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The Influence of Physical Habitat and Land Use on Stream Fish Assemblages in Southeastern Michigan

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Abstract.—The influence of land use and instream physical habitat on biotic condition of fish assemblages was investigated for 48 stream reaches in the Huron and Raisin rivers. The amount of agriculture and wetland in the catchment and 100-m stream buffers had the strongest relationships with instream physical habitat, and these two categories of land use/cover were negatively correlated with each other ($r = -0.70$, $p = <0.01$). Agriculture was associated with high levels of sedimentation and reduced flow stability, while wetland was associated with low sedimentation and stable flows. The index of biotic integrity (IBI) was positively related to low sedimentation, stable flows, and the presence of fine gravel (2–8 mm). It was not significantly correlated with agricultural land use, but was positively related to natural land cover (forest + wetland combined) in the buffer. The best linear regression model using physical habitat and land-use variables from all sites adequately predicted IBI scores (adjusted $R^2 = 0.52$). However, when the Huron and Raisin basins were treated separately, some of the included variables differed, and model fit increased (Huron adjusted $R^2 = 0.76$, Raisin adj. $R^2 = 0.79$), indicating that relations of fish assemblages to physical habitat and land use differed between basins. The Raisin model included land cover variables, while the Huron model included only variables related to physical habitat. Thus instream habitat and land cover may play different roles in these basins, suggesting the benefit of forming separate models for individual basins when sufficient data are available.

INTRODUCTION

Land-use change has major influences on stream ecosystems. Agriculture is one of the main factors responsible for stream degradation in the United States (Judy et al. 1984; U.S. Environmental Protection Agency 1996). Urban land use also has adverse effects on stream and water quality, especially when present in critical amounts and close to the stream channel (Wang et al. 1997, 2000, 2001). Agriculture is the dominant land-use feature of many southern Michigan basins, including the Raisin, while others, including the Huron, are in areas of high urban sprawl (Hay-Chmielewski et al. 1995). In addition, wetlands have been reduced to half or less of presettlement estimates (Mitsch and Gosselink 2000), leading to changes in flow stability and aquatic habitat.

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Human activities reflected in altered land use have resulted in high levels of degradation in stream ecosystems in many areas (Allan 2004).

Land use throughout catchments and along stream margins can substantially influence instream physical, chemical, and biological habitat. Physical habitat for fish includes substrate, extent of pools versus riffles, vegetation, undercut banks, flow amount and variability, and any other stream feature whose presence and quality can be important to the presence and abundance of fish species in a stream segment (Gorman and Karr 1978; Milner et al. 1985). Physical habitat degradation can therefore have large effects on the fish assemblages present in a stream.

Numerous studies report agriculture to have a strong influence on fish assemblages (Trautman 1981; Harding et al. 1998; Walser and Bart 1999; Brown 2000). Agriculture increases run-off and sediment transfer to a stream (Waters 1995; Walser and Bart 1999) through the clearing of vegetation and the installation of structures such as drainage tiles (Alexander et al. 1995). Increased sediment loads limit fish habitat and are associated with poor biotic condition (Berkman and Rabeni 1987), due to sediment deposition covering gravel, filling interstitial spaces, and burying logs (Alexander and Hansen 1986). Many fish require stream substrate relatively free of fine sediments for reproduction (Waters 1995). The increased sedimentation associated with agricultural practices decreases survival of eggs and larvae of fish, and the availability of food for fish (Berkman and Rabeni 1987; Chapman 1988). Walser and Bart (1999) observed a reduction in substrate complexity in tributaries to the Chattahoochie River as a result of the sediment deposited in agricultural streams, and Roth et al. (1996) reported a negative correlation between habitat metrics and fish biotic condition for sites within the Raisin River basin.

