance from river (m), duration of connection (d), and mean exchange] ($P<0.05$).

RESULTS

Connectivity

Timing and duration of connection during the study interval varied substantially among sites (Figures 2-3, Table 4). Connection with the river was never observed for isolated scours, while continuous scours were connected to the river throughout the study (Table 4). Duration of connection varied more than four-fold among periodic scours. Site P397 connected to the river on 3 May and was connected on all subsequent dates during the study (Figure 2). In contrast, site P421 was connected on only 27 dates during the study; these connections coincided with five floods during May, June, and late July. Timing of connection for sites P257 and P303 was similar to that of P421, but these sites had lower connection thresholds and remained connected longer than site P421 during flood events. Site P257 was also connected for two days during August. Greater durations of connection for P397 and continuous scours compared to P421, P257, and P303 were due in large part to more connection dates during July and August for the former group of scours.

Mean exchange for all dates during the study varied widely among periodic sites and was greater in continuous sites compared to periodic sites (Table 4). Mean exchange on the 26 dates when all periodic and continuous sites were connected to the river was ≥ 5.6 for all periodic and continuous sites except P421. Mean exchange on all other dates during the study (non-flood periods) was <1 for all periodic sites except P397 and >3 for all continuous sites. Site P421 was shielded by a levee on its northern, eastern, and southern sides that prohibited the site from exhibiting an exchange index >5 during the study (Figure 2). All other periodic and continuous

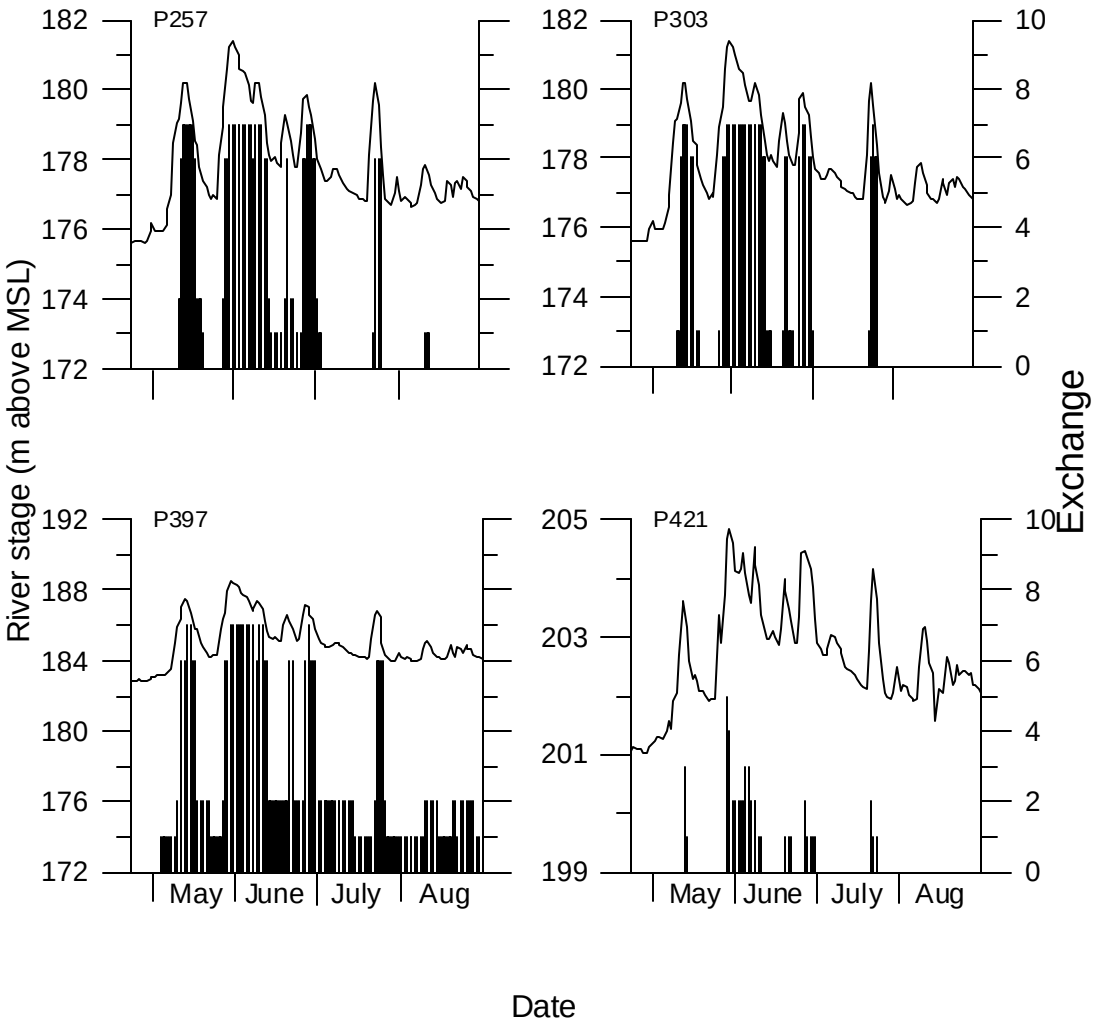

Figure 2. Exchange index (vertical bars; 0 = no exchange with river, 7 = complete exchange with river) for four periodically connected lower Missouri River scour basins on all dates from 22 April to 31 August 1996. River stages (m above mean sea level) are indicated by solid lines. River stages for sites P257 and P303 are from the Boonville, Missouri gauge (river km 317.3), river stages for site P397 are from the Glasgow, Missouri gauge (river km 364.3), and river stages for site P421 are from the Waverly, Missouri gauge (river km 472.4). Note different y-axis scales for river stage among graphs.

sites experienced complete exchange with the river (i.e., exchange index = 7) on at least 14 dates (Figures 2-3). Exchange index values $\geq$6 coincided with five floods during May, June, and late July for all sites except C351. Water flowing through site C351 during a flood that peaked on 27 June cut a chute across a meander bend in the river (Kubisiak 1997), lowering river stage thresholds for this site to exhibit all levels of exchange. Exchange index values were

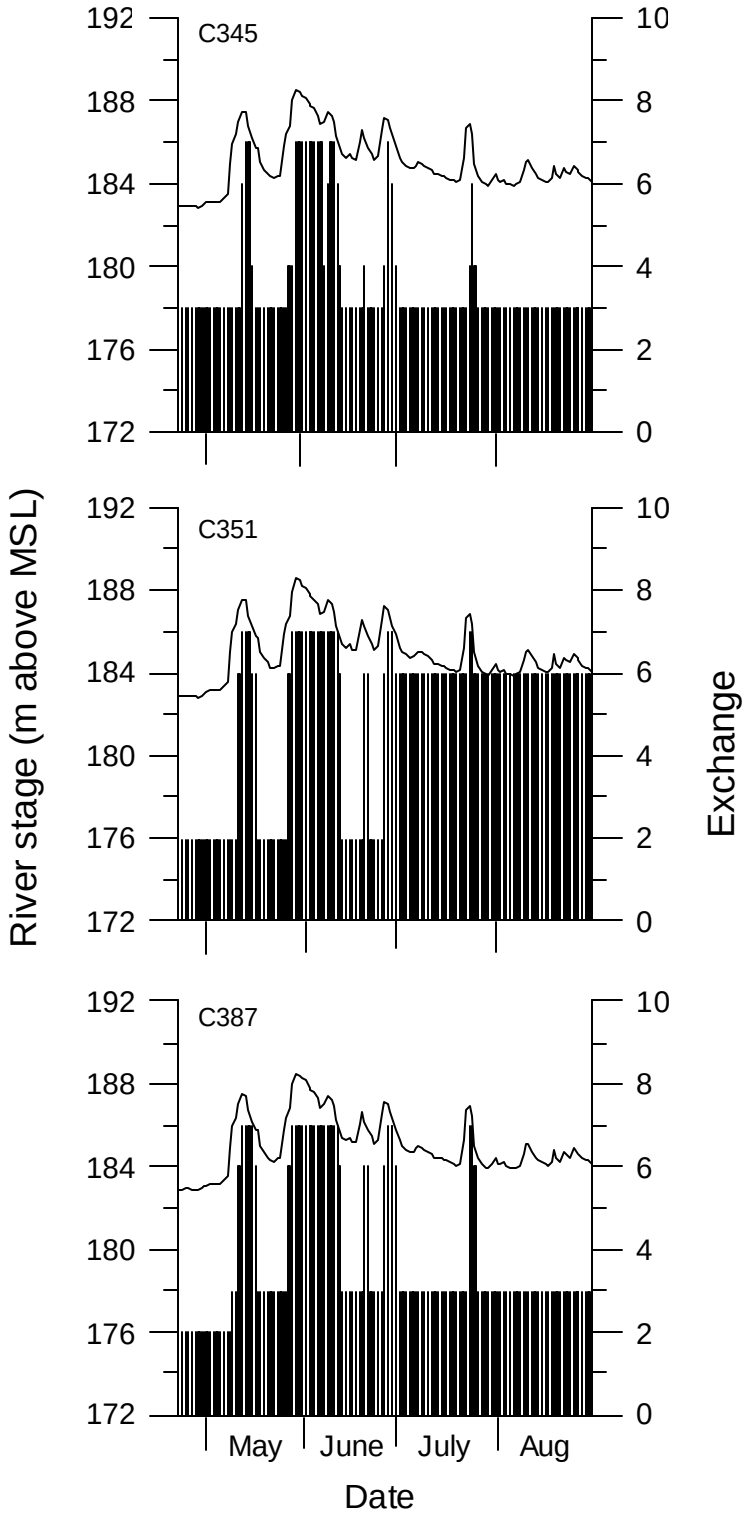

Figure 3. Exchange index (vertical bars; 0 = no exchange with river, 7 = complete exchange with river) for three continuously connected lower Missouri River scour basins on all dates from 22 April to 31 August 1996. River stages (m above mean sea level) at Glasgow, Missouri (river km 364.3) are indicated by solid lines.

Table 4. Duration of connection, mean exchange for all dates, mean exchange on 26 dates when all periodic and continuous sites were connected, and mean exchange on all other dates for Missouri River scour basins from 22 April to 31 August 1996. Exchange index ranges from 0 = no exchange to 7 = complete exchange; see Table 2 for more complete description of index values.

Category	Site	Duration (d)	Mean exchange	Mean exchange when all periodic and continuous sites were connected	Mean exchange on all other dates
Isolated	I305	0	0.0	0.0	0.0
	I330	0	0.0	0.0	0.0
	I442	0	0.0	0.0	0.0
	I513	0	0.0	0.0	0.0
	I529	0	0.0	0.0	0.0
Periodically connected	P421	27	0.4	1.8	< 0.1
	P303	44	1.7	6.3	0.6
	P257	54	1.8	6.1	0.8
	P397	121	2.6	6.2	1.8
Continuously connected	C345	132	3.6	5.6	3.1
	C387	132	3.8	6.5	3.1
	C351	132	5.0	6.6	4.6

≥6 for site C351 for all dates during the study after 26 June.

