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# Habitat, Land Use, and Fish Assemblage Relationships in Iowa Streams: Preliminary Assessment in an Agricultural Landscape

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*Abstract*.—Iowa leads the nation in percentage of land area converted to cropland, with a resulting negative impact on streams. We examined physical habitat, land use, and fish assemblage data from 37 second- to sixth-order stream sites, representing 7 of the 10 ecoregions within Iowa. Physical habitat conditions varied widely among sites, with sand dominating substrate composition. A nonmetric multidimensional scaling ordination of physical habitat variables suggested a pattern of among-site similarities defined by a stream size axis, an axis contrasting sites dominated by either woody or rocky fish cover, and an axis characterizing degree of riparian canopy coverage. Bluntnose minnow *Pimephales notatus* and sand shiner *Notropis stramineus* were the most abundant fish species, followed by green sunfish *Lepomis cyanellus* and common carp *Cyprinus carpio*. These four species were collected in more than 80% of the sites. Fish species richness at sites averaged 22, ranging from 6 to 38, and fish index of biotic integrity (IBI) at sites averaged 47 (fair), ranging from 21 (poor) to 96 (excellent). Species richness and IBI were highest at sites characterized by rocky fish cover and relatively coarse substrates. Values for several physical habitat and land use variables were significantly different between sites with IBI $\leq$ 30 (fair) and sites with IBI $\geq$ 50 (good). We found a general pattern of IBI, species richness, total fish abundance, and width-to-depth ratio decreasing from the northeast to the southwest ecoregions, and percentage of unvegetated banks and bank slope increasing from northeast to southwest. Stable and vegetated banks, wide stream channels with coarse substrates, and rocky fish cover were associated with high biotic condition; while unvegetated and eroding banks, and deep channels with predominantly fine substrates were associated with lower biotic condition. Land use was calculated at three spatial scales: catchment, network riparian buffer, and local riparian buffer. We found few relationships of fish assemblages with land use, potentially due to sampling design and the pervasiveness of agriculture across Iowa. There is substantial variation among physical habitat, land use, and fish assemblage conditions across Iowa, due to a combination of geology, climate, zoogeography, and human alteration.

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## INTRODUCTION

Iowa streams have been drastically altered, primarily due to land use changes associated with agriculture (Bulkley 1975; Menzel 1981, 1983). Iowa leads the nation, with 72% of land area converted to cropland (Natural Resources Conservation Service 2000). Combined with pastureland (10%) and developed land (5%), 87% of Iowa's land area is altered by either agriculture or urban development. Comparable figures for surrounding states are slightly lower for Illinois (84%) and much lower for Missouri (63%), Wisconsin (57%), Minnesota (53%), Nebraska (46%), and South Dakota (41%) (Natural Resources Conservation Service 2000). Agricultural impacts to streams are known to include modification of: habitat structure, water quality, flow regimes, energy patterns, and biotic community structure (Menzel 1983; Karr et al. 1985; Wang et al. 1997). Fish can be affected through reductions in feeding efficiency, growth, reproduction, and recruitment (Waters 1995; Stevenson and Mills 1999).

Sedimentation is one way agriculture has negatively affected Iowa streams (Waters 1995). Sedimentation is a direct consequence of pervasive agricultural land use in Iowa. Approximately 12,000 kg/ha/year of soil is eroded from one-third of Iowa's land, (Natural Resources Conservation Service 2000) and much of this eroded material enters streams (Menzel 1983; Waters 1995). Sedimentation often results in naturally diverse habitats being replaced with wider, shallower channels, decreased substrate size, decreased water velocity, and steep eroding streambanks, negatively effecting fish assemblages (Schumm 1977; Rosgen 1994; Waters 1995).

Efforts to drain land for agriculture have also altered Iowa streams (Menzel 1983). Within the last 150 years, tiling and ditching were used to drain 95% of Iowa's wetlands (Whitney 1994), resulting in the creation of artificial stream channels (Anderson 2000). In contrast, more than 4,800 km of streams have been lost due to channelization (Bulkley 1975), which results in decreased habitat area and diversity (Waters 1995). Studies have linked channelization with increased gradient, current velocity, bank erosion, and sediment bedload (Bulkley 1975; Rosgen 1994), as well as decreased depth variation, velocity variation, and numbers and biomass of drifting invertebrates (Zimmer and Bachman 1976). Studies of fish assemblages in Iowa streams have linked habitat degradation and channelization to reduced abundance and diversity of fish species (Paragamian 1987, 1990a, 1990b; Wilton 2004). Low-head dams, removal of vegetative land cover, and point and nonpoint pollution have also altered Iowa's streams and fish assemblages (Menzel 1981; Paragamian 1987).

Landscape conditions are intimately related to stream conditions across a range of spatial scales from local to regional. At a local scale, well-vegetated banks with diverse plant assemblages provide erosion resistance, shade, allochthonous carbon inputs, woody debris, nutrient removal, reduction of overland flow, and fish refuge during flooding (Simonson et al. 1994a; Mills and Stevenson 1999; Stevenson and Mills 1999). At an intermediate scale forested riparian buffers have been positively related to habitat and fish index of biotic integrity (IBI; Wang et al. 1997; Lammert and Allan 1999). Catchment scale land uses have also been shown to influence habitat and biotic condition (Wang et al. 1997; Meixler 1999; Wang et al. 2003). In Midwestern streams, instream physical habitat quality and IBI scores were positively related to the amount of forest and negatively related to the amount of agriculture within a catchment (Roth et al. 1996; Allan et al. 1997; Wang et al. 1997). At a larger scale, agriculture and other alterations can lead to regional fish and physical habitat characteristics becoming less distinctive (Li and Reynolds 1994).

The question of which spatial scale reveals the strongest relationships among physical habitat, land use, and fish assemblages has attracted considerable interest. Of the studies that directly addressed this question, four reported stronger relationships at local scales (Lammert and Allan 1999; Stauffer et al. 2000; Nerbonne and

Vondracek 2001; Wang et al. 2003) and six reported stronger relationships at catchment-level scales (Steedman 1988; Roth et al. 1996; Wang et al. 1997; Fitzpatrick et al. 2001; Snyder et al. 2003; Van Sickle et al. 2004). The question of how landscapes are related to stream conditions across a range of land uses and geographical settings has profound implications for stream management and restoration.