Urbanization also has well-documented effects on fish assemblages (Wang et al. 2000, 2001). Runoff delivered to a stream increases markedly due to greater imperviousness of the basin (Klein 1979; Wang et al. 2001), causing increased flow variability and reduced base flows, which in turn alter the erosion and temperature in a stream. Wetlands are important because they trap sediments and other materials in surface flow that would normally reach the stream (Patten 1998), and wetlands help to stabilize streamflows because they hold water during storm events. Thus the presence of wetlands in a catchment may reduce the rate of runoff delivery and levels of sedimentation in a stream.

Our objectives were to identify the major factors, including land use and instream habitat, influencing variation in biotic condition of headwater streams in southeastern Michigan. Fish assemblage structure was assessed using the index of biotic integrity (IBI), a biomonitoring technique that uses fish assemblages to assess biotic condition and environmental quality of a stream (Karr et al. 1986; Karr 1991; Karr and Chu 1997). The main strength of the IBI is its ability to integrate information from several levels of assemblage structure and function into a single, ecologically based index (Hlass et al. 1998). We identified major causes of variation in the IBI through its correlation with land-use and physical habitat variables. Land-use and physical habitat variables have been shown to be strongly related to biological metrics in other studies of the Raisin River (Roth et al. 1996; Lammert and Allan 1999). We examined small headwater streams throughout the Raisin and Huron basins to identify trends in subcatchments and to explore the relative contributions of land-use versus instream physical habitat variables in explaining variation in biotic condition among stream reaches.

METHODS

Study Area

The Huron (2,350 km^2; mean $Q = 18.3$ m^3/s) and Raisin (2,700 km^2; mean $Q = 22.1$ m^3/s) basins are located in southeastern Michigan and drain east into the western basin of Lake Erie (Figure 1). The Huron basin includes a mixture of agricultural and relatively undisturbed (forest,