Water temperature and transparency

Missouri River temperatures at Lexington, Missouri (river km 510.8) ranged from 6.0 to 28.0 °C during the study (Figure 4). Mean water temperatures measured in scours on larval fish sampling dates were usually equal to or greater than river temperatures on the same date,

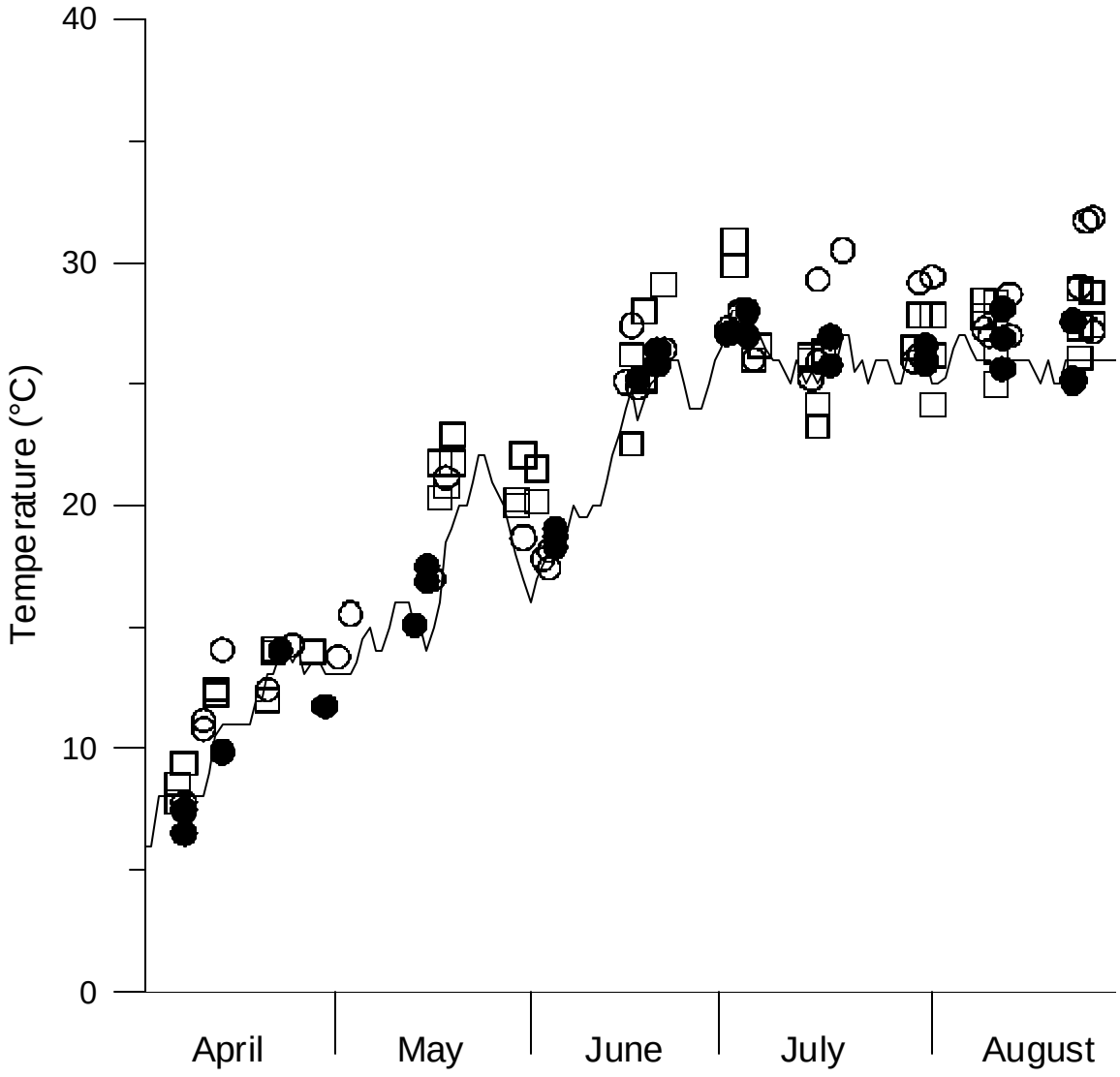

Figure 4. Daily Missouri River temperatures (°C, solid line) obtained from the water treatment plant in Lexington, Missouri (river km 510.8) and mean water temperatures measured in conjunction with larval fish sampling in five isolated (open squares), four periodic (open circles) and three continuous (filled circles) scours during April-August 1996. N=5 for each data point.

although some scours that were visited before 0930 on sampling dates during June, July, and August had mean temperatures that were lower than river temperature on the same date. Mean site-river temperature differences from April through August were significantly different from zero for two of the five isolated scours (I330, I529, Table 5). Isolated scours averaged 1.52 °C (±0.16 °C SE) warmer than the river over all sampling dates. Periodic scours averaged 1.63 °C (±0.21 °C SE) warmer than the river, but these differences were not significantly different from zero for any periodic site after applying Bonferroni corrected probabilities (Table 5). Mean water temperature differences between each of the continuous scours and the Missouri River during the study were <0.40 °C and were also not significantly different from zero. Scours that were not connected with the river during the seven days prior to a sampling date were significantly warmer than the river (mean 1.58 °C ±0.22 °C SE, P = <0.0001; Bonferroni corrected paired t-test). Scours that were connected with the river on at least one date during the week prior to a sampling date were also signiciantly warmer than the river (0.81 °C ±0.21 °C SE, P = 0.0004; Bonferroni corrected paired t-test).

River secchi depth rose from 8.4 cm on 7 April to 29.2 cm on 29 April, then declined to <5 cm during flooding in mid-May and remained $\leq$16 cm thereafter (Figure 5). All mean secchi depths $\geq$50 cm except two occurred at isolated scours. Overall, mean secchi depth was 50.2 cm (±3.2 cm SE) for isolated scours, 24.1 cm (±3.3 cm SE) for periodic scours, and 12.8 cm (±1.6 cm SE) for continuous scours. Mean differences in secchi depth between scours and the Missouri River during April through August 1996 were significantly different from zero for all sites except C351 (Table 5). Mean secchi depth averaged 40.4 cm (±3.2 cm SE) greater than the river for isolated scours, 14.2 cm (±3.6 cm SE) greater than the river for periodic scours, and 2.6 cm (±1.0 cm SE) greater than the river for continuous scours. Mean secchi depth in scours that did not experience a connection with the river during the seven days prior to a sampling date averaged 35.9 cm (±2.6 cm SE) greater than river secchi depth on the same date (Bonferroni corrected paired t-tests, P<0.0001). Mean secchi depth in scours that were connected with the river on at least one date during the week prior to a sampling date averaged 5.8

Table 5. Mean differences in water temperature (°C) and secchi depth (cm) between each scour site and the lower Missouri River ± SE from April through August 1996. N=10 sampling dates per site. Missouri River temperatures were measured at the water treatment plant in Lexington, Missouri (km 510.8). River secchi depths were measured adjacent to periodic and continuous sites on all sampling dates when a connection was present. River secchi depths measured within two days of sampling dates for isolated and disconnected periodic sites were used to calculate site-river transparency differences for unconnected sites. Asterisks indicate mean site-river temperature and secchi depth differences that were significantly different from zero using a Bonferroni corrected paired t-test, $P \leq 0.05/N$ adjusted independently for each of the scour categories.

	Mean site – river difference			
Site	Temperature	SE	Secchi depth	SE
Isolated				
I305	1.52	0.76	41.4*	6.9
I330	1.46*	0.35	31.1*	6.2
I442	1.95	0.62	36.0*	5.2
I513	0.98	0.66	49.3*	6.1
I529	1.69*	0.46	44.4*	6.5
Periodically connected				
P257	1.24	0.46	10.1*	2.4
P303	1.99	0.63	14.7*	3.7
P397	1.98	0.63	7.9^{+}	2.2
P421	1.30	0.57	24.0*	6.3
Continuously connected				
C345	0.13	0.30	3.4*	0.9

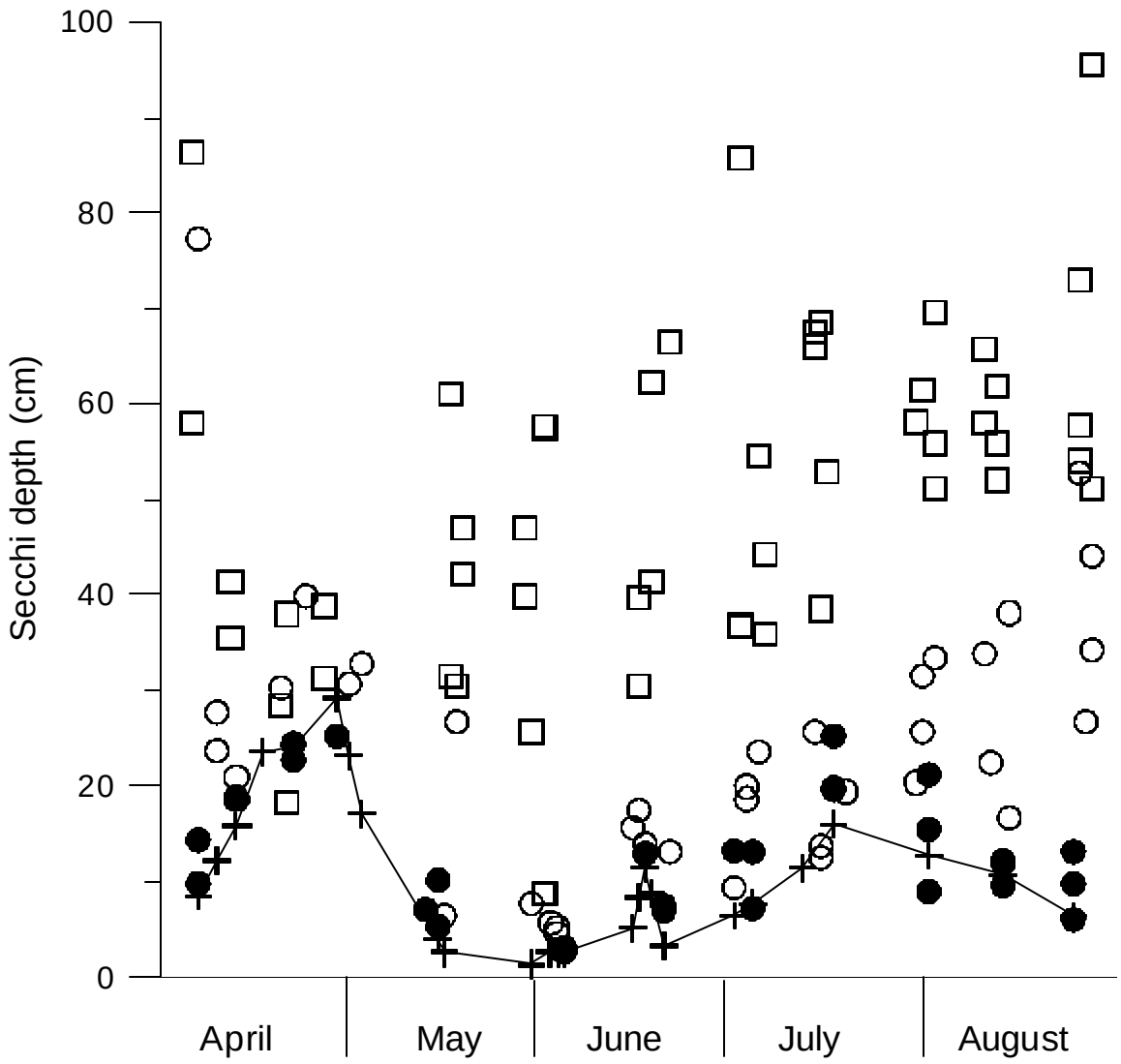

Figure 5. River secchi depths (cm) measured adjacent to periodic and continuous scours on all dates when connection was present (crosses connected by solid line, N=1 to 3 for each value) and mean secchi depths measured in conjunction with larval fish sampling in five isolated (open squares), four periodic (open circles), and three continuous (filled circles) scours during April-August 1996. N=5 for each mean secchi depth value for scours.

cm (±0.9 cm SE) greater than river secchi depth on the same date (Bonferroni corrected paired t-tests, $P<0.0001$).

Larval Fishes

Taxa richness and total density in relation to basin type and connectivity

Table 6. Larval taxa presence by scour category. Order of common names under spp. represents probable relative species abundance based on adults reported in Galat et al. (2004).