Although Iowa is often perceived as having a flat, homogeneous landscape, terrestrial features and stream habitat conditions differ among Iowa's ecoregions (Menzel 1987; Paragamian 1990b; Griffith et al. 1994; Wilton 2004). Ecoregions are areas of relatively homogeneous soils, vegetation, climate, geology, physiography, and responses to degradation (Omernik 1987; Griffith et al. 1994). Most of Iowa falls within seven ecoregions: the Central Irregular Plains (CP), Des Moines Lobe (DL), Iowan Surface (IS), Loess Hills and Rolling Prairies (LH) Northwest Iowa Loess Prairies (NW), the Paleozoic Plateau (PP), and Southern Iowa Rolling Loess Prairies (SI). Previous research suggests there is an increase in percent fine substrates and decrease in percent forested riparian land cover and fish IBI scores from northeast Iowa to southern and western Iowa (Menzel 1987; Paragamian 1990b; Griffith et al. 1994; Wilton 2004). The PP region in northeast Iowa is described as having highest IBI scores, most topographical relief, most riparian forests, narrowest stream channels, and highest percentages of coarse substrates. The LH ecoregion in southwest Iowa is described as having lowest average IBI scores, silty substrates, highly eroding banks, turbid water, straightened channels, and numerous low-head dams and streambed stabilization structures. Compared with the PP and LH ecoregions, IBI scores and physical habitat conditions are intermediate in the rest of the state.

Our overall goal was a preliminary assessment of relationships among physical habitat, land use, and fish assemblages in streams throughout Iowa. We addressed this goal with three specific objectives. First, because Iowa's streams are often thought of as homogeneous, we sought to determine how physical habitat conditions varied among sites using a multivariate ordination. Second, we explored differences among ecoregions. We hypothesized that physical habitat, land use, and fish assemblage conditions would vary among ecoregions, along a gradient from northeastern Iowa to the southwest. Third, we determined which physical habitat and land use variables could distinguish sites with good or excellent IBI scores ($\geq$50) from those with poor or fair scores ($\leq$30). We hypothesized that this test would contrast less degraded landscape and physical habitat conditions typical of northeast Iowa with more degraded conditions in the southwest. We also hypothesized that regardless of ecoregion, sites with high amounts of agricultural land uses would be associated with lower IBI scores.

## STUDY SITES

The physical habitat and fish assemblage data we examined for this study were collected by the Iowa Department of Natural Resources between July and September 1995–2001 as part of an ongoing inventory of Iowa's interior streams (Siegwarth 1998; Gelwicks 1999, 2000). Data were available from 37 sites on 32 second- to sixth-order streams, representing 7 of the 10 ecoregions in Iowa (Figure 1). Each site was sampled once. The number of sites within each ecoregion was variable, ranging from 1 in the PP to 12 in the IS. Most sites were at locations sampled during an earlier statewide fish inventory (Paragamian 1990b). Sites ranged from 145 to 2,566 m long, depending on width. Sampling occurred under base flow conditions.

## METHODS

### Data Collection

*Physical habitat.*—Instream and riparian physical habitat features were measured or visually estimated at sites (Table 1). Transect habitat

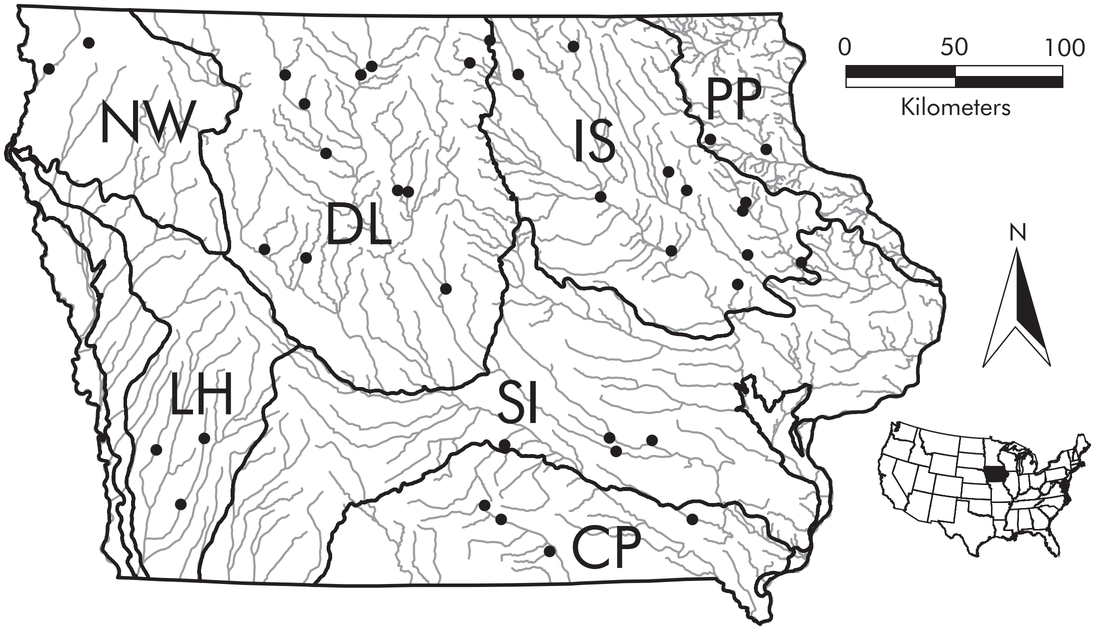


Figure 1. Locations of sampling sites within ecoregions in Iowa. Ecoregions are Central Irregular Plains (CP), Des Moines Lobe (DL), Iowan Surface (IS), Loess Hills and Rolling Prairies (LH), Northwest Iowa Loess Prairies (NW), Paleozoic Plateau (PP), and Southern Iowa Rolling Loess Prairies (SI). The number of sites in each ecoregion is PP (1), IS (12), NW (2), DL (11), SI (4), CP (4), and LH (3).

assessment procedures developed in adjacent states (Bovee 1982; Illinois EPA 1987; Simonson et al. 1994a, 1994b) were modified to accommodate both wadeable and unwadeable conditions, and available personnel and resources in Iowa. Instream physical habitat features were surveyed at transects, including depth, wetted width, current velocity, types and abundance of fish cover, and substrate (Table 1). Riparian features surveyed included bank type (e.g., cut eroding, sloping, undercut), slope, vegetation, canopy, and high water cover (from the water's edge to two vertical meters above the water level). Riparian and instream physical habitats were sampled along transects spaced two average stream widths apart (Simonson et al. 1994a). The number of transects ranged from 15 to 30; most sites had 20. Sites with 20 transects had a minimum of 420 measurements or visual estimates. Details of physical habitat assessment methods are given in Heitke (2002).