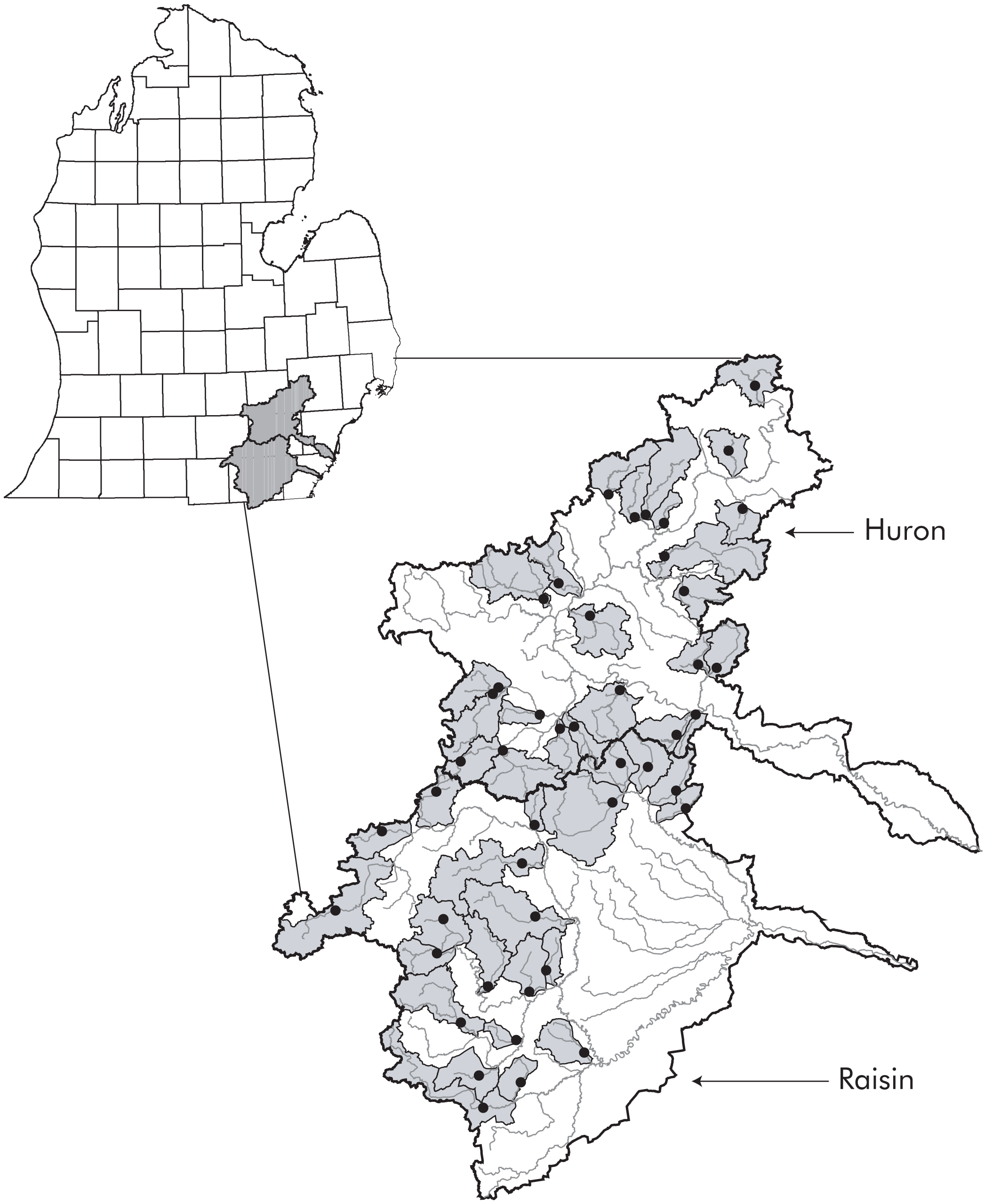

Figure 1. Locations of the Huron and Raisin basins in southeastern Michigan. The study catchments are shown in gray.

wetland, and some herbaceous areas) land uses, with large urban areas interspersed (Hay-Chmielewski et al. 1995). The Southeast Michigan Council of Governments projects population to increase by 6% and urban land-use area to increase by 40% over the next one to two decades, with most growth occurring in the Huron basin (Hay-Chmielewski et al. 1995). By comparison, the Raisin River basin has higher levels of agricultural land, which is considered to be an important factor causing water quality declines in this basin (Dodge 1998). Fish species richness is high, with at least 90 species recorded from each basin. See Cifaldi et al. (2003) and Roth et al. (1996) for further description of the region.

Site Selection

The Huron and the Raisin basins were subdivided into smaller catchments to select a set of distinct tributaries and catchments. We delineated 48 catchments from the tributary junction with the main stem or a larger branch of the Huron River or Raisin River. We sampled 25 catchments in 1999 and 23 in 2000. Because catchments differed in their extent of urban and agricultural land (see below), sampling effort was distributed over the 2 years to ensure that a broad range of land cover/use (hereafter, cover) was sampled each year.

Each sample site was at least 1 km above the tributary's confluence with the main stem and at least 1 km from any lake connection to reduce the presence of main-stem and lake fishes (Osborne and Wiley 1992). Sites were located as close to the downstream terminus of the catchment as feasible. All sites were classified as warmwater streams.

Fish Sampling and Analysis

Fish were sampled during midsummer, under low-flow conditions using three-pass depletion electrofishing within a 100-m reach blocked with nets at each end. Due to the small size of the sample sites (mean width = 3.72 m; range 1.47–6.76 m), a stream reach of 100 m was chosen because it was thought to exceed 20 times the stream width and removed the need for reach measurements prior to sampling. Stream segments exceeded 20 times the mean wetted width in 40 of the 48 sites. We used a Wisconsin ABP backpack electrofisher or a Smith-Root SR-6 Tow-Barge and model 2.5 GPP electrofisher, depending on stream size and accessibility. All fish collected were identified to species, measured (total length in millimeters), and weighed (wet weight in grams). Total numbers of fish as well as total biomass were recorded for each site.