Scientific name	Common name	Isolated	Periodic	Continuous
Dorosoma cepedianum	gizzard shad	X	X	X
Lepomis spp.	bluegill, green sunfish	X	X	X
Micropterus spp.	largemouth/spotted bass	X		X
Semotilus atromaculatus or *Campostoma* spp.	creek chub or central/largescale stoneroller	X	X	X
Notropis atherinoides	emerald shiner	X	X	X
Cyprinella lutrensis	red shiner	X	X	X
Pomoxis spp.	white/black crappie	X	X	X
Carpiodes spp.	river carpsucker, quillback, highfin carpsucker		X	X
Hiodon alosoides	goldeye		X	X
Aplodinotus grunniens	freshwater drum	X	X	X
Hypophthalmichthys spp.	bighead/silver carp	X	X	X
Stizostedion spp.	sauger/walleye		X	X
Cyprinus carpio	common carp	X	X	X
Cycleptus elongatus	blue sucker		X	X
Ctenopharyngodon idella	grass carp		X	X
Hybognathus spp.	western silvery/ plains/brassy minnow		X	X
Macrhybopsis meeki or *M. gelida*	sicklefin or sturgeon chub		X	X
Macrhybopsis storeriana or *M. aestivalis*	silver or speckled chub		X	X
Morone chrysops	white bass	X	X	X
Scaphirhynchus spp.	shovelnose/pallid sturgeon		X	
Ictiobus spp.	bigmouth/smallmouth buffalo	X	X	X

Twenty-one taxa representing nine families were collected from the 12 scour basins (Table 6). Twelve taxa were collected from isolated scours and 20 taxa were collected in both periodic and continuous scours. All 12 taxa collected from isolated scours were also collected in at least one of the other two categories of scours. Number of taxa collected from individual scours increased with increasing connectivity (Table 7). Mean taxa richness (number of taxa) was 5.6 (±0.4 SE) for isolated scours, 13.5 (±0.9 SE) for periodic scours, and 17.7 (±0.3 SE) for continuous scours. Taxa richness for individual scours was positively correlated with mean exchange

Table 7. Total number of larval fish taxa collected at each lower Missouri River scour site.

Site	Number of taxa collected
I305	5
I330	6
I442	5
I513	7
I529	5
P257	14
P303	15
P397	14
P421	11
C345	17
C351	18
C387	18

and duration of connection and negatively associated with distance from scour to the Missouri River (Spearman rank correlations, $P<0.05$), but was not significantly correlated with variables describing site morphology (area, mean depth, and shoreline development; Spearman rank correlations, $P>0.05$).

Mean total density (number of fish/100 m^3 for all taxa combined) was highest during sample period 5 (15-21 June) for all three scour categories (Table 8). Larvae were first collected

Table 8. Mean larval fish densities for all taxa combined (number of fish/100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period

		Sample period dates 1996										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
		Sample period										
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.0	0.0	13.3	40.9	374.2	68.1	20.5	9.9	400.6	17.3	94.5
	C351	0.0	0.0	17.8	21.4	296.9	53.0	17.0	0.0	33.4	11.3	45.1
	C387	0.0	1.0	3.1	29.9	264.3	88.7	16.3	21.1	395.3	18.1	83.8
Continuous mean		0.0	0.3	11.4	30.8	311.8	69.9	18.0	10.3	276.4	15.5	74.5
Isolated	I305	0.0	0.0	13.7	29.9	891.4	5.0	2.0	0.0	1.1	0.0	94.3
	I330	0.0	0.0	0.0	487.6	1061.3	112.4	24.0	7.2	6.1	0.0	169.9
	I442	0.0	0.0	0.0	143.1	1557.2	30.9	3.3	48.7	6.4	0.0	179.0
	I513	0.0	0.0	21.8	709.5	38.6	23.8	1.1	108.4	19.9	0.0	92.3
	I529	0.0	0.0	60.2	841.8	10.4	12.7	12.3	22.8	1.1	0.0	96.1
Isolated mean		0.0	0.0	19.1	442.4	711.8	37.0	8.5	37.4	6.9	0.0	126.3
Periodic	P257	0.0	0.0	18.3	261.5	212.6	64.9	18.0	79.1	2.3	0.0	65.7
	P303	0.0	0.0	8.2	30.0	488.9	63.4	19.4	1.1	3.1	0.0	61.4
	P397	0.0	0.0	0.0	179.9	455.9	208.4	12.4	230.6	3.8	0.0	109.1
	P421	0.0	0.0	0.0	237.8	2266.8	67.3	14.5	1.1	0.0	0.0	258.8
Periodic mean		0.0	0.0	6.6	177.3	856.0	101.0	16.1	78.0	2.3	0.0	123.7
Sample period mean		0.0	0.1	12.4	216.8	626.5	69.3	14.2	41.9	95.2	5.2	108.26

during sample periods 3 (13-19 May) or 4 (29 May-4 June) for all scours except C387, where 1 larva was collected on 29 April. Larvae were last collected during sample period 10 (24-27 August) in all continuous scours and during sample period 9 (10-14 August) for all isolated and periodic scours except P421, where the last larva was collected on 2 August. Mean total densities over the entire study interval exceeded 150 larvae/100 m^3 in three scours (I330, I442, and P421) where relatively high numbers of gizzard shad (*Dorosoma cepedianum*) were collected, particularly during sample period 5. Site means for total density over the entire study interval were not significantly associated with any variables describing scour basin connectivity (distance from river, mean exchange, and duration of connection) or morphology (mean depth, area, and shoreline development) (Spearman rank correlations, $P>0.05$).

Relative abundance of larval taxa in scour basins

Gizzard shad were the most abundant taxon collected from all isolated scours and all periodic scours except P257, where they were the second most abundant taxon collected (Table 9). Ninety-eight to 99% of larvae collected from isolated scour basins were either gizzard shad or centrarchids (*Lepomis* spp., *Pomoxis* spp., and *Micropterus* spp.). Total catch at site P421 was also composed primarily of gizzard shad and centrarchids, although goldeye (*Hiodon alosoides*), which were absent from isolated sites, were the second most abundant taxon collected at P421. Goldeye were also the second most abundant taxon collected in site P303 and the most abundant taxon collected from site P257. *Hypophthalmichthys* spp. composed 16% of total catch at site P257, while common carp (*Cyprinus carpio*) composed 4% of total catch at sites P257 and P303. All other taxa composed <3% of total catch at these two sites. Total catch at site P397 consisted of 36% gizzard shad, 27% *Hypophthalmichthys* spp., 16% common carp, 8% emerald (*Notropis antherinoides*) and red shiners (*Cyprinella lutrensis*), 4% goldeye, 3% freshwater drum (*Aplodinotus grunniens*), and eight other taxa that each contributed <2% to total catch. *Hypophthalmichthys* spp. was the most abundant taxon collected from each of the continuous sites, composing 40%, 21%, and 42% of total catch at sites C345, C351, and C387, respectively.

Table 9. Total number of each larval taxon collected by sample period for each scour site. Dates below sample periods are starting and ending dates for each sample period.

I305	Sample Period										
	1	2	3	4	5	6	7	8	9	10	
Taxa	4/6-4/16	4/22-5/3	5/13-5/19	5/29-6/4	6/15-6/21	7/1-7/6	7/14-7/19	7/30-8/2	8/10-8/14	8/24-8/27	Total
Dorosoma cepedianum	0	0	6	15	511	3	0	0	0	0	535
Pomoxis spp.	0	0	5	10	148	1	1	0	0	0	165
Ictiobus spp.	0	0	0	0	13	0	0	0	0	0	13
Hypopthalmichthys spp.	0	0	0	0	0	0	1	0	0	0	1
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	0	0	1	0	0	0	1

I330	Sample Period										
	1	2	3	4	5	6	7	8	9	10	
Taxa	4/6-4/16	4/22-5/3	5/13-5/19	5/29-6/4	6/15-6/21	7/1-7/6	7/14-7/19	7/30-8/2	8/10-8/14	8/24-8/27	Total
Dorosoma cepedianum	0	0	0	356	602	0	1	0	0	0	959
Lepomis spp.	0	0	0	0	0	104	21	6	6	0	137
Pomoxis spp.	0	0	0	2	34	3	0	0	0	0	39
Aplodinotus grunniens	0	0	0	2	1	0	1	0	0	0	4
Morone chrysops	0	0	0	1	0	0	0	0	0	0	1
Cyprinus carpio	0	0	0	1	0	0	0	0	0	0	1

I442	Sample Period										
	1	2	3	4	5	6	7	8	9	10	
Taxa	4/6-4/16	4/22-5/3	5/13-5/19	5/29-6/4	6/15-6/21	7/1-7/6	7/14-7/19	7/30-8/2	8/10-8/14	8/24-8/27	Total
Dorosoma cepedianum	0	0	0	128	1072	1	1	0	0	0	1202
Lepomis spp.	0	0	0	0	8	27	2	44	6	0	87
Pomoxis spp.	0	0	0	1	0	1	0	0	0	0	2
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	1	0	0	0	0	0	1
Micropterus spp.	0	0	0	0	1	0	0	0	0	0	1

Table 9 (continued)

I513

	Sample Period										
	1	2	3	4	5	6	7	8	9	10	
Taxa	4/6-4/16	4/22-5/3	5/13-5/19	5/29-6/4	6/15-6/21	7/1-7/6	7/14-7/19	7/30-8/2	8/10-8/14	8/24-8/27	Total
Dorosoma cepedianum	0	0	1	138	22	0	1	0	0	0	162
Lepomis spp.	0	0	0	0	5	22	0	106	17	0	150
Pomoxis spp.	0	0	19	103	6	0	0	0	0	0	128
Morone chrysops	0	0	0	2	0	0	0	0	0	0	2
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	1	0	0	0	0	0	1
Hypopthalmichthys spp.	0	0	0	0	1	0	0	0	0	0	1
Semotilus atromaculatus/ Campostoma spp.	0	0	0	0	1	0	0	0	0	0	1

I529

	Sample Period										
	1	2	3	4	5	6	7	8	9	10	
Taxa	4/6-4/16	4/22-5/3	5/13-5/19	5/29-6/4	6/15-6/21	7/1-7/6	7/14-7/19	7/30-8/2	8/10-8/14	8/24-8/27	Total
Dorosoma cepedianum	0	0	30	215	0	0	0	0	0	0	245
Pomoxis spp.	0	0	25	43	0	0	0	0	0	0	68
Lepomis spp.	0	0	0	0	10	12	13	22	1	0	58
Aplodinotus grunniens	0	0	0	3	0	0	0	0	0	0	3
Morone chrysops	0	0	0	1	0	0	0	0	0	0	1

Table 9 (continued)

P257	Sample Period										
Taxa	1 4/6-4/16	2 4/22-5/3	3 5/13-5/19	4 5/29-6/4	5 6/15-6/21	6 7/1-7/6	7 7/14-7/19	8 7/30-8/2	9 8/10-8/14	10 8/24-8/27	Total
Hiodon alosoides	0	0	7	180	52	0	0	0	0	0	239
Dorosoma cepedianum	0	0	0	15	140	41	8	2	0	0	206
Hypopthalmichthys spp.	0	0	0	0	4	13	0	77	0	0	94
Cyprinus carpio	0	0	1	20	0	0	0	0	0	0	21
Stizostedion spp.	0	0	5	1	0	0	0	0	0	0	6
Aplodinotus grunniens	0	0	0	5	0	0	0	0	0	0	5
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	0	1	1	0	2	0	4
Pomoxis spp.	0	0	0	0	0	0	2	0	0	0	2
Lepomis spp.	0	0	0	0	0	0	2	0	0	0	2
Carpiodes spp.	0	0	0	2	0	0	0	0	0	0	2
Ictiobus spp.	0	0	0	2	0	0	0	0	0	0	2
Semotilus atromaculatus/ Campostoma spp.	0	0	0	0	0	0	1	0	0	0	1
Ctenopharyngodon idella	0	0	0	1	0	0	0	0	0	0	1
Hybognathus spp.	0	0	0	0	0	1	0	0	0	0	1

Table 9 (continued)

P303	Sample Period										
Taxa	1 4/6-4/16	2 4/22-5/3	3 5/13-5/19	4 5/29-6/4	5 6/15-6/21	6 7/1-7/6	7 7/14-7/19	8 7/30-8/2	9 8/10-8/14	10 8/24-8/27	Total
Dorosoma cepedianum	0	0	1	5	252	36	11	0	0	0	305
Hiodon alosoides	0	0	1	6	55	0	2	0	0	0	64
Cyprinus carpio	0	0	5	11	0	1	0	0	0	0	17
Aplodinotus grunniens	0	0	0	10	0	3	0	0	0	0	13
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	1	5	3	0	0	0	9
Pomoxis spp.	0	0	0	2	1	0	0	0	0	0	3
Lepomis spp.	0	0	0	0	1	0	1	1	0	0	3
Ctenopharyngodon idella	0	0	0	0	0	2	1	0	0	0	3
Semotilus atromaculatus/ Campostoma spp.	0	0	0	0	0	2	0	0	0	0	2
Macrhybopsis meeki/M. gelida	0	0	0	0	0	2	0	0	0	0	2
Macrhybopsis storeriana/ M. aestivalis	0	0	0	0	0	1	0	0	0	0	1
Scaphirhynchus spp.	0	0	0	1	0	0	0	0	0	0	1
Hypopthalmichthys spp.	0	0	0	0	1	0	0	0	0	0	1
Ictiobus spp.	0	0	0	0	0	0	1	0	0	0	1
Cycleptus elongates	0	0	1	0	0	0	0	0	0	0	1

