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# Fish Assemblages of Natural and Artificial Habitats within the Channel Border of the Upper Mississippi River

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ABSTRACT.—The influence of specific types of habitat structure on fish assemblage struc-
ture, diversity and abundance in large rivers is largely unknown. This study determined
whether fish assemblages differed among various artificial and natural habitats within the
main channel border (shallow, nearshore areas) of the upper Mississippi River, and assessed
whether different types of artificial structure influenced fish assemblage structure over long
(>0.2 km) sections of shoreline habitat. Daytime electrofishing during August and October
1994 captured 31 different fish taxa from main channel border habitats in Pool 6 of the
upper Mississippi River. Nine species of fish preferred specific types of nearshore habitat.
Fish abundance and diversity measures differed little among habitat types, but significantly
larger fish were present at locations with structure (wing dikes, woody snags) than at sites
without (bare shore). Cluster analysis indicated that different fish assemblages occupied dif-
ferent habitat types. Riprapped shorelines had fish assemblages different from those in river
sections containing only instream artificial rocky structures. Aggregations of various habitat
types, especially artificial rocky structures, are important in determining fish assemblage
structure within large river sections.

## INTRODUCTION

River systems throughout the world have been impacted by a wide variety of human
activities. Large rivers in particular have been subjected to dramatic physical alterations
(Sheehan and Rasmussen, 1993; Gore and Shields, 1995; Johnson *et al.*, 1995; Ligon *et al.*,
1995; Sparks, 1995). These alterations have reduced habitat heterogeneity within the river
channel (Johnson *et al.*, 1995; Gore and Shields, 1995; Ligon *et al.*, 1995), ultimately re-
ducing the diversity and abundance of riverine fish assemblages (Weaver and Garman, 1994;
Ligon *et al.*, 1995; Welcomme, 1995).

The main channel of the upper Mississippi River, extending from St. Paul, Minnesota to
St. Louis, Missouri, has a history of modification that dates back more than 170 yr (Fremling
and Claflin, 1984). During this period, the channel has been modified and regulated to
facilitate commercial navigation and to control flooding (Fremling *et al.*, 1989; Holland-
Bartels, 1992). Over 130 fish species have been recorded from this section of the river
(Fremling *et al.*, 1989). Habitats available to these fishes within the main river channel have
changed dramatically as a result of channel modifications, and now represent a mixture of
natural (submerged woody debris, grassy shorelines, barren sand banks) and artificial, hu-
man-created features (dam tailwaters, submerged and emergent wing dikes, revetted and
riprapped shorelines, bridge pilings) (Fremling *et al.*, 1989; Lehtinen *et al.*, 1997). Many
previous fishery investigations within the upper Mississippi River have focused on fish as-

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sociated with artificial habitats within the river channel, and have reported strong habitat preferences displayed by several species for different types of artifical structure (Holzer, 1980; Pierce, 1980; LGL, 1981; Pitlo, 1981, 1985; Boland and Ackerman, 1982; Corley, 1982; Anderson *et al.,* 1983; Seegert *et al.,* 1984; Southall and Hubert, 1984). However, seldom have fish associations with artificial and natural habitats been examined concurrently to assess habitat preferences.

This study was designed to assess the fish assemblages inhabiting several common types of artificial and natural habitats along the main channel shoreline (hereafter referred to as channel-border habitats) of Pool 6 of the upper Mississippi River. The objectives for this study were to estimate total fish abundance, compare fish species richness and diversity, determine possible differences in fish assemblage structure, and assess fish preferences among several of these types of habitat. In addition, we examined several long (0.3–6.4 km) stretches of shoreline with varying habitats to determine assemblage-level responses to habitat on a broader scale. We predicted that natural and artificial habitats would have different fish assemblages, and that these differences would have a strong influence upon the assemblages of fish over the broader habitat scale.

## METHODS

*Study area.*—Pool 6 of the upper Mississippi River (44°02′N, 91°34′W, 196.8 m above sea level) extends 22.9 km upstream from Lock and Dam 6 (River Km 1150.0 upstream from Cairo, Illinois) at Trempealeau, Wisconsin, to Lock and Dam 5A (River Km 1172.9) at Winona, Minnesota. The Mississippi River at Winona has an average discharge of 703 m³/ sec (range = 71 to 7595 m³/sec) and drains an area of approximately 153,500 km² (Fremling *et al.,* 1973). Discharge during the August and October 1994 study periods averaged 959 and 1193 m³/sec, respectively. This study was conducted in the upper pool, which is characterized by braided channels (main channel maintained for barge traffic), forested islands, and a variety of backwater lakes and sloughs. Riparian zones are primarily forested (eastern cottonwood, *Populus deltoides* Marsh; silver maple, *Acer saccharinum* L.; river birch, *Betula nigra* L.; willow, *Salix* spp. and swamp white oak, *Quercus bicolor* Willd.) and contribute large woody debris to the channel. Approximately 10 km of shoreline bordering the main channel of Pool 6 have been covered with large rock riprap to protect banks from erosion (Fremling *et al.,* 1973). Dredging to maintain a minimum 2.75-m channel depth for navigation has occurred along 18 km of channel (Fremling *et al.,* 1973). There also are 104 rock and willow wing dikes and closing dikes within the channel-border areas of Pool 6. Wing dikes extend perpendicularly from the shore to the edge of the shipping channel, whereas closing dikes extend across the upstream openings of side channels. Dikes in Pool 6 were submerged by lock and dam construction in 1936 (most covered by <2 m of water), but still affect channel hydrology.