To evaluate stream condition from fish collections, we used an IBI developed for warm Wisconsin streams (Lyons 1992), which have similar geology, climate, and fish species as southeastern Michigan. The IBI scores fish assemblages based on the numbers and types of fish species sampled at a site (Karr 1991). All fish species collected in the Raisin and Huron River basins in this study were listed in the classification of Wisconsin fishes (Lyons 1992). Maximum species richness plots used in calculating the Wisconsin IBI described similar numbers of potential fish species for each IBI metric as the Raisin and Huron basins. Maximum species richness plots created using data from the Raisin and Huron basins yielded similar scores, and all metrics were significantly correlated ($p < 0.01$) to Wisconsin IBI scores. Because of the high level of correlation between metric scores and the similar number of potential species used in maximum species richness plots between southern Wisconsin and southern Michigan, we believe the Wisconsin IBI adequately scores biotic condition in southern Michigan streams. Ten metrics were scored based on the abundance of different guilds or taxonomic groups and then summed and reported as a total score (maximum 100).

Physical Habitat Sampling

Physical habitat quality of the 100-m reach was evaluated using the Michigan Department of Environmental Quality's (M-DEQ) Procedure 51 (M-DEQ 1997). This nine-metric index estimates physical habitat quality from visual estimates at a site. The metrics are bottom cover/available substrate, embeddedness/siltation, velocity/depth variation, flow stability, bottom deposition/sedimentation, variety of pools-riffles-runs-bends, bank stability, bank vegetative stability, and streamside cover. Scores were assigned for each metric based on observed condition of each physical habitat feature. We used guidelines defined by the M-DEQ Procedure 51 (MDEQ 1997) to categorize each metric as poor, marginal, suboptimal, or optimal. Scores from individual metrics were summed to estimate physical habitat quality at each site (maximum 135).

Additional measures of physical habitat supplemented the visually assessed metrics. Substrate size composition was estimated using a pebble count based on 100 particles chosen from the thalweg at meter intervals of the 100-m reach. Pebble counts were used to calculate the proportion of fines and sand (<2 mm), fine gravel (2–8 mm), medium gravel (8–16 mm), coarse gravel (16–32 mm), pebble (32–64 mm), cobble (64–256 mm), and boulder (>256 mm) at each site. We also measured the ratio of fines to the volume of total substrate at the 0, 50, and 100-m point of each reach by recording the volume of substrate that passed through a 2-mm sieve. At 5-m intervals, we also visually estimated habitat type (pool, riffle, or run) and proportion of substrate types (fines and sand, gravel, cobble, boulder, claypan), maximum depth, and number of snags, to estimate habitat condition as a percent of the 100-m stream reach. Slope was measured as the change in elevation between the site and 5 km upstream of the site using 1:100,000 topographic maps.

Data Analysis

We examined scatter plots and simple correlations among physical habitat variables, the IBI, and percent land use to explore relationships, followed by multiple linear regression (MLR) to determine the variables best predicting IBI score. Variables used in MLR model formation included MDEQ habitat metrics and their sum, percent substrate in various size categories, percent habitat type, and percent land cover in the catchment and the 100-m buffer. These variables were examined for colinearity using a Pearson correlation matrix and a partial colinearity correlation *y* statistic. Variables that were redundant or highly correlated to other variables were not included in modeling. Forward stepwise regression was used to produce MLR models that predicted IBI scores from land cover and stream physical habitat variables. This analysis was performed on all 48 catchments and on the Raisin and Huron basins separately.