Table 9 (continued)

P397	Sample Period										
	1	2	3	4	5	6	7	8	9	10	
Taxa	4/6-4/16	4/22-5/3	5/13-5/19	5/29-6/4	6/15-6/21	7/1-7/6	7/14-7/19	7/30-8/2	8/10-8/14	8/24-8/27	Total
Dorosoma cepedianum	0	0	0	12	245	95	10	0	0	0	362
Hypopthalmichthys spp.	0	0	0	0	29	39	0	203	3	0	274
Cyprinus carpio	0	0	0	158	0	0	0	0	0	0	158
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	19	58	1	3	0	0	81
Hiodon alosoides	0	0	0	3	33	1	0	0	0	0	37
Aplodinotus grunniens	0	0	0	9	6	12	0	0	0	0	27
Hybognathus spp.	0	0	0	0	5	13	1	1	0	0	20
Ictiobus spp.	0	0	0	18	1	0	0	0	0	0	19
Ctenopharyngodon idella	0	0	0	0	2	12	0	0	0	0	14
Carpiodes spp.	0	0	0	1	4	2	0	0	0	0	7
Macrhybopsis meeki/M. gelida	0	0	0	0	0	4	0	0	0	0	4
Semotilus atromaculatus/ Campostoma spp.	0	0	0	0	0	4	0	0	0	0	4
Pomoxis spp.	0	0	0	0	1	1	0	0	0	0	2
Lepomis spp.	0	0	0	0	0	0	1	0	0	0	1

Table 9 (continued)

P421	Sample Period										
Taxa	1 4/6-4/16	2 4/22-5/3	3 5/13-5/19	4 5/29-6/4	5 6/15-6/21	6 7/1-7/6	7 7/14-7/19	8 7/30-8/2	9 8/10-8/14	10 8/24-8/27	Total
Dorosoma cepedianum	0	0	0	132	1185	53	2	0	0	0	1372
Hiodon alosoides	0	0	0	81	0	0	0	0	0	0	81
Lepomis spp.	0	0	0	0	0	23	8	0	0	0	31
Pomoxis spp.	0	0	0	16	7	1	0	0	0	0	24
Hypopthalmichthys spp.	0	0	0	0	13	0	0	0	0	0	13
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	7	3	0	1	0	0	11
Ctenopharyngodon idella	0	0	0	2	1	0	0	0	0	0	3
Carpiodes spp.	0	0	0	1	0	0	0	0	0	0	1
Hybognathus spp.	0	0	0	0	0	0	0	1	0	0	1
Ictiobus spp.	0	0	0	0	1	0	0	0	0	0	1
Morone chrysops	0	0	0	0	1	0	0	0	0	0	1

Table 9 (continued)

C345	Sample Period										
Taxa	1 4/6-4/16	2 4/22-5/3	3 5/13-5/19	4 5/29-6/4	5 6/15-6/21	6 7/1-7/6	7 7/14-7/19	8 7/30-8/2	9 8/10-8/14	10 8/24-8/27	Total
Hypopthalmichthys spp.	0	0	0	0	84	0	0	1	345	4	434
Hybognathus spp.	0	0	0	0	147	10	3	0	10	1	171
Aplodinotus grunniens	0	0	0	1	62	35	1	2	0	0	101
Ctenopharyngodon idella	0	0	0	1	66	1	0	1	16	9	94
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	80	0	0	0	1	0	81
Cyprinus carpio	0	0	2	37	0	0	0	0	0	0	39
Dorosoma cepedianum	0	0	0	2	14	14	2	0	0	0	32
Macrhybopsis storeriana/ M. aestivalis	0	0	0	0	0	0	0	3	8	2	13
Semotilus atromaculatus/ Campostoma spp.	0	0	1	0	12	0	0	0	0	0	13
Carpiodes spp.	0	0	0	0	2	4	5	1	0	0	12
Hiodon alosoides	0	0	2	0	8	0	0	0	0	0	10
Ictiobus spp.	0	0	0	7	0	0	0	0	0	0	7
Stizostedion spp.	0	0	5	0	0	0	0	0	0	0	5
Macrhybopsis meeki/M. gelida	0	0	0	0	0	0	0	2	2	0	4
Pomoxis spp.	0	0	0	0	2	1	0	0	0	0	3
Lepomis spp.	0	0	0	0	2	0	1	0	0	0	3
Cycleptus elongatus	0	0	1	0	0	0	0	0	0	0	1

Table 9 (continued)

C351	Sample Period										
Taxa	1 4/6-4/16	2 4/22-5/3	3 5/13-5/19	4 5/29-6/4	5 6/15-6/21	6 7/1-7/6	7 7/14-7/19	8 7/30-8/2	9 8/10-8/14	10 8/24-8/27	Total
Hypopthalmichthys spp.	0	0	0	0	104	3	0	0	9	0	116
Aplodinotus grunniens	0	0	0	0	87	21	0	0	2	0	110
Notropis atherinoides/ Cyprinella lutrensis	0	0	4	0	73	4	0	0	0	0	81
Ctenopharyngodon idella	0	0	0	0	48	2	0	0	16	8	74
Carpiodes spp.	0	0	1	0	24	16	15	0	0	0	56
Hybognathus spp.	0	0	0	0	39	2	0	0	0	0	41
Cyprinus carpio	0	0	2	17	1	1	0	0	0	0	21
Dorosoma cepedianum	0	0	2	0	9	1	0	0	0	0	12
Hiodon alosoides	0	0	2	0	9	0	0	0	0	0	11
Semotilus atromaculatus/ Campostoma spp.	0	0	0	2	1	7	0	0	0	0	10
Macrhybopsis meeki/M. gelida	0	0	0	0	0	6	0	0	1	1	8
Ictiobus spp..	0	0	0	4	1	0	0	0	0	0	5
Macrhybopsis storeriana/ M. aestivalis	0	0	0	0	0	1	0	0	1	1	3
Pomoxis spp.	0	0	2	0	0	0	0	0	0	0	2
Stizostedion spp.	0	0	1	0	0	0	0	0	0	0	1
Micropterus spp.	0	0	1	0	0	0	0	0	0	0	1
Morone chrysops	0	0	0	0	0	0	1	0	0	0	1
Cycleptus elongatus	0	0	1	0	0	0	0	0	0	0	1

Table 9 (continued)

C387	Sample Period										
Taxa	1 4/6-4/16	2 4/22-5/3	3 5/13-5/19	4 5/29-6/4	5 6/15-6/21	6 7/1-7/6	7 7/14-7/19	8 7/30-8/2	9 8/10-8/14	10 8/24-8/27	Total
Hypopthalmichthys spp.	0	0	0	1	21	39	0	5	278	2	346
Ctenopharyngodon idella	0	0	0	1	19	4	0	0	150	12	186
Notropis atherinoides/ Cyprinella lutrensis	0	0	0	0	25	38	4	3	0	0	70
Dorosoma cepedianum	0	0	0	3	16	18	8	0	0	0	45
Aplodinotus grunniens	0	0	0	1	15	17	3	0	1	0	37
Hybognathus spp.	0	0	0	0	13	5	2	7	0	6	33
Hiodon alosoides	0	0	0	1	22	0	0	0	0	0	23
Cyprinus carpio	0	0	1	16	0	2	0	0	0	0	19
Semotilus atromaculatus/ Campostoma spp.	0	0	0	0	4	10	3	0	0	0	17
Macrhybopsis meeki/M. gelida	0	0	0	0	1	9	0	1	3	1	15
Carpiodes spp.	0	0	0	0	5	1	3	0	0	0	9
Macrhybopsis storeriana/ M. aestivalis	0	0	0	0	3	1	1	2	0	0	7
Lepomis spp.	0	0	0	0	0	0	0	3	0	0	3
Ictiobus spp.	0	0	0	2	0	0	0	0	0	0	2
Stizostedion spp.	0	1	0	1	0	0	0	0	0	0	2
Pomoxis spp.	0	0	1	1	0	0	0	0	0	0	2
Morone chrysops	0	0	0	0	0	0	0	1	0	0	1
Cycleptus elongatus	0	0	1	0	0	0	0	0	0	0	1

Other taxa that composed ≥3% of total catch at one or more of the continuous sites included *Hybognathus* spp., freshwater drum, grass carp (*Ctenopharygodon idella*), emerald and red shiners, common carp, *Carpiodes* spp., gizzard shad, and goldeye.

Taxa-specific scour basin use in relation to connectivity and scour morphology

Larval taxa separated into five groups based their presence or absence by scour type and relationships between their mean annual CPUE (number/100 m^3) and variables describing site connectivity (duration, exchange, and distance from river) (Table 10). Gizzard shad, *Pomoxis* spp., and *Lepomis* spp. occurred in all three scour types, but mean CPUEs for these taxa were negatively associated with connectivity. Mean CPUEs for common carp and *Sander* spp. were positively associated with connectivity, but only when isolated scours were included in the analysis; these two taxa were rare (common carp) or absent (*Sander* spp.) in isolated scours. Goldeye were not collected from isolated scours; mean CPUE for goldeye was positively related to connectivity when all scours were included in the analysis, but negatively associated with connectivity when isolated scours were excluded. Buffaloes occurred in all three scour types, but were collected from only one of the isolated scours (I305). Mean CPUE for buffaloes was positively related to connectivity when all scours were included in the analysis or two scours with very high densities (I305 and P397) were excluded. Mean CPUE for buffaloes was negatively correlated with distance, but was not significantly correlated with duration or exchange when all isolated scours were excluded. *Micropterus* spp., white bass (*Morone chrysops*), blue sucker (*Cycleptus elongatus*) and sturgeons (*Scaphirhynchus* spp.) were excluded from analyses due to low numbers of larvae collected. All other taxa were either uncommon or absent in isolated scours and were positively associated with connectivity when all scours were included in the analysis and when isolated scours were excluded.

Mean CPUE for gizzard shad was positively correlated with mean scour depth (Spearman rank correlation, $P<0.05$). No other correlations were observed between variables describing site morphology [mean depth (m), area (ha), and shoreline development] and mean CPUE for

Table 10. Summary of correlations between mean annual densities of each taxon by site and environmental variables (duration, mean exchange, distance from river, mean depth, and area).

Gizzard shad, *Pomoxis* spp., *Lepomis* spp.
Occurred in all 3 scour types
Negatively correlated with duration and exchange; positively correlated with distance
Highest densities of these taxa in PC & CC sites occurred in P421, the site with the lowest exchange and duration among connected scours

Common carp, *Sander* spp.
Occurred in all 3 scour types, but were uncommon in isolated scours (CARP) **or** absent from isolated scours (SGER/WLYE)
Positively correlated with duration and exchange; negatively correlated with distance when all scours were included in analysis
Not correlated with any environmental variables when isolated scours were excluded

Goldeye
Not collected in isolated scours
Positively correlated with duration and exchange; negatively correlated with distance when all scours were included in analysis
Negatively correlated with duration and exchange when isolated scours excluded

Ictiobus spp.
Occurred in all 3 scour types, abundant in I305, but absent from other isolated scours
Positively correlated with duration and exchange and negatively correlated with distance regardless of whether all scours were included in analysis, two scours with very high densities (I305 and P397) were excluded, or all isolated scours excluded

Blue sucker, *Carpiodes* spp., *Macrhybopsis* spp., Freshwater drum, Grass carp, *Hypopthalmichthys* spp., *Semotilus atromaculatus* and *Campostoma* spp., *Notropis atherinoides* and *Cyprinella* lutrensis, *Hybognathus* spp.
Were not collected from isolated scours (Blue sucker, *Carpiodes* spp., *Macrhybopsis* spp., Grass carp, *Hybognathus* spp.) or very few collected from isolated scours (Freshwater drum, *Hypopthalmichthys* spp., *Semotilus atromaculatus* and *Campostoma* spp., *Notropis atherinoides* and *Cyprinella* lutrensis)

Positively correlated with duration and exchange and negatively correlated with distance when all scours were included in analysis and when isolated scours were excluded

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any other taxon.