Eighty-four species of fish have been collected in Pool 6, with 36 species considered abundant or common (Van Vooren, 1983). The fish assemblage supports both commercial and recreational fishing activities (Fremling *et al.,* 1973).

*Field collections.*—During August 1994, fish were collected from channel-border habitats in Pool 6 by electrofishing (Coffelt CPS boomshocker mounted on a 5.5-m, flat-bottom boat). Sampling occurred during daylight hours between River Km 1157.3 and 1171.3. Seven separate collections were made, covering 17.7 km of shoreline (Table 1). Channel-border habitats included 3.4 km of riprap, 33 wing dikes, one closing dike, and three bridge pilings. Habitats were electrofished parallel to the shoreline in an upstream direction, as close to the shoreline as possible. When a woody snag (partially submerged woody debris) was encountered, a single electrofishing pass was made around it. At wing dikes and closing

TABLE 1.—Artificial structures associated with seven long shoreline sites in the channel border of Pool 6, upper Mississippi River, August 1994. Sites designations are based on their dominant artificial habitat (RR = riprap, WD = wing dikes, CD = closing dike, BP = bridge pilings)

| Site | Shoreline length (km) | Riprap length (km) | Wing dikes | Closing dikes | Bridge pilings |
|------|-----------------------|---------------------|------------|---------------|----------------|
| RR 1 | 1.9 | 1.5 | — | — | — |
| RR 2 | 6.4 | 1.6 | 11 | — | — |
| WD 1 | 2.6 | — | 9 | — | — |
| WD 2 | 2.4 | 0.2 | 10 | — | — |
| WD 3 | 2.4 | — | 3 | — | — |
| CD | 0.3 | 0.2 | — | 1 | — |
| BP | 1.6 | — | — | — | 3 |

dikes, a single electrofishing pass was made above the submerged structure along its entire length. The total electrofishing time (when current was being applied to the water) was recorded for each collection. All fish collected (except for a few of uncertain identity retained for laboratory identification) were identified, weighed and returned alive to the river. For analysis, all redhorses (*Moxostoma* spp.) were grouped together because of some questionable field identifications. Redhorse species captured from the study area during other projects have included river redhorse [*M. carinatum* (Cope)], golden redhorse [*M. erythrurum* (Rafinesque)] and shorthead redhorse [*M. macrolepidotum* (Lesueur)].

During October 1994, the fish assemblages occupying individual habitats within the channel border of Pool 6 were assessed. Six wing dikes, six woody snags and seven sandy and/or grassy shoreline sites (hereafter referred to as bare shore) were sampled by electrofishing. Woody snag habitats were sampled by first electrofishing them from the downstream side of the snag. They were then shocked on the upstream end and near the root wad until no additional fish were collected. Woody snags primarily were fallen cottonwood and silver maple trees, 7.4 to 28.1 m long, 19–56 cm trunk diam, and with five to 17 major branches. Wing dikes (approximately 50–100 m long, 5 m wide) were sampled by making three electrofishing passes along the length of the wing dike. Bare shore sites were first sampled by shocking perpendicular to the shoreline for 10–20 m, and then continuing parallel along the shore for 5–15 m. Electrofishing continued at each site until no additional fish were captured. Electrofishing time varied for each site depending on the site size. For example, bare shore sites required approximately one-third the electrofishing time of the wing dikes. Mean current velocity (m/sec) and water depth (m) were measured at each site.

*Data analyses.*—During both August and October, taxa richness, Simpson diversity and catch-per-effort (CPE) estimates (fish/min and kg/min) were determined for each individual collection. CPE estimates, taxa richness and diversity were compared between seasons using the Wilcoxon two-sample rank sum test (Choi, 1978). Total relative abundances of fish collected during summer and autumn were compared with a Spearman rank correlation test (Zar, 1984).

For August collections, fish assemblage composition was compared among individual site pairs with Spearman rank correlation analyses, as well as the Bray-Curtis community similarity index and single linkage cluster analysis (Krebs, 1989).

For October collections, total numbers of fish, total fish biomass, CPE estimates, taxa richness and diversity indices were compared among the three habitat types sampled using Kruskal-Wallis tests (Zar, 1984). Fish assemblage similarities among the individual habitats were determined using the Bray-Curtis community similarity index and single linkage cluster

analysis (Krebs, 1989). Chi-square tests (Zar, 1984) were used to assess individual fish species distribution patterns among wing dike, woody snag, and bare shore habitats. In the absence of habitat preferences, we assumed that fish would exhibit random distributions among the habitats sampled, with expected numbers collected within a habitat type directly proportional to the total electrofishing time for that habitat type. Mean depths and current velocities were compared among habitat types using analysis of variance and least significant difference tests (Choi, 1978).

RESULTS

*August collections.*—During August, 1743 fish representing 12 families and 30 species were collected (Table 2). Emerald shiners (*Notropis atherinoides* Rafinesque) dominated collections, representing 68% of the total catch by number (Table 3). Redhorses and common carp (*Cyprinus carpio* Linnaeus) together comprised 80% of the 303 kg of fish collected (Table 3).

Despite large differences in the lengths of the various shoreline sites sampled, total electrofishing times did not differ greatly among the seven sites (mean ± SD = 33.03 ± 4.88 min). However, abundance CPE (Table 4) and biomass CPE (mean ± SD = 1.29 ± 0.79 kg/min) varied eight-fold and four-fold among sites, respectively. Numbers of taxa collected per site ranged from 3 to 18 (mean ± SD = 14.0 ± 5.2), and average fish wet weight per site ranged from 0.05 to 0.57 kg (mean ± SD = 0.26 ± 0.22 kg).