RESULTS

Fish Assemblages

A total of 12,587 individuals and 43 species were collected from 48 sites throughout the Huron and Raisin basins (Figure 2). Of these, the common carp *Cyprinus carpio* was the only nonnative fish. The average number of species caught at a site was 9.5 (range: 2–20), and the average number of fish caught at a site was 262 (range: 18–1,353). Fish assemblages were dominated by cyprinids and centrarchids, including several species that were abundant across most habitats, such as creek chub *Semotilus atromaculatus*, bluegill *Lepomis macrochirus*, white sucker *Catostomus commersonii*, and eastern blacknose dace *Rhinichthys atratulus*. Seven darter species were found in streams with substantial gravel, including the relatively abundant johnny darter *Etheostoma nigrum*, and rainbow darter *E. caeruleum*, as well as the less abundant blackside darter *Percina maculata*, fantail darter *E. flabellare*, greenside darter *E. blennioides*, and logperch *Percina caprodes*. Sites also varied widely in biological condition. The IBI ranged from 5 to 77, with an average score of 37.7 and a median score of 38.5. (Figure 3).

Physical Habitat

Physical habitat quality varied widely across sample sites. Michigan Department of Environmental Quality's habitat scores ranged from 45 to 107. Substrate composition of study reaches ranged from fine sediments to large gravels and cobbles. Pebble counts showed few sites with a high proportion of large cobbles and boulders, and most sites were dominated by fine sediments (<2 mm). Glides comprised more than 85% of all observed habitat types.

Michigan Department of Environmental Quality's metrics were significantly correlated with substrate measurements (Diana 2002). Gravel and larger substrate size categories were negatively correlated to the percent fine substrate

Figure 2. Fish species caught throughout the 48 sample sites and the number of individuals for each species. The number of sites a species was collected in is shown in parentheses.

category. The MDEQ total habitat score, bottom cover/substrate, velocity/depth, bottom deposition, and pools-riffles-runs-bends were negatively correlated with glide habitats and substrate measurements of fine material (proportion ≤ 2 mm, and average fines), and positively correlated with riffle habitat and substrate measurements of medium and large size gravel (proportion of substrate as boulder, cobble, coarse gravel). Slope for the stream segment was not significantly correlated with proportion of boulder, cobble, coarse gravel, fine gravel, sand, or fines ($P > 0.01$). Slope was correlated with MDEQ habitat metrics that were associated with channel and sedimentation (bottom cover/available substrate [$r = 0.40$, $p = 0.005$], velocity/depth

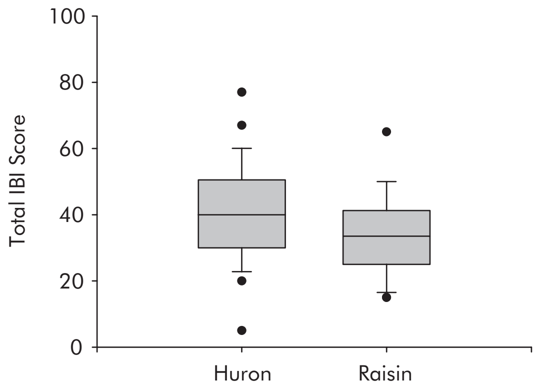

Figure 3. IBI scores for sites sampled in the Raisin and Huron basins.

variation [$r = 0.40$, $p = 0.004$], bottom deposition/sedimentation, [$r = 0.43$, $p = 0.002$], streamside cover [$r = 0.40$, $p = 0.005$]).

Land Cover

The sampled catchments of the Raisin River basin included a higher percentage of agricultural land and a lower percentage of urban land than observed in Huron catchments (Table 1). Percentage of forest was similar between Huron and Raisin catchments, and percentage of wetland was somewhat greater in the Huron. Percent agricultural land was negatively correlated with percent urban land across the catchments (Figure 4). Land use in the catchment was significantly correlated with land use in the 100-m stream buffer for all land-use categories (urban, $r = 0.96$; agriculture, $r = 0.94$; grassland, $r = 0.75$; forest, $r = 0.66$; wetland, $r = 0.89$; for all $p < 0.001$) and both were similarly correlated with physical habitat and IBI variables (Diana 2002). In the small headwater streams of this study, land use in the buffer and catchment appears to influence instream physical habitat and fish assemblage structure in similar ways.