Timing of scour basin use by larval taxa in relation to basin type

Timing of scour basin use by larval fishes differed by basin type for some taxa but not others. Eight taxa were collected in continuous scours over a longer time interval in comparison to isolated or periodic scours. Six of these taxa (*Hypophthalmichthys* spp., freshwater drum, emerald/red shiners, grass carp, *Hybognathus* spp., and *Macrhybopsis* spp.) were present in scours that connected to the river on at least one date during sample periods 8-10 (30 July to 27 August; all continuous scours, P257 and P397), but were rare or absent from scours not connected to the river during this same time interval (Tables 11-17). *Carpiodes* spp. were most abundant in continuous sites during sample periods 5-7 (15 June to 19 July), but were collected in periodic scours only during sample periods 4-6 (29 May to 6 July) (Table 18). Creek chub and stonerollers were present in continuous scours during sample periods 3-7 (13 May to 19 July), but were collected from periodic scours only during sample periods 6 and 7 (1-19 July); only one individual was collected from isolated scours (Table 19).

Three taxa that were most abundant in isolated scours exhibited slight differences in timing of their use of isolated scours compared to periodic and continuous scours. *Pomoxis* spp. and gizzard shad were collected from all scour types during sample periods 4-6 (29 May to 6 July), but mean CPUEs for these taxa during sample period 3 (13-19 May) exceeded 2 fish/100 m^3 only in some isolated scours (Tables 20-21). Mean CPUE for gizzard shad during sample period 7 (14-19 July) was >1.5 fish/100 m^3 only in continuous and periodic scours. *Lepomis* spp. were collected during sample periods 5-8 (15 June to 2 August) for all three scour types, but were collected only in isolated scours during sample period 9 (10-14 August); mean CPUE for *Lepomis* spp. exceeded 6 fish/100 m^3 in three of the five isolated scours during sample period 9 (Table 22).

Six taxa exhibited either no substantial differences or no clear patterns of differences in timing of scour basin use in relation to basin type. All blue suckers were collected during sample

Table 11. Mean bighead carp (*Hypopthalmicthys nobilis*) and silver carp (*H. molitrix*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	93.28	0.00	0.00	0.98	361.78	4.07	46.01
	C351	0.00	0.00	0.00	0.00	103.57	3.12	0.00	0.00	10.36	0.00	11.71
	C387	0.00	0.00	0.00	1.11	40.81	37.21	0.00	4.59	284.71	2.58	37.10
Continuous mean		0.00	0.00	0.00	0.37	79.22	13.44	0.00	1.86	218.95	2.21	31.61
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.10
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.11
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.21	0.00	0.20	0.00	0.00	0.00	0.04
Periodic	P257	0.00	0.00	0.00	0.00	4.34	14.81	0.00	75.21	0.00	0.00	9.44
	P303	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.11
	P397	0.00	0.00	0.00	0.00	29.58	37.17	0.00	227.22	3.76	0.00	29.77
	P421	0.00	0.00	0.00	0.00	14.21	0.00	0.00	0.00	0.00	0.00	1.42
Periodic mean		0.00	0.00	0.00	0.00	12.31	12.99	0.00	75.61	0.94	0.00	10.19
Sample period mean		0.00	0.00	0.00	0.12	30.58	8.81	0.07	25.82	73.30	0.74	13.95

Table 12. Mean emerald shiner (*Notropis atherinoides*) and red shiner (*Cyprinella lutrensis*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	88.84	0.00	0.00	0.00	1.05	0.00	8.99
	C351	0.00	0.00	3.75	0.00	72.70	4.16	0.00	0.00	0.00	0.00	8.06
	C387	0.00	0.00	0.00	0.00	24.29	36.25	3.64	2.75	0.00	0.00	6.69
Continuous mean		0.00	0.00	1.25	0.00	61.94	13.47	1.21	0.92	0.35	0.00	7.91
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.10
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.10
	I513	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.11
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.42	0.00	0.34	0.00	0.00	0.00	0.06
Periodic	P257	0.00	0.00	0.00	0.00	0.00	1.14	1.06	0.00	2.26	0.00	0.45
	P303	0.00	0.00	0.00	0.00	1.09	5.35	3.24	0.00	0.00	0.00	0.97
	P397	0.00	0.00	0.00	0.00	19.38	65.54	1.13	3.36	0.00	0.00	8.94
	P421	0.00	0.00	0.00	0.00	7.65	3.66	0.00	1.13	0.00	0.00	1.24
Periodic mean		0.00	0.00	0.00	0.00	7.03	18.92	1.36	1.12	0.57	0.00	2.90
Sample period mean		0.00	0.00	0.42	0.00	23.13	10.80	0.97	0.68	0.31	0.00	3.62

Table 13. Mean freshwater drum (*Aplodinotus grunniens*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample Period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.83	64.26	38.42	0.89	1.97	0.00	0.00	10.64
	C351	0.00	0.00	0.00	0.00	85.82	18.71	0.00	0.00	2.30	0.00	10.68
	C387	0.00	0.00	0.00	1.11	14.58	16.22	2.72	0.00	1.02	0.00	3.56
Continuous mean		0.00	0.00	0.00	0.65	54.88	24.45	1.20	0.66	1.11	0.00	8.30
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	2.04	1.06	0.00	1.00	0.00	0.00	0.00	0.41
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.31
Isolated mean		0.00	0.00	0.00	1.03	0.21	0.00	0.20	0.00	0.00	0.00	0.14
Periodic	P257	0.00	0.00	0.00	6.23	0.00	0.00	0.00	0.00	0.00	0.00	0.62
	P303	0.00	0.00	0.00	8.56	0.00	3.22	0.00	0.00	0.00	0.00	1.18
	P397	0.00	0.00	0.00	7.78	6.11	13.52	0.00	0.00	0.00	0.00	2.74
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	0.00	5.64	1.53	4.18	0.00	0.00	0.00	0.00	1.14
Sample period mean		0.00	0.00	0.00	2.44	18.87	9.55	0.47	0.22	0.37	0.00	3.19

Table 14. Mean grass carp (*Ctenopharyngodon idella*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample Period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.83	167.91	1.10	0.00	0.98	16.78	9.15	19.68
	C351	0.00	0.00	0.00	0.00	52.28	2.08	0.00	0.00	18.42	9.04	8.18
	C387	0.00	0.00	0.00	1.11	18.46	3.82	0.00	0.00	106.51	7.74	13.76
Continuous mean		0.00	0.00	0.00	0.65	79.55	2.33	0.00	0.33	47.24	8.64	13.87
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10
	P303	0.00	0.00	0.00	0.00	0.00	2.15	1.08	0.00	0.00	0.00	0.32
	P397	0.00	0.00	0.00	0.00	3.05	13.52	0.00	0.00	0.00	0.00	1.66
	P421	0.00	0.00	0.00	2.08	1.09	0.00	0.00	0.00	0.00	0.00	0.32
Periodic mean		0.00	0.00	0.00	0.78	1.04	3.92	0.27	0.00	0.00	0.00	0.60
Sample period mean		0.00	0.00	0.00	0.48	26.86	2.08	0.09	0.11	15.75	2.88	4.82

Table 15. Mean *Hybognathus* spp. larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (ategory mean) and period density averaged by category (sample period mean). Dates above period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	152.36	10.98	2.67	0.00	10.49	1.02	17.75
	C351	0.00	0.00	0.00	0.00	38.47	2.08	0.00	0.00	0.00	0.00	4.06
	C387	0.00	0.00	0.00	0.00	12.64	4.75	2.72	7.35	0.00	6.88	3.43
Continuous mean		0.00	0.00	0.00	0.00	67.82	5.94	1.80	2.45	3.50	2.63	8.41
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.11
	P303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P397	0.00	0.00	0.00	0.00	5.10	14.69	1.13	1.12	0.00	0.00	2.20
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.11
Periodic mean		0.00	0.00	0.00	0.00	1.28	4.66	0.28	0.56	0.00	0.00	0.61
Sample period mean		0.00	0.00	0.00	0.00	23.03	3.53	0.69	1.00	1.17	0.88	3.01

Table 16. Mean sicklefin chub (*Macrhybopsis meeki*) and sturgeon chub (*M. gelida*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.97	2.10	0.00	0.41
	C351	0.00	0.00	0.00	0.00	0.00	6.24	0.00	0.00	1.15	1.13	0.85
	C387	0.00	0.00	0.00	0.00	0.97	8.59	0.00	0.92	3.07	0.86	1.44
Continuous mean		0.00	0.00	0.00	0.00	0.32	4.94	0.00	0.96	2.11	0.66	0.90
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P303	0.00	0.00	0.00	0.00	0.00	2.15	0.00	0.00	0.00	0.00	0.21
	P397	0.00	0.00	0.00	0.00	0.00	4.51	0.00	0.00	0.00	0.00	0.45
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.17
Sample period mean		0.00	0.00	0.00	0.00	0.11	2.20	0.00	0.32	0.70	0.22	0.36

Table 17. Mean silver chub (*Macrhybopsis storeriana*) and speckled chub (*M. aestivalis*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95	8.39	2.03	1.34
	C351	0.00	0.00	0.00	0.00	0.00	1.04	0.00	0.00	1.15	1.13	0.33
	C387	0.00	0.00	0.00	0.00	2.92	0.95	0.91	1.84	0.00	0.00	0.66
Continuous mean		0.00	0.00	0.00	0.00	0.97	0.66	0.30	1.60	3.18	1.05	0.78
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P303	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.11
	P397	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.03
Sample period mean		0.00	0.00	0.00	0.00	0.32	0.31	0.10	0.53	1.06	0.35	0.27

Table 18. Mean carpsucker (*Carpiodes* sp.) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	2.07	5.49	4.46	0.98	0.00	0.00	1.30
	C351	0.00	0.00	0.94	0.00	22.69	16.63	16.06	0.00	0.00	0.00	5.63
	C387	0.00	0.00	0.00	0.00	4.86	0.95	1.81	0.00	0.00	0.00	0.76
Continuous mean		0.00	0.00	0.31	0.00	9.87	7.69	7.45	0.33	0.00	0.00	2.57
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.21
	P303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P397	0.00	0.00	0.00	0.86	3.05	2.25	0.00	0.00	0.00	0.00	0.62
	P421	0.00	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Periodic mean		0.00	0.00	0.00	0.99	0.76	0.56	0.00	0.00	0.00	0.00	0.23
Sample period mean		0.00	0.00	0.10	0.33	3.55	2.75	2.48	0.11	0.00	0.00	0.93

Table 19. Mean creek chub (*Semotilus atromaculatus*) and stoneroller (*Campostoma* sp.) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	1.02	0.00	12.42	0.00	0.00	0.00	0.00	0.00	1.34
	C351	0.00	0.00	0.00	1.86	1.97	7.28	0.00	0.00	0.00	0.00	1.11
	C387	0.00	0.00	0.00	0.00	3.88	9.50	2.73	0.00	0.00	0.00	1.61
Continuous mean		0.00	0.00	0.34	0.62	6.09	5.59	0.91	0.00	0.00	0.00	1.35
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.11
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.02
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	0.00	0.00	0.11
	P303	0.00	0.00	0.00	0.00	0.00	2.15	0.00	0.00	0.00	0.00	0.22
	P397	0.00	0.00	0.00	0.00	0.00	4.52	0.00	0.00	0.00	0.00	0.45
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	0.00	0.00	0.00	1.67	0.27	0.00	0.00	0.00	0.20
Sample period mean		0.00	0.00	0.11	0.21	2.10	2.42	0.39	0.00	0.00	0.00	0.52