Most sites generally had similar fish assemblages (Tables 4 and 5). Emerald shiner, redhorses and gizzard shad [*Dorosoma cepedianum* (Lesueur)] were the three most abundant taxa at four (sites RR 1, WD 2, WD 3, BP) of the seven sites, and the remaining sites each had two of these three taxa as dominant forms. Fifteen of the 21 site-to-site comparisons showed significant similarity in the relative abundances of fish species between sites (Table 5). Bray-Curtis coefficients also indicated that several of the long shoreline sites had similar fish assemblages (coefficients > 0.6), but some sites had differing assemblages (Fig. 1). The cluster analysis dendrogram revealed three site groupings. Group 1 sites (WD 1–3, BP) contained either wing dikes (dikefield areas) or bridge pilings, relatively little riprap and fish assemblages dominated by emerald shiners, redhorses and gizzard shad. In addition, they also had high numbers of white bass [*Morone chrysops* (Rafinesque)], smallmouth bass (*Micropterus dolomieu* Lacepede), logperch [*Percina caprodes* (Rafinesque)] and freshwater drum (*Aplodinotus grunniens* Rafinesque). Group 2 sites (RR 1–2) contained relatively long sections of riprapped shoreline, and had fewer emerald shiners and redhorses but more common carp and bigmouth buffalo [*Ictiobus cyprinellus* (Valenciennes)] than Group 1 sites. These sites also had high numbers of white bass, smallmouth bass and sauger [*Stizostedion canadense* (Smith)]. Group 3 (site CD) contained a unique combination of a closing dike and riprap, and was the only site where redhorses outnumbered emerald shiners.

No difference was found in taxa richness between Group 1 and Group 2 sites (t = 0.13, P = 0.91). However, Simpson diversity was significantly higher (t = 6.08, P = 0.004) at riprap-dominated sites than at dikefield locations.

*October collections.*—Water depths (ANOVA F = 8.14, P = 0.004) and current velocities (ANOVA F = 9.46, P = 0.002) were significantly different among the three habitat types sampled (Table 6). Wing dikes had the highest mean values for both depth and current velocity, snags had intermediate values for both categories, and bare shore sites had the lowest values.

During the study of individual main channel border habitats, 18 different species of fish were collected, eight of which were limited to only one of the three habitat types (Table 6). However, five of these taxa were represented by only a single individual. Relative abun-

TABLE 2.—Identity and numbers of fish collected during August and October sampling of channel border habitats in Pool 6, upper Mississippi River

| Family/species | Common name | Numbers | |
| --- | --- | --- | --- |
| | | Aug | Oct |
| Petromyzontidae | | | |
| *Ichthyomyzon unicuspis* | | | |
| Hubbs & Trautman | silver lamprey | 1 | 1 |
| Lepisosteidae | | | |
| *Lepisosteus osseus* (Linnaeus) | longnose gar | 1 | |
| *Lepisosteus platostomus* Rafinesque | shortnose gar | 1 | |
| Clupeidae | | | |
| *Dorosoma cepedianum* (Lesueur) | gizzard shad | 127 | 18 |
| Hiodontidae | | | |
| *Hiodon tergisus* Lesueur | mooneye | 7 | 1 |
| Esocidae | | | |
| *Esox lucius* Linnaeus | northern pike | 1 | |
| Cyprinidae | | | |
| *Cyprinella spiloptera* (Cope) | spotfin shiner | 25 | |
| *Cyprinus carpio* Linnaeus | common carp | 34 | 20 |
| *Notropis atherinoides* Rafinesque | emerald shiner | 1195 | 54 |
| Catostomidae | | | |
| *Catostomus commersoni* (Lacepede) | white sucker | 2 | |
| *Carpiodes cyprinus* (Lesueur) | quillback | 8 | 9 |
| *Cycleptus elongatus* (Lesueur) | blue sucker | 2 | |
| *Ictiobus bubalus* (Rafinesque) | smallmouth buffalo | 4 | 4 |
| *Ictiobus cyprinellus* (Valenciennes) | bigmouth buffalo | 8 | 7 |
| *Moxostoma* spp. | redhorses | 158 | 53 |
| Ictaluridae | | | |
| *Ictalurus punctatus* (Rafinesque) | channel catfish | 3 | 10 |
| *Pylodictis olivaris* (Rafinesque) | flathead catfish | 2 | |
| Moronidae | | | |
| *Morone chrysops* (Rafinesque) | white bass | 35 | 11 |
| Centrarchidae | | | |
| *Ambloplites rupestris* (Rafinesque) | rock bass | 5 | 8 |
| *Lepomis macrochirus* Rafinesque | bluegill | 5 | |
| *Micropterus dolomieu* Lacepede | smallmouth bass | 39 | 6 |
| *Pomoxis nigromaculatus* (Lesueur) | black crappie | 4 | |
| Percidae | | | |
| *Ammocrypta asprella* (Jordan) | crystal darter | 2 | |
| *Etheostoma asprigene* (Forbes) | mud darter | | 1 |
| *Etheostoma nigrum* Rafinesque | johnny darter | 1 | |
| *Percina caprodes* (Rafinesque) | logperch | 27 | 1 |
| *Percina phoxocephala* (Nelson) | slenderhead darter | 3 | |
| *Percina shumardi* (Girard) | river darter | 3 | |
| *Stizostedion vitreum* (Mitchill) | walleye | 16 | 1 |
| *Stizostedion canadense* (Smith) | sauger | 4 | 4 |
| Sciaenidae | | | |
| *Aplodinotus grunniens* Rafinesque | freshwater drum | 20 | 6 |
| Totals | | 1743 | 215 |