*Fish assemblages.*—Fish were collected using a single upstream electrofishing pass through the entire length of sites. A DC tow-barge electrofisher was used for most sites. A DC boat electrofisher was used for unwadeable habitats at six sites and a DC backpack shocker was used at one site too small for the tow-barge. An effort was made to collect all fish observed. Species, and wet weight (nearest 0.1 g) and length of captured fish (nearest millimeter) were recorded in the field. Most fish were returned to the stream alive. In nearly all cases fish sampling occurred the same day as physical habitat sampling.

*Land use.*—A GIS was used to determine land use percentages upstream of each site. Land use was calculated at three spatial scales: catchment, network buffer, and local buffer. Catchment land use included use percentages in entire catchments of sampling sites. Network-buffer land use included use percentages within 60 m riparian buffers of entire drainage networks

Table 1. Station descriptors and physical habitat variables used to characterize Iowa streams.

| Variable | Average | SE | Description |
|---|---|---|---|
| **Station descriptors** | | | |
| Stream order | 3.81 | 0.15 | Strahler ranking of channel size |
| Drainage area | 876.89 | 208.46 | Drainage area ($km^2$) |
| Sinuosity | 1.5 | 0.05 | Ratio of 5,000-m segment of stream (centered on station) to the straight line distance between the start and end of the segment |
| **Stream morphology** | | | |
| Average stream width | 17.3 | 1.63 | Station average of stream width measurements taken at each transect (m) |
| Average stream width CV | 23.08 | 1.16 | Coefficient of variation of stream width measurements |
| Average depth | 0.49 | 0.05 | Average of depth measurements (m) |
| Average depth CV | 52.96 | 2.02 | Coefficient of variation of depth measurements |
| Width to depth ratio | 50.09 | 4.38 | Stream width divided by average depth for each transect, then averaged for station |
| Width to depth ratio CV | 57.03 | 4.66 | Coefficient of variation of width to depth ratios |
| Average velocity | 0.22 | 0.03 | Average of velocity measurements taken 0.4 of depth from the stream bottom (m/s) |
| Average velocity CV | 79.09 | 9.8 | Coefficient of variation of average velocity measurements |
| **Substrate** | | | |
| % clay | 6.09 | 1.98 | Substrate particles < 0.004 mm |
| % silt | 13.72 | 2.34 | Substrate particles 0.004–0.062 mm |
| % sand | 54.22 | 3.97 | Substrate particles 2.0–0.062 mm |
| % gravel | 54.22 | 3.97 | Substrate particles 2.1–64 mm |
| % cobble | 12.3 | 2.01 | Substrate particles 65–256 mm |
| % boulder | 6.03 | 1.65 | Substrate particles > 256 mm |
| % CPOM (coarse particulate organic matter) | 2.75 | 0.58 | Substrate of partially decayed coarse organic matter such as leaves, dead macrophytes, sticks, and so forth. |
| **In-stream fish cover**[c] | | | |
| Cover types[a] | 0.32 | 0.02 | Average number of fish cover types per transect |
| Cover abundance[a] | 2.04 | 0.22 | Average number of fish cover units per transect |
| Rock cover[b] | 1.06 | 0.23 | Average number of rock fish cover units per transect |
| Wood cover[c] | 0.82 | 0.13 | Average number of wood fish cover units per transect |
| **Riparian vegetation, bank condition and high water fish cover**[d] | | | |
| Vegetation types | 2.72 | 0.1 | Average number of vegetation types (trees, shrubs, forbs, grasses, etc.) per bank |
| % banks open | 32.38 | 0.03 | Percent of bank area with no vegetation |
| % banks with trees | 28.08 | 0.04 | Percent of transects with standing trees |
| % cut eroding banks | 20.94 | 0.02 | Percent of bank area classified as "eroding cutbank": near vertical slope, no vegetation and evidence of erosion |
| Bank slope | 37.11 | 1.5 | Average bank slope (°) |
| % banks with canopy | 33.63 | 0.04 | Proportion of banks that shade stream channel when the sun is directly overhead |
| Average canopy | 1.61 | 0.24 | Average canopy per bank (m) |
| High water cover types[d] | 0.42 | 0.03 | Average number of high water fish cover types per transect |
| High water cover abundance[d] | 2.46 | 0.28 | Average number of high water fish cover units per transect |
| High water rock cover[b,c] | 0.26 | 0.06 | Average number of high water rock fish cover units per transect |
| High water wood cover[c,d] | 1.85 | 0.26 | Average number of high water wood fish cover units per transect |

[a] fish cover: Any object, channel feature, or bank feature that provides shelter from the current or visual isolation was considered to be fish cover (Simonson et al. 1994a). Instream cover categories included tree falls, submerged trees, root balls, log piles, debris dams, stumps, boulders, boulder fields, and rip rap fields.

[b] rock cover: Bedrock outcropping, single boulders, and boulder aggregates; concrete, rip-rap were excluded.

[c] wood cover: Logs, tree falls, partially submerged trees, submerged trees, standing trees in stream channel, overhanging trees, root balls, protruding bank roots, brush piles, debris dams, stumps.

[d] high water fish cover: Fish cover that was above the water's surface but would have been submerged or partially submerged if the water level rose 2 m.

upstream of sites. Local buffer included 60 m riparian buffer land use located within a 1-km-diameter radius centered on sampling sites. The amount of land included in local buffer calculations was variable and depended on channel sinuosity; more sinuous stream segments had more buffer area included in radii than straighter segments. Shapefiles of the three land use scales were generated for each site and used to extract land use data. Land use data were clipped from the Iowa Land Cover 2000, Minnesota's 1990 Land Use and Cover, and South Dakota's National Land Cover Data (portions of some catchments extended into Minnesota and South Dakota). Four categories were used to summarize land uses: agriculture, grass (pasture and prairie), forest, and other.

## DATA ANALYSIS

All variables were analyzed untransformed. The *P*-values of Shapiro-Wilk normality tests ranged from less than 0.0001 to 0.9448, while skewness ranged from –1.24 to 4.07. No single transformation applied to all variables yielded consistent improvements in normality and skewness. Since a mixture of transformations would have hindered interpretation, we left all variables untransformed for analysis. We believe that departures from normality were primarily due to small sample sizes rather than nonnormal distributions of physical habitat, land use, and fish conditions we measured. When summarized for 58 physical habitat sites (Heitke 2002) the normality and skewness of physical habitat variables improved. These additional physical habitat sites were not included in this analysis because they were not accompanied by fish samples.