Table 20. Mean black crappie (*Pomoxis nigromaculatus*) and white crappie (*P. annularis*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean), and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	2.07	1.10	0.00	0.00	0.00	0.00	0.32
	C351	0.00	0.00	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
	C387	0.00	0.00	1.02	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Continuous mean		0.00	0.00	0.97	0.37	0.69	0.37	0.00	0.00	0.00	0.00	0.24
Isolated	I305	0.00	0.00	6.83	11.94	161.68	1.00	1.01	0.00	0.00	0.00	18.25
	I330	0.00	0.00	0.00	3.07	36.19	3.15	0.00	0.00	0.00	0.00	4.24
	I442	0.00	0.00	0.00	1.09	0.00	1.06	0.00	0.00	0.00	0.00	0.22
	I513	0.00	0.00	20.80	108.51	6.44	0.00	0.00	0.00	0.00	0.00	13.58
	I529	0.00	0.00	27.35	44.80	0.00	0.00	0.00	0.00	0.00	0.00	7.21
Isolated mean		0.00	0.00	10.99	33.88	40.86	1.04	0.20	0.00	0.00	0.00	8.70
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	3.17	0.00	0.00	0.00	0.32
	P303	0.00	0.00	0.00	1.71	3.28	0.00	0.00	0.00	0.00	0.00	0.50
	P397	0.00	0.00	0.00	0.00	1.02	1.13	0.00	0.00	0.00	0.00	0.21
	P421	0.00	0.00	0.00	16.62	7.65	1.22	0.00	0.00	0.00	0.00	2.55
Periodic mean		0.00	0.00	0.00	4.58	2.99	0.59	0.79	0.00	0.00	0.00	0.89
Sample period mean		0.00	0.00	3.99	12.94	14.85	0.67	0.33	0.00	0.00	0.00	3.28

Table 21. Mean gizzard shad (*Dorosoma cepedianum*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample Period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	2.50	14.51	15.37	1.79	0.00	0.00	0.00	3.42
	C351	0.00	0.00	1.87	0.00	9.86	1.04	0.00	0.00	0.00	0.00	1.28
	C387	0.00	0.00	0.00	3.33	15.51	16.22	6.34	0.00	0.00	0.00	4.14
Continuous mean		0.00	0.00	0.62	1.94	13.29	10.88	2.71	0.00	0.00	0.00	2.95
Isolated	I305	0.00	0.00	6.83	17.91	714.44	2.99	0.00	0.00	0.00	0.00	74.22
	I330	0.00	0.00	0.00	478.39	1024.08	0.00	1.00	0.00	0.00	0.00	150.35
	I442	0.00	0.00	0.00	139.86	1544.10	2.13	1.09	0.00	0.00	0.00	168.72
	I513	0.00	0.00	0.95	598.91	23.61	0.00	1.05	0.00	0.00	0.00	62.45
	I529	0.00	0.00	32.81	792.85	0.00	0.00	0.00	0.00	0.00	0.00	82.57
Isolated mean		0.00	0.00	8.12	405.58	661.25	1.02	0.63	0.00	0.00	0.00	107.66
Periodic	P257	0.00	0.00	0.00	18.68	151.88	46.71	8.45	3.91	0.00	0.00	22.96
	P303	0.00	0.00	1.02	4.28	419.97	48.34	11.83	0.00	0.00	0.00	48.54
	P397	0.00	0.00	0.00	10.38	402.98	106.99	10.14	0.00	0.00	0.00	53.05
	P421	0.00	0.00	0.00	133.98	2231.78	63.60	3.11	0.00	0.00	0.00	243.25
Periodic mean		0.00	0.00	0.26	41.83	801.65	66.41	8.38	0.98	0.00	0.00	91.95
Sample period mean		0.00	0.00	3.00	149.79	492.06	26.10	3.91	0.33	0.00	0.00	67.52

Table 22. Mean sunfish (*Lepomis* spp.) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	2.07	0.00	0.89	0.00	0.00	0.00	0.30
	C351	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C387	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76	0.00	0.00	0.28
Continuous mean		0.00	0.00	0.00	0.00	0.69	0.00	0.30	0.92	0.00	0.00	0.19
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	109.26	22.01	6.19	6.14	0.00	14.36
	I442	0.00	0.00	0.00	0.00	11.07	27.68	2.19	48.72	6.37	0.00	9.60
	I513	0.00	0.00	0.00	0.00	5.37	23.79	0.00	108.37	19.89	0.00	15.74
	I529	0.00	0.00	0.00	0.00	10.35	12.74	12.33	22.78	1.10	0.00	5.93
Isolated mean		0.00	0.00	0.00	0.00	5.36	34.69	7.31	37.21	6.70	0.00	9.13
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	0.00	0.21
	P303	0.00	0.00	0.00	0.00	1.09	0.00	1.08	1.05	0.00	0.00	0.32
	P397	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.11
	P421	0.00	0.00	0.00	0.00	0.00	28.06	8.30	0.00	0.00	0.00	3.64
Periodic mean		0.00	0.00	0.00	0.00	0.27	7.02	3.16	0.26	0.00	0.00	1.07
Sample period mean		0.00	0.00	0.00	0.00	2.11	13.90	3.59	12.80	2.23	0.00	3.46

period 3 (13-19 May) (Table 23). All but one *Ictiobus* spp. were collected during sample periods 4 and 5 (29 May to 21 June) (Table 24). Common carp were collected during sample periods 3-6 (13 May to 6 July) for both continuous and periodic scours; only one individual was collected from isolated scours (Table 25). Goldeye were most frequently collected during sample periods 3-5 (13 May to 21 June) in both continuous and periodic scours; only 3 individuals were collected after 21 June (Table 26). Mean CPUE for *Sander* spp. was highest in sample period 3 (13-19 May for continuous and periodic scours; one individual was captured during sample period 2 at site C387 and two individuals were collected during sample period 4 (Table 27). Only seven white bass were collected during the study. Four individuals were collected from isolated scours during sample period 4 (29 May to 4 June). The other three individuals were collected from P421 during sample period 5, C351 during sample period 7, and C387 during sample period 8 (Table 28).

Detrended correspondence analysis of mean CPUE for larval taxa in scour basins and relations between larval fish assemblage structure and connectivity

Detrended correspondence analysis of mean catch per unit effort (CPUE, number/100^3) for larval taxa by site indicated a strong segregation along the first ordination axis, with isolated scours to the left, continuous scours to the right, and periodic scours distributed from the left to the middle of the diagram (Figure 6). Axis 1 scores for sites were positively correlated with duration of connection (d) and mean exchange and negatively correlated with distance from the river (m) (Spearman rank correlations, $P<0.05$), but were not significantly correlated with site location (river km) or variables describing scour morphology [mean depth (m), area (ha), and shoreline development] ($P>0.05$). Isolated scours were tightly clustered, indicating high degree of similarity of larval fish assemblages among these sites. Distribution of periodic scours along axis 1 was related to three components of site connectivity. Site P421 ordinated close to the isolated scours and had the lowest mean exchange and duration and the second highest distance from the river among periodic scours. The next site to the right of P421 in the diagram is P303,

Table 23. Mean blue sucker (*Cycleptus elongatus*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above period numbers are the starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
	C351	0.00	0.00	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
	C387	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Continuous mean		0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P303	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
	P397	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Sample period mean		0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05

Table 24. Mean buffalo (*Ictiobus* spp.) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	6.90	0.00	0.00	0.00	0.00	0.00	0.00	0.69
	C351	0.00	0.00	0.00	3.72	1.97	0.00	0.00	0.00	0.00	0.00	0.57
	C387	0.00	0.00	0.00	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Continuous mean		0.00	0.00	0.00	4.28	0.66	0.00	0.00	0.00	0.00	0.00	0.49
Isolated	I305	0.00	0.00	0.00	0.00	14.20	0.00	0.00	0.00	0.00	0.00	1.42
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	2.84	0.00	0.00	0.00	0.00	0.00	0.28
Periodic	P257	0.00	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10
	P303	0.00	0.00	0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.11
	P397	0.00	0.00	0.00	15.56	1.02	0.00	0.00	0.00	0.00	0.00	1.66
	P421	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.11
Periodic mean		0.00	0.00	0.00	4.15	0.53	0.00	0.27	0.00	0.00	0.00	0.50
Sample period mean		0.00	0.00	0.00	2.81	1.34	0.00	0.09	0.00	0.00	0.00	0.42

Table 25. Mean common carp (*Cyprinus carpio*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	1.02	30.86	0.00	0.00	0.00	0.00	0.00	0.00	3.19
	C351	0.00	0.00	1.87	15.85	1.97	1.04	0.00	0.00	0.00	0.00	2.07
	C387	0.00	0.00	1.02	17.74	0.00	0.95	0.00	0.00	0.00	0.00	1.97
Continuous mean		0.00	0.00	1.31	21.48	0.66	0.66	0.00	0.00	0.00	0.00	2.41
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Periodic	P257	0.00	0.00	1.22	20.76	0.00	0.00	0.00	0.00	0.00	0.00	2.20
	P303	0.00	0.00	5.12	9.41	0.00	1.07	0.00	0.00	0.00	0.00	1.56
	P397	0.00	0.00	0.00	136.66	0.00	0.00	0.00	0.00	0.00	0.00	13.67
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	1.59	41.71	0.00	0.27	0.00	0.00	0.00	0.00	4.36
Sample period mean		0.00	0.00	0.96	21.13	0.22	0.31	0.00	0.00	0.00	0.00	2.26

Table 26. Mean goldeye (*Hiodon alosoides*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and sample period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample Period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	2.05	0.00	8.29	0.00	0.00	0.00	0.00	0.00	1.03
	C351	0.00	0.00	1.87	0.00	8.88	0.00	0.00	0.00	0.00	0.00	1.08
	C387	0.00	0.00	0.00	1.11	25.27	0.00	0.00	0.00	0.00	0.00	2.64
Continuous mean		0.00	0.00	1.31	0.37	14.14	0.00	0.00	0.00	0.00	0.00	1.58
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	9.78	208.60	56.41	0.00	0.00	0.00	0.00	0.00	27.48
	P303	0.00	0.00	1.02	5.13	60.15	0.00	2.15	0.00	0.00	0.00	6.85
	P397	0.00	0.00	0.00	2.59	33.58	1.13	0.00	0.00	0.00	0.00	3.73
	P421	0.00	0.00	0.00	84.13	0.00	0.00	0.00	0.00	0.00	0.00	8.41
Periodic mean		0.00	0.00	2.70	75.11	37.54	0.28	0.54	0.00	0.00	0.00	11.62
Sample period mean		0.00	0.00	1.34	25.16	17.23	0.09	0.18	0.00	0.00	0.00	4.40

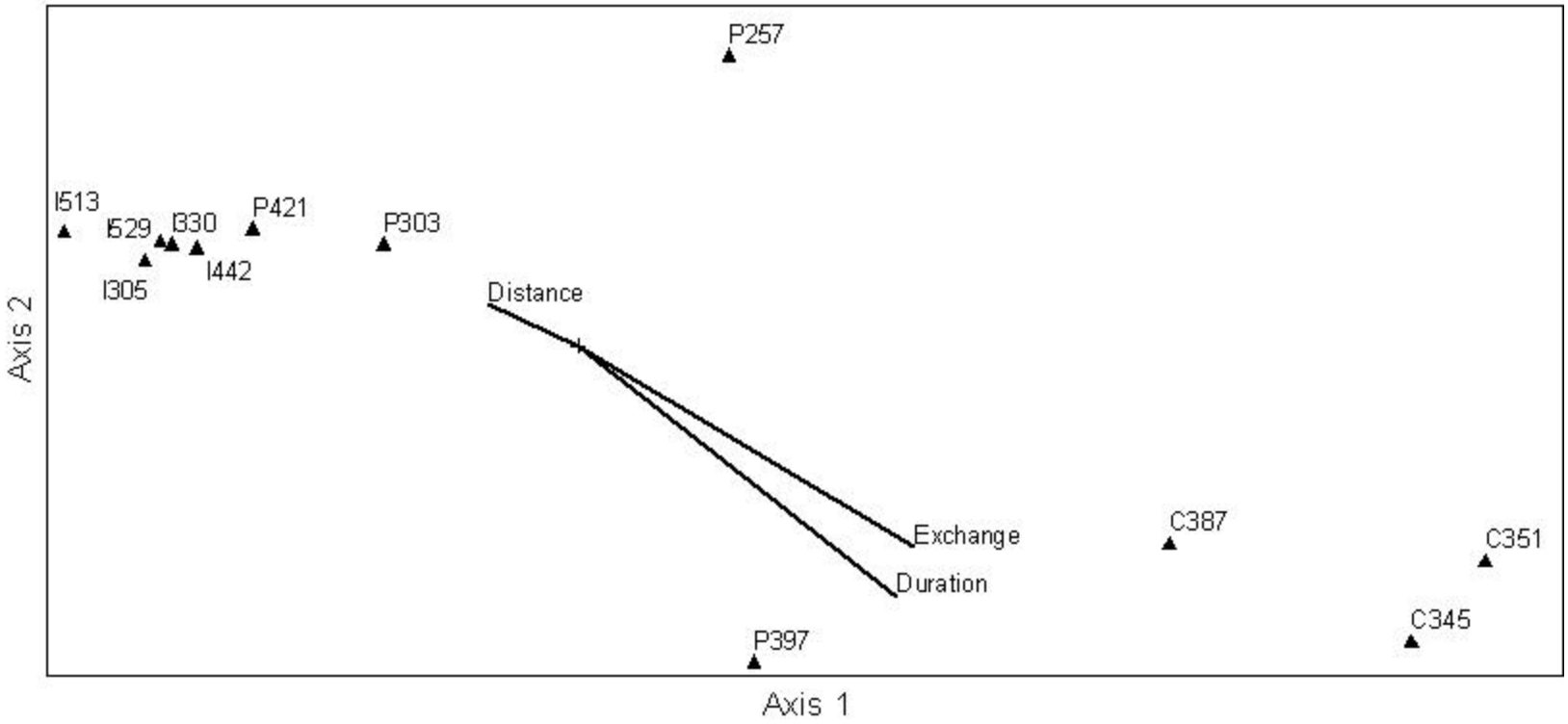
Table 27. Mean sauger (*Sander canadense*) and walleye (*S. vitreum*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (sample period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51
	C351	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
	C387	0.00	1.03	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Continuous mean		0.00	0.34	2.02	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.27
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I529	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isolated mean		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic	P257	0.00	0.00	6.11	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.71
	P303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P397	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P421	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Periodic mean		0.00	0.00	1.53	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.18
Sample period mean		0.00	0.11	1.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.15