TABLE 3.—Dominant fish species (percent of total number and total biomass) in August 1994 collections from channel border habitats of Pool 6, upper Mississippi River

|  | Percent of total number |  | Percent of total biomass |
| --- | --- | --- | --- |
| Emerald shiner | 68.6 | Redhorses | 49.1 |
| Redhorses | 9.1 | Common carp | 31.2 |
| Gizzard shad | 7.3 | Bigmouth buffalo | 4.5 |
| Smallmouth bass | 2.2 | Smallmouth bass | 4.2 |
| White bass | 2.0 | Smallmouth buffalo | 1.8 |
| Common carp | 2.0 | Freshwater drum | 1.5 |
| Logperch | 1.6 | Quillback | 1.5 |
| Spotfin shiner | 1.4 | Channel catfish | 1.3 |
| Freshwater drum | 1.2 | Blue sucker | 1.2 |
|  |  | White sucker | 1.0 |

dances of fish species in these collections were very similar (Spearman rank correlation r = 0.713, P < 0.001) to those from August collections.

The three individual habitat types did not differ in abundance CPE (Kruskal-Wallis K = 3.47, P = 0.18), but bare shore sites had significantly lower fish biomass CPE (Kruskal-Wallis K = 10.13, P < 0.01) than those for wing dikes and woody snags (Fig. 2). Compared to October values, CPE in August sampling of long shoreline sites was significantly higher for fish numbers (Wilcoxon signed rank R = 145, P < 0.01) but not for fish biomass (Wilcoxon signed rank R = 111, P > 0.1) (Fig. 2).

Among habitat types, bare shore sites had significantly (Kruskal-Wallis K = 9.81, P < 0.01) smaller fish (mean ± SD = 0.02 ± 0.01 kg) than those found at snags (0.99 ± 0.95 kg) and wing dikes (1.30 ± 0.25 kg). No significant difference (Wilcoxon signed rank R = 88, P > 0.10) in fish size was detected between sampling seasons (August = 0.26 ± 0.22 kg; October = 0.73 ± 0.77 kg).

TABLE 4.—Catch per effort (CPE, fish/min) values for the 10 most abundant fishes collected at long shoreline sites in Pool 6, upper Mississippi River in August 1994. CPE values for each species from all sites combined, total site CPE and Simpson diversity estimates for the entire fish collection from each site also are shown. Site designations as in Table 1

|  | Sites | | | | | | | All sites |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | RR 1 | RR 2 | WD 1 | WD 2 | WD 3 | CD | BP |  |
| Emerald shiner | 2.4 | 1.8 | 7.0 | 7.5 | 9.3 | 0.6 | 7.3 | 5.2 |
| Redhorses | 0.4 | 0.3 | 0.4 | 0.7 | 0.6 | 0.8 | 1.7 | 0.7 |
| Gizzard shad | 0.8 | 0.5 | 0.2 | 1.1 | 1.0 | 0.0 | 0.4 | 0.6 |
| Smallmouth bass | 0.2 | 0.1 | 0.2 | 0.3 | 0.2 | 0.0 | 0.3 | 0.2 |
| White bass | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 | 0.0 | 0.1 | 0.2 |
| Common carp | 0.2 | 0.6 | 0.0 | 0.0 | <0.1 | 0.0 | 0.1 | 0.2 |
| Logperch | <0.1 | <0.1 | 0.2 | 0.1 | 0.3 | 0.0 | 0.1 | 0.1 |
| Spotfin shiner | 0.0 | 0.3 | 0.2 | 0.0 | <0.1 | 0.0 | 0.1 | 0.1 |
| Freshwater drum | 0.1 | <0.1 | 0.1 | 0.0 | 0.4 | 0.0 | 0.1 | 0.1 |
| Sauger | 0.1 | 0.1 | <0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| Total site CPE | 4.8 | 4.4 | 8.6 | 10.5 | 12.3 | 1.4 | 10.3 | 7.5 |
| Simpson diversity | 0.71 | 0.79 | 0.34 | 0.47 | 0.42 | 0.53 | 0.47 |  |

TABLE 5.—Spearman rank correlation matrix for paired comparisons of fish assemblages (based on species abundance) at seven long shoreline sites in Pool 6, upper Mississippi River in August 1994. ***P < 0.001, **P < 0.01, *P < 0.05, NS P > 0.05. Site designations as in Table 1

| | Sites | | | | | |
|---|---|---|---|---|---|---|
| Sites | RR 2 | WD 1 | WD 2 | WD 3 | CD | BP |
| RR 1 | 0.62*** | 0.58*** | 0.52** | 0.76*** | 0.30 NS | 0.62*** |
| RR 2 | — | 0.50** | 0.22 NS | 0.63*** | 0.23 NS | 0.60*** |
| WD 1 | | — | 0.44* | 0.68*** | 0.44* | 0.67*** |
| WD 2 | | | — | 0.53** | 0.26 NS | 0.44* |
| WD 3 | | | | — | 0.30 NS | 0.69*** |
| CD | | | | | — | 0.29 NS |

Taxa richness and diversity exhibited similar patterns among habitat types, with wing dikes having the highest taxa richness and diversity and woody snags the lowest (Fig. 3). However, only taxa richness values were significantly different (Kruskal-Wallis K = 6.04, P < 0.05) among habitats. As expected, mean taxa richness of the large August samples was significantly higher (Wilcoxon R = 150.5, P < 0.01) than that of the much smaller site samples in October. However, Simpson diversity did not differ (Wilcoxon R = 61, P > 0.10) between August and October samples.