Surficial geology was also related to the land use in a catchment. Agricultural land use in a catchment was negatively correlated with proportion of coarse end moraine ($r = -0.48$, $p = 0.001$) and outwash ($r = -0.56$, $p < 0.001$) and positively correlated with fine end moraine ($r = 0.627$, $p < 0.001$) (Diana 2002). Lake plain geology was not significantly correlated with any land-use components.

Relationships between Instream Habitat and Land Use

Correlations among land cover of the catchments and instream physical habitat suggest that the relative amounts of disturbed (agriculture + urban) and undeveloped land were important factors affecting stream physical habitat. Physical habitat quality was higher in catchments that contained less disturbed land. Total MDEQ habitat scores were negatively correlated with agriculture in the

Table 1. Land use (%) in the Huron and Raisin basins and study catchments and buffers. The Huron catchments are generally composed of a higher proportion of urban land while the Raisin has higher levels of agricultural land.

	Urban	Agriculture	Forest	Wetland	Grassland
Huron					
Basin	28	25	12	19	16
Catchment median	17.8	30.4	11.4	11.0	21.2
Catchment range	1.8–65.4	8.1–70.0	2.2–21.4	2.7–25.0	5.0–28.7
Buffer median	14.0	23.9	8.1	19.1	22.9
Buffer range	1.1–64.4	1.3–70.7	0.0–19.6	0.7–71.0	6.0–40.2
Raisin					
Basin	12	63	10	10	6
Catchment median	6.9	68.5	10.2	2.6	8.0
Catchment range	0.1–27.0	39.7–88.2	3.1–29.1	0.2–10.0	1.8–19.0
Buffer median	3.2	60.2	15.3	3.8	10.9
Buffer range	0.0–18.2	13.8–91.6	0.6–36.1	0.0–35.7	2.2–37.4

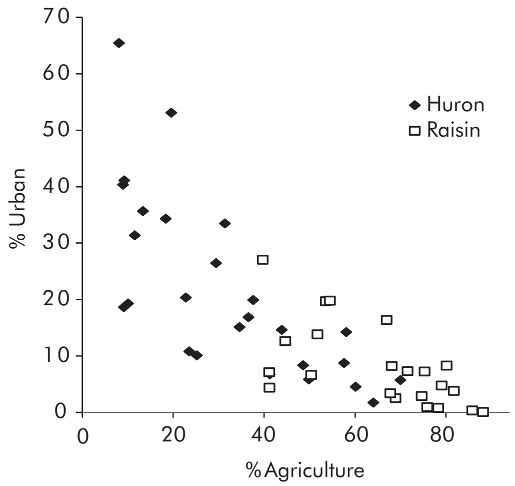

Figure 4. Land use within handpicked catchments ranged from high urban and low agriculture to the opposite extreme. Huron sites tended to have higher percentage of urban land, while Raisin sites generally had higher percentages of agriculture.

catchment (Table 2), while catchments with greater amounts of natural land (forest, wetland) were associated with higher physical habitat scores. Specific physical habitat metrics tended to receive low scores in areas of high agriculture, and higher scores in catchments with high forest and wetland components. Flow stability, bank stability, and bank vegetative stability were positively correlated with wetland and natural land, and negatively correlated with agriculture at the buffer and catchment scales (Table 2; Figure 5). Land cover variables were also examined for correlations with measures of physical habitat. Agricultural land was associated with sites that contained high amounts of fine substrate, while natural land was associated with greater abundance of gravel at a site (Table 2). Although geology was correlated with land use, we observed no significant correlations of geology with proportion of boulder, cobble, coarse gravel, fine gravel, sand, or fines ($P > 0.01$).

Relationship of the IBI to Land Cover and Instream Habitat

No significant correlations were found between the abundance or biomass of any fish species and

Table 2. Pearson correlation coefficients between land use variables, M-DEQ total and metric scores, IBI scores, and substrate measurements. Urban, agricultural, grassland, forested, and wetland refers to the land cover in the catchment. Disturbed land is the sum of urban and agricultural land in the catchment, and natural land is the sum of grassland, forested, and wetland in the catchment. Bold numbers are significant at $p < 0.05$, and bold and underlined numbers are significant at $p < 0.01$.