Table 28. Mean white bass (*Morone chrysops*) larval densities (number of fish / 100 m^3) by site and sample period with site density averaged by period (site mean), category density averaged by period (category mean) and period density averaged by category (period mean). Dates above sample period numbers are starting and ending dates for each sample period.

		Sample period										
	Start	04/06	04/22	05/13	05/29	06/15	07/01	07/14	07/30	08/10	08/24	
	End	04/16	05/03	05/19	06/04	06/21	07/06	07/19	08/02	08/14	08/27	
Category	Site	1	2	3	4	5	6	7	8	9	10	Site mean
Continuous	C345	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C351	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.09
	C387	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.09
Continuous mean		0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.31	0.00	0.00	0.06
Isolated	I305	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I330	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.10
	I442	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	I513	0.00	0.00	0.00	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.21
	I529	0.00	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Isolated mean		0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Periodic	P257	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P397	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	P421	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.11
Periodic mean		0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.03
Sample period mean		0.00	0.00	0.00	0.28	0.09	0.00	0.10	0.10	0.00	0.00	0.06

Figure 6. Detrended correspondence analysis ordination plot of mean CPUE number/100 m^3) for larval taxa by site. Vectors indicate magnitude and direction of associations between axis scores and variables that describe site connectivity (distance from river (m), mean exchange, and duration of connection (d)).



which was a similar distance from the river (Table 1), but had higher mean exchange and duration (Table 4) compared to P421. Connectivity of the next site to the right (P257) was distinguished from that of P303 primarily by P257's much shorter distance from the river (Table 1), but also by its slightly longer duration of connection (Table 4). Axis 1 scores for sites P257 and P397 were nearly identical despite P397 having higher mean exchange and duration more than twice that of P257 (Table 4). However, both P257 and P397 were located within 10 m of the river (Table 1). Continuous scours and P397 were separated along axis 1; connectivity of P397 was distinguished from that of continuous scours primarily by its lower mean exchange (Table 4). P397 also had a slightly lower duration than connected scours (Table 4), but was disconnected from the river during late April and early May (sample periods 1 and 2) before larval fishes became abundant in collections.

The second ordination axis separated two groups of scours: P397 and the continuous scours toward the bottom of the figure, and all other periodic scours and isolated scours toward the top of the diagram. Axis 2 scores for sites were associated only with duration of connection (Spearman rank correlation, $P<0.05$). Scours near the top of the diagram were connected for <55 d during the study. Only one of these scours (P257) was connected (2 d) during August. Scours near the bottom of the diagram were connected for >120 d during the study, including all of August.

DISCUSSION

Connectivity of floodplain water bodies is often treated conceptually or qualitatively rather than as a quantitative variable (Junk et al. 1989, Ward 1989, Ward and Stanford 1995). However, results of this study confirm that connectivity is a continuous variable that encompasses multiple temporal and spatial components (Amoros and Roux 1988; Kubisiak 1997). Galat et al. (1997) identified five structural metrics to quantify a floodplain waterbody's relative connectivity: distance, duration, timing, exchange, and type. Connectivity of scoured floodplain waterbodies was positively associated with duration and exchange and negatively related to dis-

tance from the river. A wide range of connectivity, as represented by these three variables, was evident among periodic scours. Higher variability in connectivity among periodic scours compared to isolated or continuously connected scours resulted in greater variation in larval fish assemblages among periodic scours. Site P397 exhibited the highest duration and mean exchange and the lowest distance from the river among periodic scours and had many taxa in common with continuous scours. Site P421 had the lowest duration and exchange and the second highest distance from the river among periodic scours. Gizzard shad and centrarchids dominated the larval fish assemblage at this site, similar to the fish fauna observed in all isolated scours. Increasing connectivity via greater duration or exchange or shorter distance from the river will enhance accessibility of scours for riverine fishes.

Water temperature and transparency

Connectivity strongly influenced scour temperatures. Daytime temperatures in disconnected scours were $\geq$1.5 °C warmer than the river on average, whereas scours that experienced connection within the previous week had daytime temperatures that averaged $\leq$0.8 °C warmer than the river. Results of a more intensive study of larval fish habitat use in sites P421 and C387 during 1996 and 1997 (Galat et al. 2003) indicated that mean open-water temperature averaged 1.9 °C warmer than the river at site P421 when larval fishes were present (mid-May to mid-August) and 1.2 °C warmer than the river at site C387 when larval fishes were present (1 May to early October). Water temperature in the portion of scour C387 that was adjacent to and receiving water from the river was only 0.3 °C warmer than river temperature on average during the same time period. Water temperatures in scours or portions of scours that experience greater exchange will more closely resemble those of the Missouri River compared to scours or areas within scours where exchange is reduced or absent. Disconnected scours have higher daytime temperatures than the river, but occurrence of water temperatures lower than the river in scours that were visited before 0930 during summer suggests that diurnal fluctuation may cause scour

temperatures to drop below river temperature at night. Disconnected scours are expected to exhibit greater diurnal water temperature fluctuation compared to connected scours due to lower thermal inertia of relatively small, isolated water bodies in comparison to the Missouri River. Warmer temperatures in scours compared to the Missouri River would likely enhance larval fish growth potential (Weatherly and Gill 1987). However, effects of diurnally fluctuating temperatures on fish growth are equivocal and may be species-specific and dependent on the location of water temperatures with respect to minimum, optimum, and maximum growth temperatures or the amplitude of temperature oscillations (Bestgen 1996, Jobling 1997).

Mean water transparency in scours increased with greater isolation from the Missouri River. Recent or occurring connection increased turbidity in scours and resulted in greater similarity in water transparency between scours and the river, consistent with findings of Knowlton and Jones (1997). Greater variation in water transparency was present in isolated and periodic scours compared to continuously connected scours, although causes of greater variability in water transparency likely differed for isolated and periodic scours. Increases in turbidity are associated with connection with the more turbid Missouri River in periodic scours, but are driven by sediment resuspension from wind mixing or runoff from agricultural land in isolated scours (Knowlton and Jones 1997). Variation in turbidity among scour basin types is likely most significant for sight-feeding fishes such as centrarchids that can forage more effectively in clearer water. Greater transparency in isolated scours may partly account for higher densities of centrarchids in isolated sites.

Larval fishes

Connectivity strongly influenced taxa richness and assemblage structure of larval fishes in lower Missouri River scour basins. A positive association between larval fish taxa richness and scour basin connectivity is consistent with predicted effects of hydrologic connectivity with the floodplain on fish diversity in large rivers (Scheimer 2000). Taxa richness increased in connected floodplain scours with increasing connectivity due to addition of rheophilic taxa that were

rare or absent in isolated scours. The proportion of rheophilic age-0 fishes also increased along a gradient of increasing water flow between the lower Rhine River and rehabilitated floodplain waterbodies (Grift et al. 2003). Havel et al. (2000) reported that crustacean species richness in Missouri River scours also followed a trend of sites with higher exchange having more species present.

Mean CPUE for all larval taxa combined was not related to connectivity. This contrasts with results of Kubisiak (1997), who found that catch rates and biomass of juvenile and small adult fishes were significantly higher in continuously and periodically connected scours compared to isolated scours. However, Grift et al. (2003) reported that total density of age-0 fishes increased along a gradient of decreasing water flow. High catch rates for gizzard shad and centrarchids in isolated and some periodic scours in this study and negative relationships between these taxa and connectivity offset positive relationships between catch rates for many other, less-abundant taxa and connectivity, resulting in no relationship between catch rates for all larvae combined and connectivity. However, the most abundant taxon collected in this study, gizzard shad, followed the pattern of increasing density with decreasing connectivity.

Results indicated that differences in taxa richness and assemblage structure of larval fishes among scour basins and mean CPUE for all larval taxa combined were not related to morphological differences among scours. In contrast, Sabo and Kelso (1991) found that total densities of larval fishes in lower Mississippi River floodplain ponds (equivalent to periodic scours in this study) were positively associated with shoreline development, pond volume, and depth variation. Total catch and taxa richness of meso- and metalarval and juvenile fishes in continuously connected lower Missouri River scours were highest in basins with shallow maximum and nearshore depths (Tibbs and Galat 1997). Absence of significant associations between scour morphology and total density, taxa richness, or assemblage structure of larval fishes in this study is likely due to the overriding influence of connectivity on fish use of scour basins. Both Sabo and Kelso (1991) and Tibbs and Galat (1997) sampled floodplain water bodies from a single scour category (periodic or continuous connection). Morphology of floodplain waterbodies

likely influences attributes of larval fish assemblages among basins that do not differ substantially in connectivity, but its effects are masked by the strong influence of connectivity on larval fish assemblages when basins encompassing a broader range of connectivity are sampled.

Mean CPUE for gizzard shad was positively correlated with mean scour depth, but no other correlations between mean taxon-specific CPUEs and site morphological variables were detected. The positive relationship between gizzard shad catch rates and mean scour depth may have resulted from the fact that the six scours with the highest mean depths were all isolated scours or periodic scours that exhibited relatively low connectivity. Mean CPUEs >150 gizzard shad / 100 m^3 occurred in three scours (I330, I442, and P421) that represented three of the four deepest scours in this study. However, relatively high catch rates for gizzard shad in these scours may have been due primarily to higher fertility of these three scours rather than their greater mean depths. Sites I330 and I442 received water from ditches that drained agricultural land and may have enhanced nutrient inputs to these two scours. P421 received nutrient inputs from the river, as did other periodic and continuous scours, but P421 was connected on fewer dates and had a higher mean secchi depth compared to all other periodic and continuous scours. High algal productivity (as measured by chlorophyll *a*) in periodic scours is associated with periods immediately following disconnection from the river when nutrient concentrations are high and turbidity declines (Knowlton and Jones 1997). Gizzard shad are filter-feeders as adults and are especially abundant where plankton productivity is high (Pflieger 1997). Thus, enhanced productivity of sites I330, I442, and P421 as a result of relatively high nutrient inputs combined with low turbidity may have resulted in these three scours having high densities of gizzard shad. Relatively high mean depths of these scours may have enhanced productivity (and ultimately gizzard shad abundance) by inhibiting wind-driven sediment resuspension that would have reduced water clarity and potentially limited algal productivity.