Single linkage cluster analysis based on Bray-Curtis community similarity coefficients indicated that fish assemblages at the 19 individual habitats fell into four groups (Fig. 4). Group 1 was comprised of all six wing dike sites. Fish assemblages at wing dikes were dominated by redhorses and channel catfish [*Ictalurus punctatus* (Rafinesque)]. Group 2



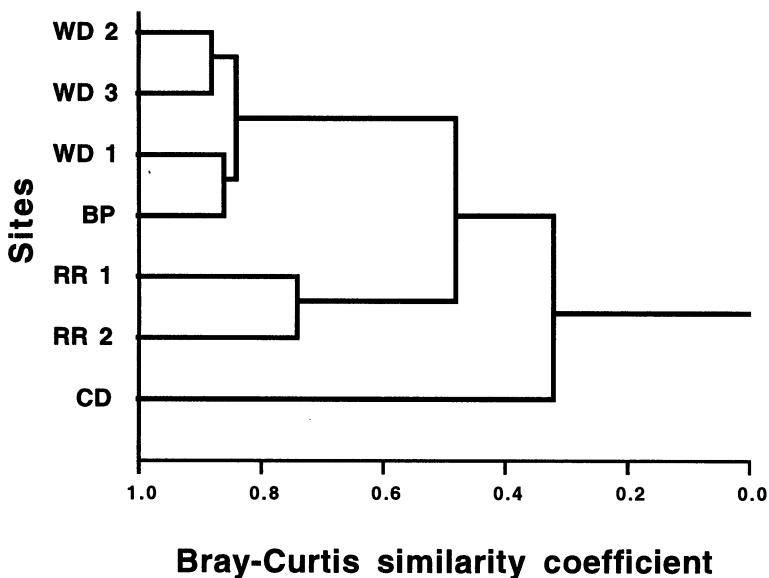**Bray-Curtis similarity coefficient**

FIG. 1.—Single-linkage cluster analysis of fish assemblages collected at long shoreline sites in the channel border of Pool 6, upper Mississippi River during August 1994. Site designations as in Table 1

TABLE 6.—Total numbers of each fish species collected at each habitat type in Pool 6, upper Mississippi River during October 1994, and results of chi-square distribution tests. Asterisks designate preferred habitat. NT = not tested. Mean (±SD) depths and current velocities for each habitat type also are shown. Values within each row followed by a common letter are not significantly different from one another (ANOVA and least significant difference test)

| | Wing dikes | Woody snags | Bare shore | Chi-square P-value |
|---|---|---|---|---|
| Silver lamprey | — | 1 | — | NT |
| Mooneye | 1 | — | — | NT |
| Gizzard shad | 4 | — | 13* | <0.001 |
| Common carp | 2 | 18* | — | <0.001 |
| Emerald shiner | — | 41* | 13 | <0.001 |
| Quillback | 1 | 1 | 7* | <0.001 |
| Redhorses | 51* | 1 | 1 | <0.001 |
| Smallmouth buffalo | 1 | 3 | — | >0.1 |
| Bigmouth buffalo | 1 | 6* | — | <0.005 |
| Channel catfish | 10* | — | — | <0.025 |
| Smallmouth bass | 3 | 2 | 1 | >0.95 |
| Rock bass | — | 8* | — | <0.001 |
| White bass | 2 | 3 | 6* | <0.01 |
| Walleye | 1 | — | — | NT |
| Sauger | 1 | 2 | 1 | >0.25 |
| Logperch | — | — | 1 | NT |
| Mud darter | — | — | 1 | NT |
| Freshwater drum | — | — | 6* | <0.001 |
| Habitat measurements | | | | |
| Depth (m) | 1.62 A | 1.56 AB | 0.55 B | |
| | (0.27) | (0.90) | (0.22) | |
| Current velocity | 0.33 A | 0.11 B | 0.06 B | |
| (m/sec) | (0.13) | (0.16) | (0.04) | |

consisted of six of the seven bare shore sites and a single woody snag site. Fish assemblages at these sites generally were comprised of gizzard shad, emerald shiners, white bass and quillback [*Carpiodes cyprinus* (Lesueur)]. Group 3 contained four snag sites and one bare shore site. These sites usually contained common carp, rock bass [*Ambloplites rupestris* (Rafinesque)], and bigmouth buffalo. Group 4 consisted of a single snag site dominated by emerald shiners.

Thirteen of the 18 fish taxa were collected in sufficient numbers to statistically assess distribution patterns among the three habitat types. Of these, 10 exhibited distribution patterns significantly different from random (Table 6), suggesting preferences for certain types of habitat. Wing dikes were the preferred habitat of redhorses and channel catfish, woody snags were selected by bigmouth buffalo, common carp, emerald shiner and rock bass, and bare shore sites were chosen by gizzard shad, freshwater drum, white bass and quillback.