	Urban	Agri-cultural	Disturbed land	Grass-land	Forested	Wetland	Natural	IBI
M-DEQ metric scores								
Bottom cover/ available substrate	0.16	–0.20	–0.15	0.19	0.08	0.05	0.15	0.03
Embeddedness/ siltation	–0.01	–0.15	–0.23	0.11	0.22	0.16	0.20	**0.40**
Velocity/depth variation	0.20	–0.26	–0.22	0.20	0.17	0.06	0.19	0.14
Flow stability	0.06	**–0.44**	**–0.60**	**0.42**	**0.42**	**0.49**	**0.59**	**0.49**
Bottom deposition /sedimentation	0.12	0.03	0.16	–0.08	–0.06	–0.20	–0.15	0.02
Pools-riffles-runs-bends	0.16	–0.28	–0.28	0.24	0.15	0.13	0.24	0.14
Bank stability	0.10	**–0.38**	**–0.47**	0.25	**0.32**	**0.48**	**0.46**	**0.36**
Bank vegetative stability	0.23	**–0.42**	**–0.43**	**0.30**	0.22	**0.41**	**0.42**	0.12
Streamside cover	0.10	–0.15	–0.14	0.07	0.28	0.00	0.34	–0.16
Total M-DEQ score	0.18	**–0.37**	**–0.38**	**0.29**	**0.29**	0.23	**0.36**	**0.29**
Substrate measures								
% fine substrate	**–0.41**	**0.36**	0.18	–0.25	0.18	–0.23	0.18	–0.11
% gravel	**0.29**	**–0.41**	**–0.35**	**0.36**	–0.11	**0.43**	**0.35**	**0.33**
% large substrate	**0.34**	–0.11	0.14	0.00	–0.19	–0.16	–0.36	–0.23
Total IBI score								
IBI	–0.01	–0.22	**–0.34**	0.24	0.09	**0.40**	**0.34**	**1.00**

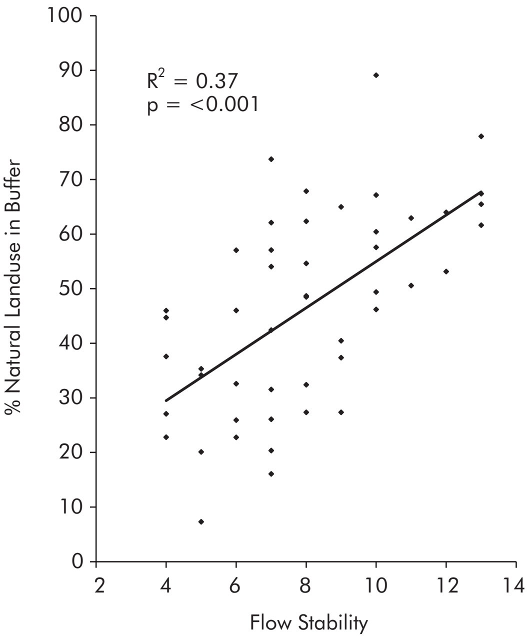

Figure 5. Flow stability versus percent natural land (sum of forest and wetland) increases in the buffer zone.

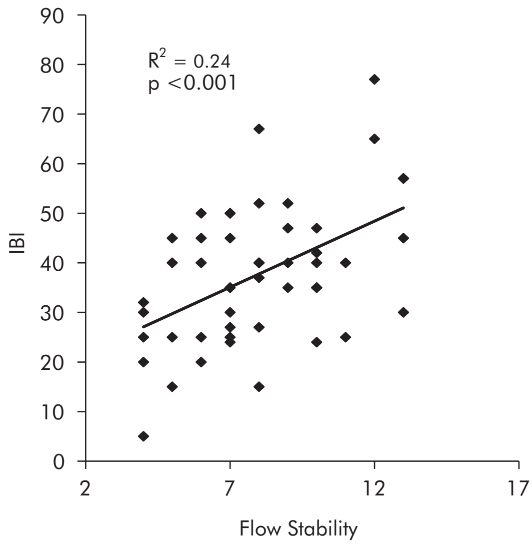

Figure 6. The IBI versus visually assessed flow stability.