*Physical habitat.*—Thirty-three variables were used to characterize physical habitat features of sites (Table 1). Instream physical habitat was characterized using stream morphology, substrate, and fish cover variables. Riparian physical habitat was characterized using bank vegetation, classification, slope, and canopy cover. Prior research suggested that these 33 variables characterized most of the variability, and encompassed the range of physical habitat conditions, among sites (Heitke 2002).

A nonmetric multidimensional scaling (MDS) ordination was used to examine physical habitat similarities among sites. Ordinations are commonly used in studies of this type to visualize physical habitat similarity based on a large number of variables (James and McCullach 1990; Paukert and Wittig 2002). Sites with similar values for physical habitat variables were plotted closer together, while sites with dissimilar values were plotted further apart. To generate the ordination we calculated pair-wise similarities between all physical habitat sites using normalized Euclidean distances of standardized variables (average of zero, standard deviation of one). Next, the resultant 37 × 37 similarity matrix was used as input for an MDS ordination. To assign axis labels to the ordination, we calculated Pearson correlations of MDS dimension scores with the original physical habitat variables. The strongest correlations revealed variables most associated with overall habitat similarities and differences among sites. The similarity matrix, MDS ordination, and dimension scores were generated using PRIMER (Clarke and Warwick 1994). Correlations were examined using SAS (SAS Institute Inc. 1999).

*Fish assemblages.*—Fish assemblages were characterized using IBI scores, number of species, number of individuals, trophic and tolerance guilds, catch rates (number of fish captured per 100 m), and percent occurrence. The IBI was based on Karr's (Karr et al. 1986) original index, but was calculated using the program developed and calibrated in Iowa (Wilton 2004). Scores could range from 0 to 100, with higher scores indicating healthier fish assemblages. Fish species were identified as being tolerant, intermediate, or sensitive to degradation. Species were also grouped into one of 7 trophic guilds: benthic invertivore, filter feeder, invertivore/carnivore, herbivore, invertivore, omnivore, or top carnivore.

*Physical habitat, land use and fish assemblage relationships.*—We examined relationships between stream physical habitat, land use, and fish assemblage data using analysis of variances and *t*-tests. ANOVAs were used to determine ecoregional differences of physical habitat, land use, and fish assemblages. If the main effect (ecoregion) was significant, pair-wise comparisons among ecoregions were performed using the Tukey-Kramer test. *T*-tests were used to determine which of the 33 physical habitat and 12 land use variables could distinguish sites with poor or fair biotic condition (IBI scores $\leq 30$) from those with good to excellent biotic condition (IBI scores $\geq 50$). Results of statistical analyses were considered significant if $P < 0.5$. All analyses were performed in SAS (SAS 1999).

## RESULTS

### Physical Habitat

Channel sizes and proportions varied widely; average wetted widths ranged from 3.8 to 44.5 m, average depths ranged from 0.12 to 1.35 m, and width-to-depth ratios ranged from 7.3 to 110.8 (Table 2). Average velocity was slow (0.22 m/s), but highly variable. Substrate was dominated by fine substrates (74%), particularly sand, which ranged from 11% to 92%. There were nearly equal amounts of instream rock and wood fish cover, while high water fish cover was dominated by wood (75%). Riparian habitat conditions varied widely, between 4% and 90% of banks were unvegetated, between 0% and 52% of banks were "cut eroding banks" and site averages of bank slope ranged from 20° to 59°. The average percent of banks with canopy cover ranged from 0% to 88%.

The stress value of the MDS ordination was low (0.09), which indicated that similarities among sites were sufficiently represented (Clarke and Warwick 1994). No distinct grouping of sites was evident, rather, sites were scattered throughout the ordination space, indicating gradual variation in physical habitat characteristics among ecoregions (Figure 2). Dimension one of the ordination depicted differences in stream size and was most correlated with drainage area ($r = 0.71$), average stream width ($r = 0.62$), and stream order ($r = 0.61$). Dimension two contrasted sites dominated by wood habitat ($r = -0.43$) (toward the left of the plot) from sites with rock cover ($r = 0.71$), cobble ($r = 0.61$), or boulder ($r = 0.64$) substrates (toward the right of the plot) (Figure 2). The latter habitat characteristics were strongly correlated with IBI score ($r = 0.53$), number of fish ($r = 0.58$), and number of species sampled at sites ($r = 0.53$). Width to depth ratio was positively correlated ($r = 0.54$), and bank slope was negatively correlated ($r = -0.63$) to Dimension 2. Dimension three of the ordination was most correlated with proportion of canopy cover ($r = -0.63$) (Figure 2).

### Fish Assemblages

The average IBI score was 47 (SE = 3.0). Four sites had poor scores, 18 had fair scores, 12 had good scores, and 3 sites rated as excellent. From 138 to 3,626 (average = 1,031, SE = 132.9) individuals and from 6 to 38 (average = 22, SE = 1.2) species were captured at sites. On average, 56% (SE = 3.1) of sampled fish had intermediate sensitivity to degradation, 38% (SE = 3.4) were tolerant, and 6% (SE = 1.1) were sensitive. Invertivores (35%) (SE = 3.8) and omnivores (31%) (SE = 3.2) were the most common trophic guilds. Bluntnose minnow *Pimephales notatus* had the highest catch rates per 100 m, followed by sand shiner *Notropis stramineus*, green sunfish *Lepomis cyanellus*, fathead minnow *Pimephales promelas*, and spotfin shiner *Cyprinella spilopterus*. Green sunfish and common carp *Cyprinus carpio* occurred at the most sites, followed by sand shiner, bluntnose minnow and white sucker *Catostomus commersonii*.