## DISCUSSION

The mixture of natural and artificial habitats within the channel border of Pool 6 has a significant effect on the fish assemblages within this river reach. Not only do certain species exhibit strong preferences for highly localized types of habitat, but fish assemblages within
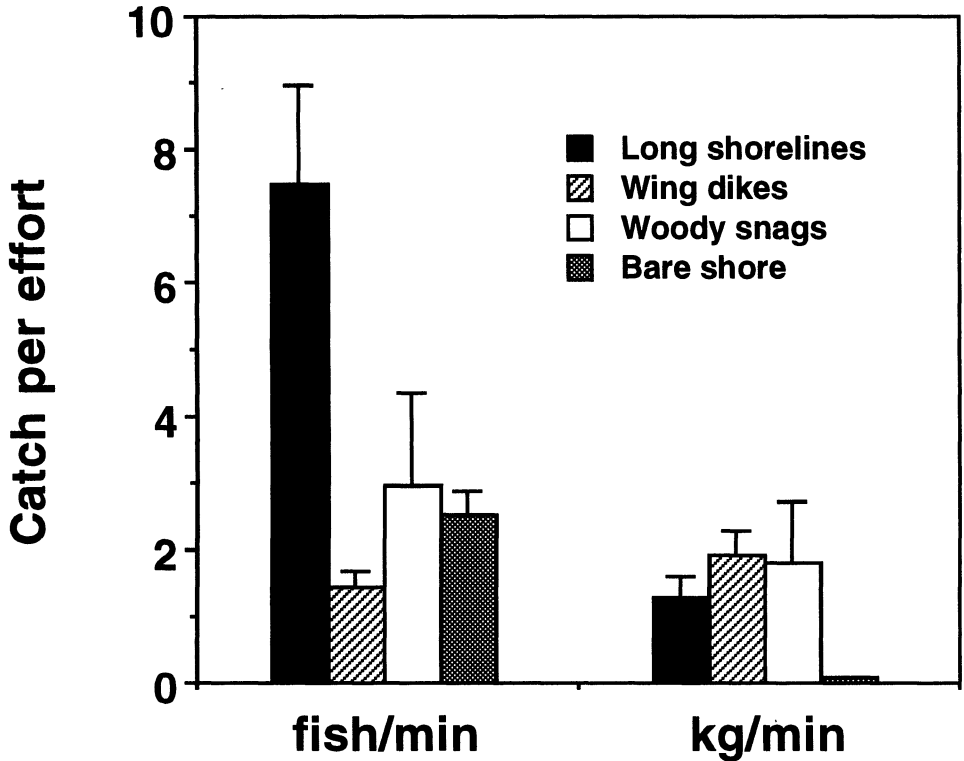
FIG. 2.—Catch per effort (fish/min and kg/min; mean ± SE) during electrofishing at channel border habitats in Pool 6, upper Mississippi River during August (long shorelines) and October (wing dikes, woody snags, bare shore) 1994

long stretches of channel border habitat are controlled to a large degree by the dominant types of artificial habitat present.

*Habitat preferences.*—Ten fish taxa exhibited nonrandom distributions among the three habitat types examined. Of these, only the redhorses and channel catfish were significantly more common at the artificial wing dike habitats. Both golden and shorthead redhorses are reported to prefer these structures in the Mississippi River (Holzer, 1980; Anderson *et al.*, 1983). Channel catfish are more common inhabitants of the main channel proper (LGL, 1981), but they have a relatively broad niche (Layher and Maughan, 1985) and often occur near cover (Pflieger, 1975). Wing dikes were the only structure sampled in close proximity to the main channel, so it is not surprising that channel catfish were collected only from them.

In addition to being habitat for redhorses and channel catfish, wing dikes are important habitats for a wide variety of other fishes (Pierce, 1980; Pitlo, 1981, 1985). Many of these fishes (*e.g.*, walleye, sauger, flathead catfish) may select wing dike habitats because of their rocky substrate, higher current velocities and shallow depths relative to channel areas nearby (Pitlo, 1981; Anderson *et al.*, 1983). Other species such as the paddlefish [*Polyodon spathula* (Walbaum)] may frequent areas near wing dikes because of scour holes or eddies created by these structures (Southall and Hubert, 1984).
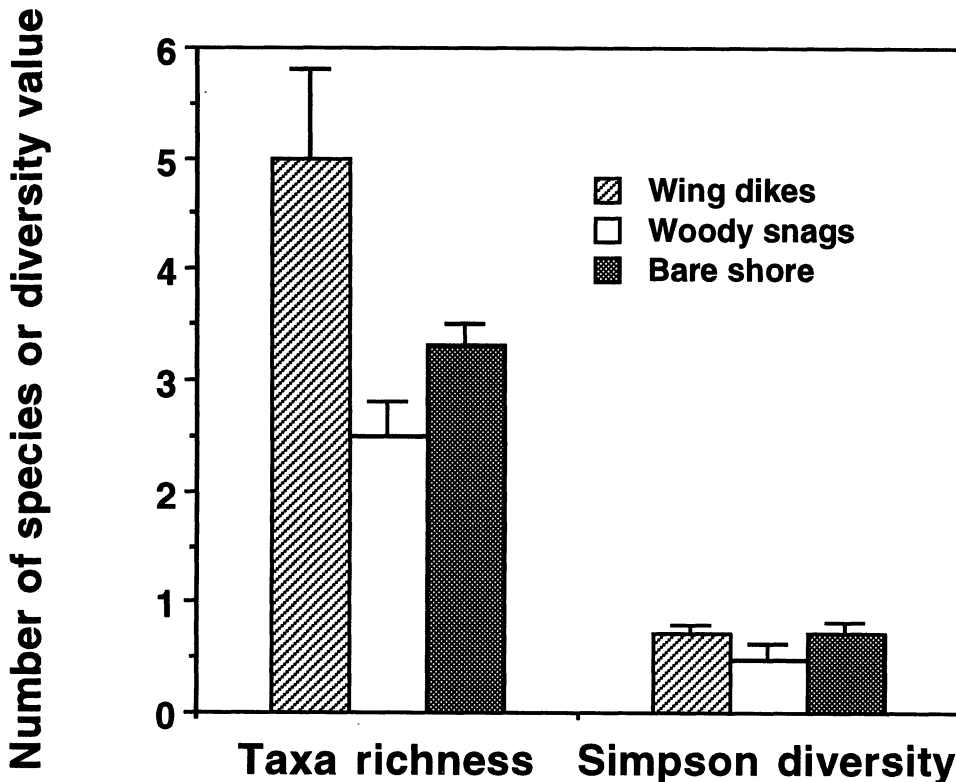
FIG. 3.—Mean (±SE) taxa richness and Simpson diversities of fish assemblages at three habitat types in the channel border of Pool 6, upper Mississippi River during October 1994