Individual taxa whose densities were positively associated with connectivity are characteristic of large rivers in Missouri as adults (Pflieger 1997) and are open substratum spawners with buoyant eggs and pelagic larvae or require hard substrates for spawning (Simon 1999). Some of

these taxa may spawn primarily or exclusively in flowing water (Pflieger 1997). The only taxa that were positively associated with connectivity and are not classified as open substratum spawners were creek chub (*Semotilus atromaculatus*) and stonerollers (*Campostoma* spp.). These species are lithophilic brood hiders (Simon 1999) that are common in smaller tributaries of the lower Missouri River (Pflieger 1997) and likely entered the mainstem as waifs. Very little gravel substrate required by these taxa for spawning exists in the lower Missouri River (Galat et al. 2001), suggesting that occurrence of their larvae in scours was primarily the result of drift from tributaries. Increasing connectivity provides greater access to floodplain water bodies for rheophilic taxa by enhancing opportunity for drifting eggs and larvae to be transported into scours and may also provide greater access for adult fishes that reproduce in scour basins.

A continuum of connectivity among scour basins yielded a gradient in larval fish assemblages from a fauna dominated by eurytopic and limnophilic taxa (gizzard shad and centrarchids) in isolated scours to an increasingly more diverse assemblage that included greater abundances of rheophilic taxa. Reproductive characteristics of gizzard shad and centrarchids likely contributed to their abundance in isolated scours. Gizzard shad spawn in backwaters where current is reduced or absent (Pflieger 1997) and their larvae are predominantly found in low-velocity backwaters in the upper Mississippi River (Holland 1986). Centrarchids collected in this study are nest spawners with adhesive eggs and are not particular in their choice of spawning substrates (Simon 1999). Higher current velocities and more frequent scouring and sediment deposition in connected scours likely inhibits reproductive success of gizzard shad and centrarchids and at least partially account for their negative associations with hydrologic connectivity. Other low-velocity habitats within the lower Missouri River floodplain, such as lower reaches of small tributaries, had larval assemblages that were composed primarily of gizzard shad and *Lepomis* spp., along with emerald and red shiners (Brown and Coon 1994). Reduced current velocities and limited exchange with the Missouri River may result in the lower reaches of these small tributaries functioning more like isolated scours than continuously connected scours for

larval fishes. Larval assemblages in lower reaches of larger tributaries commonly included rheophilic taxa (e.g., freshwater drum, goldeye), although the source of these larvae was unclear (Brown and Coon 1994). Dettmers et al. (2001) compared larval fishes collected from the main channel and connected backwater habitats along the lower Illinois River in 1997. They reported that larvae of the rheophilic taxa freshwater drum (92%) and *Morone* spp. (85%) were far more abundant in main channel habitats, whereas centrarchids (98%) and cyprinodontids (100%) were almost exclusively collected from low velocity backwater habitats. Larval cyprinids and *Dorosoma* spp. occurred with about equal frequency in both riverine and backwater habitats.

Collection of a limited number of larvae of taxa positively associated with connectivity in some isolated scours likely resulted from unobserved brief connections between these sites and the river or spawning of residual adults transported to the sites during the 1995 floods. Most catches of riverine taxa in isolated sites occurred during sample period 4 (29 May-4 June) during the largest flood of 1996 in terms of peak river discharge. Two freshwater drum, one white bass, and one common carp were collected from I330 on 1 June. This site was linked to the river via a ditch (Kubisiak 1997) that may have provided access for these fishes. Two white bass were caught in I513 on 29 May and one bighead carp was collected in I513 on 18 June. Although this scour was not directly fed by a ditch as I330 was, Kubisiak (1997) observed connection between I513 and an adjacent river-connected ditch on 17 June 1996 that was characterized as “sheet-flow over a soybean field”. Overland connection between I513 and this ditch may also have occurred on or around 29 May when river stage reached its peak for 1996 and may explain occurrence white bass larvae. Three freshwater drum and one white bass were also collected from I529 on 29 May. No connection was ever observed for this site, but collection of these larvae coincided with peak river discharge for 1996, suggesting that overland connection with a ditch linked to the Missouri River observed at I513 may also have occurred at I529. Thirteen buffalo (*Ictiobus* spp.) were captured in I305 on 16 June, coinciding with catch of 993 juvenile and adult bigmouth buffalo by Kubisiak (1997). Although bigmouth buffalo are most common in large rivers in Missouri, they frequently occur in floodplain lakes and spend their

first summer of life in these areas or in small tributaries (Pflieger 1997).

Introduced *Hypophthalmichthys* spp. were the most abundant larval fish collected from connected scours in this study and also by Tibbs and Galat (1997). Bighead carp (*H. nobilis*) and silver carp (*H. molitrix*) carp were first reported from the Missouri River, Missouri in 1982 (Pfileger 1997) and by 2000 contributed over 15,000 kg to the commercial fish catch (Galat et al. 2004). They are reported to reproduce in rivers during flow pulses and their eggs are buoyant and pelagic (Schrank et al. 2001, Verigin et al. 1978), suggesting embryos or larvae drift into floodplain waterbodies during periods of hydrologic connection. Timing of larval *Hypophthalmichthys* spp. first appearance in connected sites (early June) coincided with the seasonal flood pulse along the lower Missouri River (Galat and Lipkin 2000). However, we observed their peak abundance in mid-August in 2 of 3 connected scours. Tibbs and Galat (1997) reported multiple pulses of protolarval *Hypophthalmichthys* spp. in connected lower Missouri River scours in late May, late June, and late July 1996 during or following flow pulses with the highest abundance occurring in late May. Mesolarvae and metalarva stages combined had a single peak in late July. Spawning of *Hypophthalmichthys* spp. on flow pulses implies an adaptation for capitalizing on floodplain habitats as nurseries although the relative importance of floodplain and riverine habitats along the lower Missouri River to *Hypopthalmichthys* spp. spawning, larval nursery, and recruitment is unknown.

Results indicated that duration and timing of connection had a strong influence on larval fish assemblages in scour basins. Differences in duration of connection among periodic and continuous scours that led to site-to-site differences in larval fish assemblage structure were primarily driven by number of connection dates during July and August. Riverine taxa had access to all periodic and continuous scours on at least 24 dates during May and June, the peak spawning and larval nursery period for most Missouri River fishes (Gelwicks 1995; Galat et al. 1998). All periodic and continuous scours connected with the river within three days after river temperature first reached 15 °C (9 May), the approximate lower limit for initiation of spawning by lower Missouri River fishes (Galat et al. 1998). Thus, timing of connection in periodic scours

was appropriate for the majority of riverine taxa. However, continuous scours and P397 were the only sites that were connected to the river during all of August; connection to the river during August contributed strongly to differences in larval fish assemblages among scours. Connection to the river during August allowed access to P397 and continuous scours by *Hypopthalmichthys* spp. and greater access to continuous scours by *Hybognathus* spp., *Macrhybopsis* spp., freshwater drum, grass carp, and emerald shiner. Differences in connectivity between P397 and continuous scours during August were due to higher exchange values in continuous scours that may have enhanced access to these sites by taxa listed above. Increased duration of connection has also been demonstrated to enhance access to floodplain wetlands for larval razorback suckers in the Green River, Utah (Modde et al. 2001).

Presence or absence of connection during August strongly influenced differences in larval fish assemblages among scours. Four native riverine taxa (*Hybognathus* spp., *Macrhybopsis* spp., freshwater drum, and emerald shiner) used continuously connected scours as larval nursery during August, but were rare or absent in scours that were weakly connected or disconnected from the river during the same time period. These taxa, along with introduced grass carp and *Hypopthalmichthys* spp., were the only rheophilic larval taxa collected from lower Missouri River scours during August, September, and early October in two other studies (Tibbs and Galat 1997; Galat et al. 2003).

However, recent research on age-0 fishes indicates that nearshore habitats along primary and secondary channels, rather than floodplain waterbodies, provide the primary nursery areas for many rheophilic fishes (i.e., the "inshore retention concept", Scheimer et al. 2001, Keckeis and Scheimer 2002). Additionally, spawning of some species of riverine fishes does not appear to coincide with the annual flood pulse, but occurs primarily under non-flood conditions within the main river channel. This "low flow recruitment hypothesis" was proposed by Humphries et al. (1999) to explain why some fishes in Australia spawn during the warmest months and lowest flows and how they are able to recruit under these conditions. Whether near-shore, low-velocity, main-channel areas are sufficient for recruitment of some rheophilic Missouri River fishes

during summer, or if these fishes depend on mid-summer flow pulses that provide access to floodplain habitats for larval nursery, is unknown. How important floodplain habitats are for recruitment of rheophilic fishes relative to in-channel, shallow-water habitats is not known for the lower Missouri River as main channels were not sampled for larval fishes in previous studies or the present study. Research currently underway on larval fish use of in-channel habitats (Reeves 2001) should help answer this question.

Modifications of reservoir water releases to provide a more natural flow regime and major habitat rehabilitation programs for the lower Missouri River are proposed by the U.S. Fish and Wildlife Service (2001) and U. S. Army Corps of Engineers (2001, 2003) and supported by a National Research Council review of Missouri River ecosystem recovery (National Research Council 2002). Proposed flow regimes and habitat management along the lower Missouri River should recognize that connectivity of floodplain water bodies, including backwaters and secondary channels, is critical for some fishes during May and June (the annual flood pulse and peak spawning period for most taxa), and may also benefit these and other species during late July through September.

Management Recommendations

Acquired or constructed floodplain wetlands along the lower Missouri River should include waterbodies that remain connected to and exchange freely with the river under current or proposed river discharges during summer. In general, establishing or maintaining connectivity of floodplain water bodies will enable simultaneous provision of nursery habitats for floodplain dependent riverine fishes (Bayley 1991, Ward and Stanford 1995, Buijse et al. 2002, Tockner and Stanford 2002) as well provide forage for nesting terns (Tibbs and Galat 1998) and fledgling herons (Ehrhardt 1996) and shallow water habitat for migrating shorebirds (McColpin 2002).

Accessibility of scours located closer to the river may be enhanced by providing greater opportunity for adult riverine fishes to locate and enter scours for spawning or via higher proba-

bility of fish eggs or larvae drifting into scour basins without becoming stranded between the river and the basin. The two periodic scours located within 10 m of the river (P257 and P397) exchanged water with the river through notched revetments when connected, whereas the other periodic scours (P303 and P421) connected to the river across ~200 m of land (Kubisiak 1997). Whether greater access to P257 and P397 for riverine fishes was due solely to their shorter distance from the river compared to P303 and P421 or whether connection type may also have influenced access to periodic sites is unknown. Findings indicate that acquired or constructed floodplain water bodies immediately adjacent to the river will be most beneficial as nursery areas for riverine fishes.

Differences in mean exchange among periodic and continuous scours were driven primarily by site-to-site variation in exchange when floods were not occurring. Mean exchange index values during floods were ~6 for all sites except P421. Site P421 was shielded by a levee on its northern, eastern, and southern sides that prohibited overland flow through the scour basin (Kubisiak 1997). Thus, associations between larval fishes and mean exchange primarily reflected greater access to sites that exhibited higher exchange index values when floods were not occurring. Mean exchange incorporates not only the spatial extent of connection between the river and floodplain waterbody, but also the duration of connection. Thus, significant relationships between larval fish attributes and mean exchange may have been partly a consequence of the importance of duration to larval fishes and the dependency of exchange on duration of connection. Constructing connections to floodplain waterbodies that remain connected at low river discharges (stages) will increase duration of connection and exchange of fishes between the river and floodplain.

Recruitment of many riverine fishes depends on availability of shallow, low-velocity habitats where environmental conditions are benign, planktonic food is plentiful, and predation risk is low (Gozlan et al. 1998, Platania and Altenbach 1998, Robinson et al. 1998, Scheimer et al. 1991, 2000, Dettmers et al. 2001). An ecosystem management perspective for the lower Missouri River will seek to provide these habitat conditions in both the floodplain and channel

riverscape and over the range of existing or proposed seasonal flow conditions if recruitment opportunities for fluvial and floodplain dependent fishes are to be realized. Characterizing species-specific reproductive strategies, migratory patterns, and life-stage specific habitat use patterns of native and introduced fishes is essential if we are to benefit or discourage recruitment of targeted species and achieve intended results from flow and habitat management programs.

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