### Land Use

Agriculture in study catchments consisted of cultivated row crops. Average amount of agriculture was 69% (SE = 3.3) in catchments, 50% (SE = 24) in network buffers, but only 11%

Table 2. Summary of ANOVAs testing the effect of ecoregion on physical habitat, fish assemblage and land use variables in Iowa streams. Only significant ($P < 0.05$) main effects are shown. Significant ($P < 0.05$) Tukey-Kramer pairwise comparisons between regions[a] are shown.

| | ANOVA | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | df | MS | *F* | *P* | Significant Tukey-Kramer pairwise contrasts | | | | |
| **Habitat** | | | | | | | | | |
| Average depth CV | 6 | 316.79 | 2.7 | 0.0326 | PP>LH | | | | |
| Average velocity CV | 6 | 7298.50 | 2.6 | 0.0376 | CP>DL | CP>IS | | | |
| Width to depth ratio | 6 | 1743.83 | 3.79 | 0.0049 | NW>CP | NW>LH | | | |
| % clay | 6 | 451.86 | 6.4 | 0.0001 | CP>DL | CP>IS | CP>NW | CP>PP | CP>SI |
| % banks open | 6 | 0.09 | 3.78 | 0.0049 | CP>IS | NW>IS | SI>IS | | |
| Average bank slope | 6 | 315.19 | 11.6 | <.0001 | CP>DL | CP>IS | CP>NW | LH>DL | LH>IS |
| | | | | | LH>NW | SI>IS | | | |
| **Fish assemblage** | | | | | | | | | |
| IBI | 6 | 1021.59 | 5.81 | 0.0003 | PP>CP | PP>LH | IS>SI | IS>CP | IS>LH |
| Number of species | 6 | 164.58 | 7.03 | <0.0001 | PP>CP | PP>DL | PP>LH | PP>SI | IS>CP |
| | | | | | IS>LH | | | | |
| % sensitive species | 6 | 134.36 | 5.11 | 0.0007 | IS>CP | IS>LH | IS>SI | PP>CP | PP>DL |
| | | | | | PP>LH | PP>SI | PP>NW | | |
| % filter feeder | 6 | 0.26 | 3.64 | 0.0062 | PP>CP | PP>DL | PP>IS | PP>LH | PP>NW |
| | | | | | PP>SI | | | | |
| % herbivores | 6 | 132.16 | 2.91 | 0.0196 | PP>CP | PP>DL | PP>LH | | |
| **Land Use** | | | | | | | | | |
| % local buffer ag. | 6 | 614.90 | 4.56 | 0.0021 | LH>CP | LH>DL | LH>IS | | |
| % network buffer ag. | 6 | 865.18 | 10.04 | <.0001 | NW>SI | NW>CP | LH>IS | LH>CP | DL>CP |
| | | | | | IS>CP | | | | |
| % network buffer for. | 6 | 411.18 | 12.00 | <.0001 | CP>IS | CP>DL | CP>LH | CP>NW | SI>DL |
| | | | | | SI>LH | SI>NW | | | |
| % catchment ag. | 6 | 955.84 | 3.36 | 0.0119 | DL>CP | | | | |
| % catchment other | 6 | 570.69 | 11.76 | <.0001 | CP>IS | CP>DL | CP>LH | CP>NW | SI>IS |
| | | | | | SI>DL | SI>NW | | | |

[a] Ecoregions abbreviated as follows: CP= Central Irregular Plains; DL = Des Moines Lobe; IS = Iowan Surface; LH = Loess Hills and Rolling Prairies; NW = Northwest Iowa Loess Prairies; PP = Paleozoic Plateau; and SI = Southern Iowa Rolling Loess Prairies.

(SE = 2.4) in local buffers. Percentages of forest were highly variable across spatial scales, with average amounts ranging from 5% (SE = 1.3) in catchments to 46% (SE = 4.0) in local buffers. Network buffers and local buffers had similar average percentages of grasses (35%, 21%, respectively) and "other" (2.3%, 4.5%, respectively) land uses. Average percentages of "other" land uses were low across scales, ranging from 2.3% (SE = 0.45) in network buffers to 5.2% (SE = 1.6) in catchments. Percentages of agriculture in local buffers, buffers, and catchments differed among regions, but a northeast to southwest gradient was not evident (Figure 3). Regions also differed in percentages of forest in buffers and other land uses in catchments.

## Relationships among Physical Habitats, Land Uses, and Fish Assemblages

Fish IBI, species richness, percentage of sensitive species, width-to-depth ratios, percentage open banks, and average bank slope exhibited a northeast to southwest gradient among ecoregions (Figure 4). Other physical habitat variables that distinguished some regions were depth CV, velocity CV, and percent clay (CP had significantly more clay than all other regions except loess hills) (Table 2). Most of the significant pair-wise differences involved the CP ecoregion, which had more clay substrate than five other regions, higher velocity CV than two regions, and steeper banks than three regions.