Bigmouth buffalo, common carp, emerald shiner and rock bass preferred woody snag habitats over wing dikes or bare shorelines. Lehtinen *et al.* (1997) proposed a variety of reasons to explain the preference of these species for snags in the upper Mississippi River, including presence of food resources and refuge from current and predators. Previous studies of habitat preferences in the Mississippi River indicate that rock bass (and smallmouth bass) prefer rocky habitats such as riprapped shoreline, but generally not wing dikes (Holzer, 1980; Anderson *et al.*, 1983; Seegert *et al.*, 1984). However, none of these investigations examined fish use of woody snag habitats. Since rock bass in smaller systems readily use both rock and woody structures (*e.g.*, George and Hadley, 1979; McClendon and Rabeni, 1987; Putman *et al.*, 1995), it is highly probable that both types of habitat are important to this species in the upper Mississippi River.

Gizzard shad, quillback, white bass and freshwater drum preferred bare shore sites over other habitat types. Previous investigations have reported that these species and mooneye prefer sand or silt substrates (Holzer, 1980; Anderson *et al.*, 1983; Seegert *et al.*, 1984). In the present study, bare shore sites generally were shallow, sand-bottomed, and had reduced current velocities relative to other shoreline habitats sampled. Most of the individuals collected from this habitat were small, suggesting that they may be using this habitat to avoid
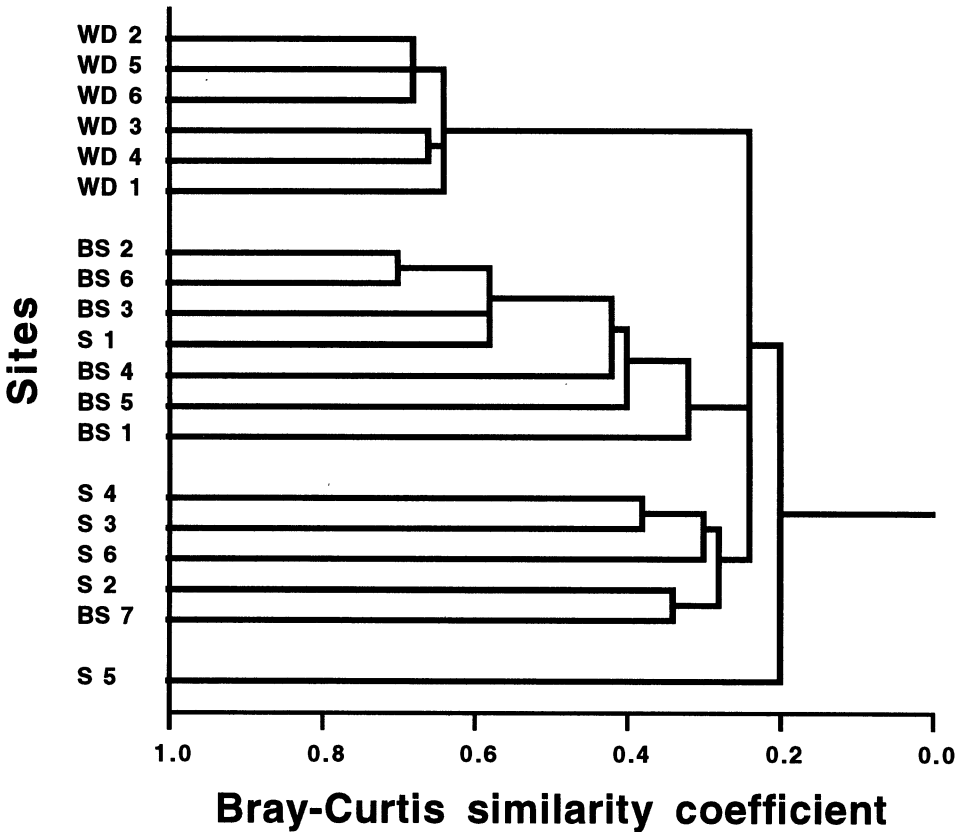
**Bray-Curtis similarity coefficient**

FIG. 4.—Single linkage cluster analysis of fish assemblages collected at wing dikes (WD 1 through 6), bare shore sites (BS 1 through 7), and woody snags (S 1 through 6) in the channel border of Pool 6, upper Mississippi River during October 1994

potential piscine predators, even though they may be more vulnerable within this habitat to avian and mammalian predators.

In lotic systems, river channel border areas with structure often hold more fish than areas devoid of structure (*e.g.*, Pierce, 1980; Pennington *et al.*, 1983; Angermeier and Karr, 1984; Benke *et al.*, 1985). In the present study, different spatial scales provided contrasting results. When individual habitats were examined, abundance CPE values were no different for sites with more structure (wing dikes, woody snags) than for sites with bare shore. These results agree with those of Anderson *et al.* (1983) and Seegert *et al.* (1984), who found no difference in abundance CPE among rock (riprap, wing dike) and sand substrate sites in Pool 5A of the upper Mississippi River. However, larger shoreline areas containing structure (multiple wing dikes, bridge pilings, riprap) often have fish abundance CPE values significantly higher than areas without these types of artificial habitats (Pennington *et al.*, 1983; present study). In contrast, fish biomass CPE at individual wing dikes, woody snags and riprapped shorelines can be up to 30 times greater than that at bare shore sites (Anderson *et al.*, 1983; Pennington *et al.*, 1983; Seegert *et al.*, 1984; present study). Since channel border sites with more structure support similar numbers but greater biomass of fish than

do sand areas, the size of fish collected at structured sites tends to be greater (Seegert *et al.*, 1984; present study).

*Habitat-fish assemblage relations.*—Since many fishes exhibit specific preferences for certain types of habitat, stream or river locations with diverse habitats may be expected to contain more fish species than locations with fewer habitat types (Gorman and Karr, 1978; Schlosser, 1982; Angermeier and Karr, 1984; Reeves *et al.*, 1993). In the present study, taxa richness and fish assemblage diversity showed only slight variation among individual habitat types. The significantly higher species richness at wing dikes was a result of longer sampling times at wing dikes relative to other habitats. When taxa richness at individual habitats was expressed on a taxa per minute basis, differences among habitat types were no longer apparent. Despite differing greatly in the amount of structure, individual habitats had equally diverse fish assemblages.

Long shoreline sites dominated by riprap contained a more diverse fish assemblage (but a similar number of species) than did shoreline sites within dikefields. These results are only in partial agreement with previous reports (Anderson *et al.*, 1983; Pennington *et al.*, 1983) of habitat-specific taxa richness and diversity in widely separated sections of the Mississippi River, where species richness and diversity declined from dikefields to rirapped shorelines to bare, sandy or revetted shorelines. In the present study, much of the difference in fish assemblage diversity between dikefield and riprap-dominated shorelines was attributable to varying dominance by emerald shiners; shiners comprised only 41–50% of the fish collected along riprap-dominated shorelines, but 71–82% of fish along dikefield shorelines.

Even though individual habitat types had equally diverse fish assemblages, very few other similarities existed among these assemblages. More than 40% of the species collected were restricted to only one of the three habitat types. Fish assemblages occupying individual habitats appear to be influenced to a large degree by habitat specialists. The separation of lotic fish assemblages into several habitat-specific guilds is a common feature in a wide variety of streams and rivers (*e.g.*, Moyle and Senanayake, 1984; Grossman and Freeman, 1987; Grossman *et al.*, 1987; Lobb and Orth, 1991; but *see* Bart, 1989, for an opposing view). The results of the present study suggest that in large rivers such as the Mississippi, fish assemblages also may segregate into habitat guilds, and both natural and artificial habitats may be very important to the overall fish assemblage of the upper Mississippi River.

Across longer shoreline sites containing a variety of habitat types, the dominant artificial structures present were very important in determining the structure of the channel border fish assemblage. In particular, series of wing dikes and bridge pilings produced fish assemblages with a very high degree of similarity (Bray-Curtis similarity coefficient > 0.8), as did sites dominated by riprap (Bray-Curtis similarity coefficient > 0.7). However, fish assemblage similarity between dikefields and riprap-dominated sites was comparatively low (Bray-Curtis similarity coefficient < 0.5), even though both types of sites had similar mixes of natural habitats. Apparently, the difference in the fish assemblages of wing dikes and riprap was so great as to override the similar fish assemblages inhabiting the other, natural habitats present at both types of sites.

*Changing channel border habitats and fish assemblages.*—While main channel border habitats of the upper Mississippi River have undergone dramatic changes during the past 2 centuries (Fremling and Claflin, 1984; Fremling *et al.*, 1989), several previously common species of fish have been reduced in number or extirpated and other rare or nonnative forms have increased in abundance (Van Vooren, 1983). Although some of the changes in Mississippi River fish assemblages may have been the result of reduced water quality, many others probably can be attributed to habitat alterations caused by channel modifications

(Fremling *et al.*, 1989; Holland-Bartels, 1992). The results of the present study indicate that many of the artificial structures within the river channel, some now in place for over a century, continue to have an important influence on fish assemblage structure within channel border areas.

Dredging activities extending back over 150 yr, and lock and dam construction during the 1930s, have had a dramatic effect on the availability of fast-water, rock-bottomed habitats within the upper Mississippi River (Fremling *et al.*, 1989; Holland-Bartels, 1992). Many fish species [*e.g.*, blue sucker, black, river, and greater redhorses, blue catfish *Ictalurus furcatus* (Lesueur), crystal darter] that likely inhabited these areas before their alteration have declined dramatically and now have various levels of protected status in many portions of the upper river (Johnson, 1987). Many other species (*e.g.*, several redhorses, smallmouth bass, walleye, sauger, rock bass, bluegill, young flathead catfish) apparently were more adaptable, able to successfully use artificial rocky structures as substitutes for their preferred gravel- or rock-bottomed habitat in unaltered rivers (Pflieger, 1975; Trautman, 1981; Page and Burr, 1991). The continued existence of the paddlefish within the upper Mississippi also may be attributed, in part, to its willingness to associate with artificial rocky structure within the main channel border (Southall and Hubert, 1984).

It is not known whether natural rocky habitats in the pre-altered Mississippi River had a major structuring influence on fish assemblages over relatively large sections of channel border habitat, as is indicated for artificial habitats in the river today. However, as methods to restore large rivers to their former form and function are investigated (Gore and Shields, 1995; Theiling, 1995), fish habitat associations must be considered to ensure that future channel modifications produce habitats suitable for the many different fish assemblages found within the channel border areas.

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