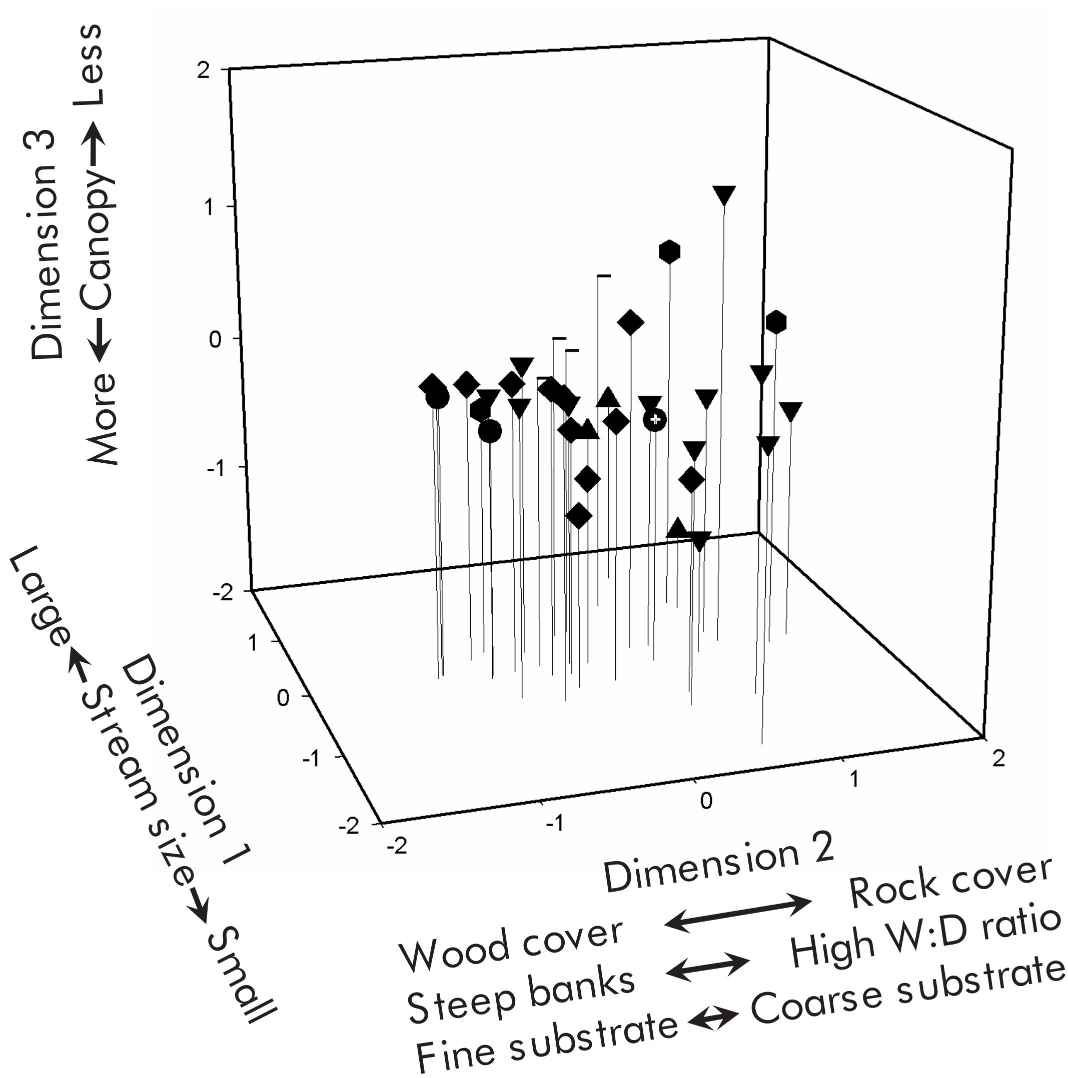


Figure 2. MDS ordination showing physical habitat similarities among 37 Iowa stream sites. Three dimensions characterized most similarities and differences among sampling sites. Ecoregions are represented by symbols as follows: PP (circle with cross), IS (triangle down), NW (circle), DL (diamond), SI (hexagon), CP (horizontal dash), and LH (triangle up).

Percent filter feeders and percent herbivores also differed among ecoregions. The only filter feeder sampled was the American brook lamprey *Lampetra appendix*, which was only found in the PP region.

Sites with good IBI (≥50) had shallower and more variable depths than sites with poor IBI (≤30; Table 3). Higher IBI scores were associated with higher percentages of boulder and gravel substrates, more rock cover, and more total fish cover. Lower IBI scores were associated with higher percentages of silt and clay substrates and steeper, more erodeable banks with less vegetative coverage. Seven land use variables were able to differentiate the IBI groups (Table 3; Figure 3). Sites with good or excellent IBI scores had lower percentages of agriculture in local buffers but higher percentages in network buffers and

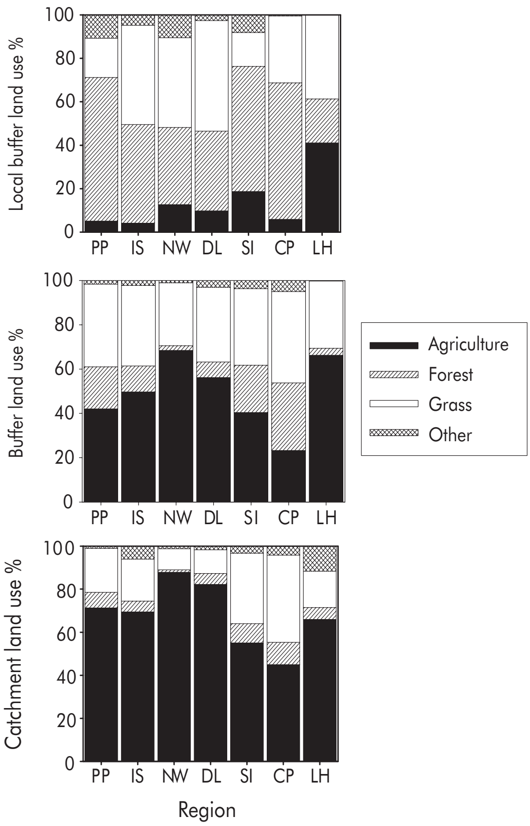


Figure 3. Land-use percentages in catchments, network buffers and local buffers upstream of sampling sites. Catchment land use included use percentages in catchments upstream of sampling sites. Network buffer land use included use percentages in 60-m riparian buffers of drainage networks upstream of sites. Local buffer included 60-m riparian buffer land uses located within 1-km-diameter circles centered on sampling sites.

catchments. Lower percentages of network buffer and catchment forests were also associated with higher IBI. Lower amounts of other land uses in buffers and catchments also distinguished sites with higher IBI scores.

## DISCUSSION

Physical habitat conditions in Iowa streams reflect attributes characteristic of Midwestern prairie streams, overlain with attributes characteristic of agricultural land use alteration. Fine substrates were common, even at our least-altered sites, which is consistent with previous research in Iowa (Griffith et al. 1994; Wilton 2004). Iowa sites had much higher percentages of sand and lower percentages of gravel and cobble than catchments with less agriculture in other Midwestern states (Goldstein et al. 2002; Putman et al. 1995), Nevada (Nelson et al. 1992), and Oregon (Whittier et al. 1988). Substrate composition at Iowa sites was similar to 27 streams in northwestern Mississippi (Shields et al. 1995), that were described as degraded due to deforestation, channel straightening, gully erosion, and sedimentation. In our study, degraded streambank conditions were common; roughly one-third of banks were devoid of vegetation and one-fifth of banks were eroding cut banks. In contrast to physical habitat conditions in Iowa streams, bank conditions in the Northern Lakes and Forests ecoregion, which includes northern portions of Minnesota, Wisconsin, and Michigan, were much better; 96% of banks were undisturbed and only 8% of banks were eroded (Wang et al. 2003). That ecoregion is dominated by forest (87.7%) and has low amounts of agricultural (5.7%) and urban (0.5%) land uses (Wang et al. 2003). The high percentage of fine substrates and eroding banks at Iowa sites is likely due in part to prairie physiography (Matthews 1988), but clearly has been intensified by agricultural land use (Menzel 1981, 1983; Waters 1995).

Physical habitat conditions in Iowa streams varied along three broad axes. The most dominant axis reflected differences in stream size. Average stream width, depth, and velocity all increased with stream size, as shown for many other rivers and streams (Leopold 1994). The next most important physical habitat axis contrasted sites with woody cover, fine substrates, and steep banks from sites with rocky cover, coarse substrates, and relatively wide and shallow channels. The other important physical habitat axis contrasted sites based on the prevalence of riparian canopy; some sites were completely barren of riparian trees shading the channel while other sites had shading trees at nearly every

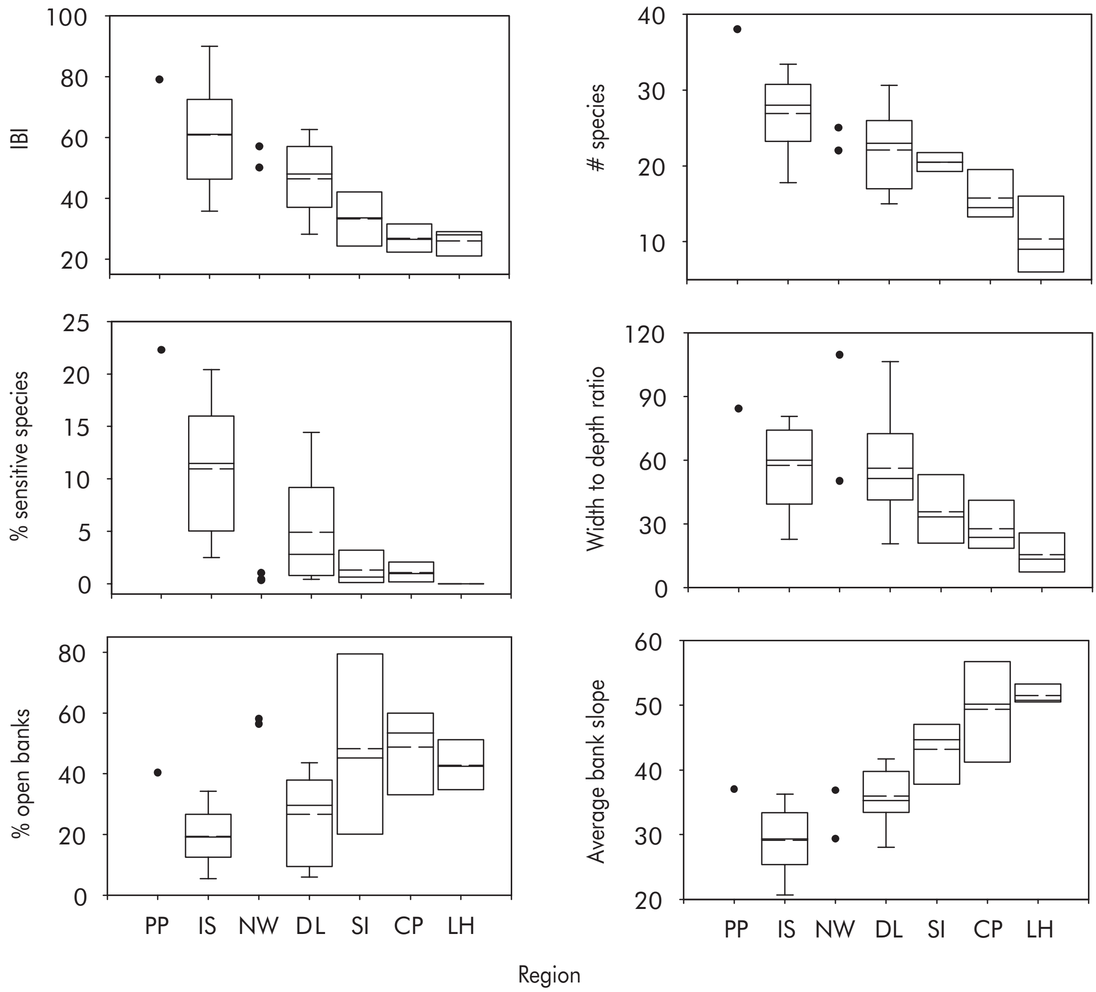


Figure 4. Fish and physical habitat variables with significant differences among ecological regions. Boxes encompass interquartile ranges; solid lines within boxes represent medians; dashed lines within boxes represent averages; vertical lines above and below boxes extend to the 95th and 5th percentiles, respectively. Dots represent individual values in ecoregions with fewer than three sites.

transect. Portions of the last two axes reflect symptoms of agricultural degradation. Severe erosion and channel down-cutting as a result of poor agricultural land use practices, most notable in southwestern Iowa (Menzel 1981, 1983), have resulted in sediment-laden streambeds, steep eroding banks, and trees falling into channels as large portions of streambanks are undermined. Riparian trees have been cleared from the banks of many rivers and streams in Iowa to allow cultivation as close to the channel as possible. A physical habitat ordination from a study of stream sites in an agriculturally dominated region just to the north of Iowa identified similar patterns (Talmage et al. 2002); boulders, woody debris, canopy cover, and stream size were among the variables that best characterized variation among those sites.

We found that fish IBI, species richness, and percentage of sensitive species were highest in northeast Iowa and decreased to the south and west, which agrees with previous findings in Iowa

Table 3. Significant differences ($P < 0.05$) among sites with IBI scores ≤ 30 ($N$ = 8) and sites with IBI scores ≥ 50 ($N$ =17) in Iowa streams.

| Variable | IBI ≤ 30 average | IBI ≥ 50 average | $P$ |
|---|---|---|---|
| Width to depth ratio | 26.54 | 61.72 | 0.0016 |
| Average depth | 0.74 | 0.38 | 0.0011 |
| Average depth CV | 42.73 | 58.63 | 0.0047 |
| % clay | 19.49 | 0.49 | 0.0003 |
| % silt | 20.51 | 8.19 | 0.0378 |
| % gravel | 4.70 | 17.19 | 0.014 |
| % boulder | 0.59 | 3.95 | 0.0489 |
| Cover abundance | 1.23 | 2.52 | 0.019 |
| Rock cover | 0.16 | 1.47 | 0.0197 |
| % banks open | 0.48 | 0.29 | 0.0113 |
| % cut eroding banks | 0.29 | 0.19 | 0.0355 |
| Bank slope | 48.03 | 31.78 | <0.0001 |
| Local buffer % agriculture | 22.24 | 5.49 | 0.0094 |
| Network buffer % ag. | 39.68 | 54.22 | 0.0369 |
| Network buffer % forest | 19.71 | 9.66 | 0.0287 |
| Network buffer % other | 4.38 | 1.36 | 0.0045 |
| Catchment % agriculture | 52.24 | 76.18 | 0.0084 |
| Catchment % forest | 9.25 | 3.25 | 0.0061 |

(Menzel 1987; Paragamian 1990b; Wilton 2004). An underlying cause of this pattern is greater numbers of native sensitive and total species in the Mississippi River basin (eastern and central Iowa) than the Missouri River basin (portions of western Iowa) (Hocutt and Wiley 1986). Even though several IBI metrics have been calibrated separately for the Mississippi and Missouri drainages in Iowa (Wilton 2004), IBI scores exhibited a marked decline from northeast (PP average IBI = 79) to southern and western Iowa (LH average IBI = 45). The statewide gradient in fish assemblage characteristics appears to reflect differences in the native species pool, geology, and climate, as well as more degraded stream conditions in portions of southern and western Iowa (Wilton 2004). We found that lower width to depth ratios, higher percentages of open banks, and higher average bank slopes exhibited the same statewide gradient and distinguished sites with poor or fair IBI scores from those with good or excellent scores.

Based on previous studies in Iowa, we hypothesized that land use differences among regions were a driving factor in the statewide IBI gradient. We did not find a northeast to southwest increase in percent agriculture and decrease in percent forest as had been reported in other studies (Menzel 1987; Paragamian 1990b; Griffith et al. 1994; Wilton 2004). Rather, we found a contradictory pattern; higher percentages of forests at all scales were associated with poor to fair IBI scores, while higher percentages of agriculture in catchments were associated with good to excellent scores. Combining grazed pasture and native prairie into the land use category "grass" may have masked different effects of grass cover of different type. Both the SI and CP regions had relatively low percentages of agriculture, but high percentages of grass. Grass land uses in these regions were primarily grazed pastures, which degrade streams (Menzel 1987; Griffith et al. 1994). We conclude that although agricultural land uses may diminish the natural distinction of ecoregions (Li and Reynolds 1994), ecoregions in Iowa have distinctive underlying landscape–stream relationships that should be examined both within ecoregions and across ecoregions. However, McCormick et al. (2000), Van Sickle and Hughes (2000), and Herlihy et al. (2006, this volume) reported that ecoregions and other spatial classification approaches explain less than half the variability possible with a biologically-based landscape classification. Future analyses will require more sites per ecoregion to adequately represent within-ecoregion variation. Even with more sites, we may find the same pattern as Stauffer et al. (2000), who examined an agriculturally dominated area of southern Minnesota. Stauffer et al. (2000) speculated that in areas like southern Minnesota and Iowa, where the percentage of agricultural land use is uniformly high, there may not be sufficient variation in land use to see its effects. The question of whether pervasive row-crop agriculture throughout Iowa may have essentially eliminated land use as a factor to explain variation in physical habitat and fish assemblages needs to be addressed at the within-ecoregion scale.

Our relationships of IBI and other fish assemblage variables with physical habitat conditions were similar to relationships reported in other studies from agriculturally dominated areas in the Midwest. An Illinois study reported that bank vegetation and width-to-depth ratio were positive predictors of IBI (Holtrop and Fischer 2002). Nerbonne and Vondracek (2001) found positive correlation of width-to-depth ratio and negative correlation of fine substrates with IBI in an agriculturally dominated landscape of southeastern Minnesota. In a statewide study for IBI calibration and development of other stream biological assessment tools for Iowa, Wilton (2004) found several relationships when comparing IBI scores with physical habitat variables. As in our study, IBI was positively correlated with coarse substrates and boulders, and negatively correlated with fine substrates and unvegetated banks. Although our findings on physical habitat agreed with Talmage et al. (2002), agreement on physical habitat and fish relationships was mixed. They found positive relationships of boulders with species richness and other fish assemblage variables. These relationships were comparable to our positive relationships of IBI, fish abundance, and species richness with habitat dimension 2, which was primarily defined by boulders and in-stream rock cover. However, their positive relationships of woody debris with IBI and other fish assemblage variables were not evident in Iowa streams. In a portion of the same area studied by Talmage et al. (2002), Stauffer et al. (2000) found a similar relationship; higher IBI at sites with wooded riparian zones than with nonwooded riparian zones. A possible difference between our findings and those of Stauffer et al. (2000) and Talmage et al. (2002) is that in some Iowa streams, woody debris is a consequence of poor bank conditions and severe bank erosion rather than a reflection of naturally forested riparian zones. Although there were differences in methodology and some details of findings, the collective evidence from studies of physical habitat and fish assemblages in agriculturally degraded upper-Midwestern streams is remarkably consistent. Stable, vegetated banks, wide stream channels with abundant coarse substrates and boulder-sized cover favor high IBI scores, while unvegetated, eroding banks and deep channels with predominantly fine substrates are associated with lower IBI scores. Presence of a wooded riparian zone and associated woody debris apparently enhances biotic integrity in some areas, as has been demonstrated in other regions (Gregory et al. 1991), while being symptomatic of stream habitat degradation in portions of Iowa.

Because of several shortcomings, we consider our study a preliminary assessment. Low sample sizes in some ecoregions limited our ability to characterize the range of stream conditions in these ecoregions. A clearer picture of within- and among-ecoregion variation would emerge with larger sample sizes, and the northeast to southwest trends in natural stream conditions would be better defined. Sites were sampled only once within a seven-year period, so it is possible that seasonal and annual variation may have further confounded comparisons. Three different gear types were used to sample fish, which may have introduced additional variation to the fish data. Several statistical tests were run, increasing the probability of type I error. Perhaps the greatest shortcoming was in the nonrandom selection of sites, which were subjectively chosen based on locations from a previous survey and ease of access. This significantly biased the local buffer land use towards artificially high percentages of forest. A study currently underway in Iowa was designed to avoid (or at least minimize) these problems, by greatly increasing within-ecoregion sample sizes and randomly choosing sites. Although these shortcomings limit conclusions based on our data alone, we believe that the congruence of many of our findings with previous studies allows broader interpretation and adds significantly to an emerging picture of streams in the agriculturally dominated Midwestern landscape.

Our results demonstrated that there is substantial variation among physical habitat, land use, and fish assemblage conditions across Iowa. Some of this variation is due to geology, climate, and zoogeographic patterns, which are depicted by ecoregion classifications. Future studies should address these natural patterns of ecoregions, particularly those aimed at identifying land use influences. Because of the dominance of agriculture, future management and restoration efforts targeting riparian zones and stream reaches will play an important role in improving biotic condition. Restored riparian buffers have been shown to improve many aspects of stream ecosystem structure and function in Iowa and elsewhere (Schultz et al. 2004). Instream and channel restoration techniques, such as those described by Newbury and Gaboury (1993), have proven effective at enhancing streams for fish by restoring natural habitat structure and the hydraulic functions that sustain them. Reducing upland and bank soil erosion, and mitigating channel sedimentation (Waters 1995) are perhaps the most important keys to improving physical habitat and biotic condition in Iowa streams.

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