instream physical habitat features. Total biomass was also not significantly correlated to any instream physical habitat variable. Individual IBI metrics were also examined for correlations with physical habitat and land use, and few significant correlations were found. The IBI total score had stronger correlations with physical habitat and land-use variables than individual IBI metrics or species abundance. Because of this, we focused on IBI as the main indicator of fish assemblage condition in the remaining analyses.

We examined the IBI for correlations with a number of habitat variables. The correlation between the IBI and the MDEQ total habitat score was weaker than the correlation of the IBI with MDEQ physical habitat metrics, including embeddedness/siltation, flow stability and bank stability (Table 2). Flow stability, which was significantly correlated with all land cover categories but urban, exhibited the strongest correlation with the IBI ($r = 0.49$, Table 2; Figure 6). The IBI score was not significantly correlated to bank vegetative stability, streamside cover, or percent fine substrates, but it was correlated with percent gravel (Table 2).

Among land cover variables, the IBI was positively correlated with percent wetland in the catchment (Table 2) and with the percent natural land in the stream buffer (Figure 7). When summed to create a measure of natural (forest + wetland) and disturbed (agricultural + urban) land, the IBI correlated positively with natural land and negatively with disturbed land (Table 2).

Relationships between the IBI and environmental variables were similar between the two basins for some variables but not others. Flow stability showed a similar relationship in both basins (Huron: $R^2 = 0.25$, Raisin, $R^2 = 0.13$, combined $R^2 = 0.24$) (Figure 8a). Siltation was much more clearly related to the IBI in the Huron ($R^2 = 0.35$) than in the Raisin ($R^2 = 0.07$, combined $R^2 = 0.16$) (Figure 8b). The IBI was significantly related to percent of the buffer as disturbed (agriculture + urban) land for the Huron ($R^2 = 0.35$) but not the Raisin ($R^2 = 0.00$) (Figure 8c), and for the combined data set ($R^2 = 0.15$) (Figure 8d).

Multiple linear regression analysis was used to produce a predictive model for the IBI and to

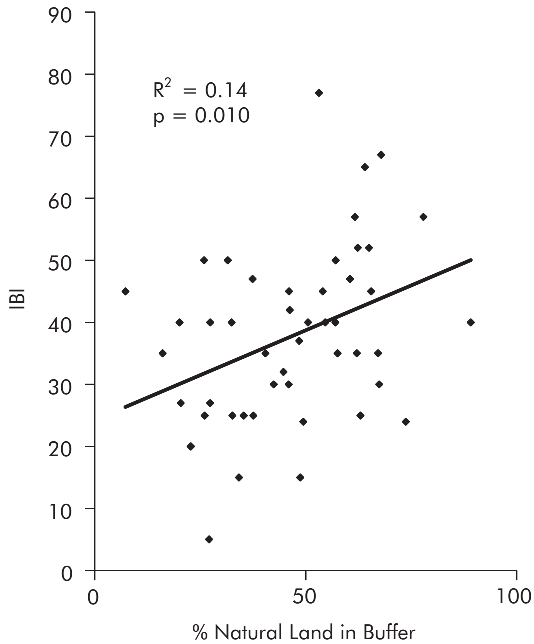

Figure 7. The IBI versus natural land (sum of forest and wetland) covers in the 100-m buffer.

examine all potential factors that may influence variation in IBI scores. All variables entered this model at the 0.05 level of significance, resulting in an overall model with an adjusted $R^2 = 0.52$ (Table 3). This model included the percents of fine gravel and sand, embeddedness/siltation, flow stability, and percent of riffles. No land cover variables were retained in this model.

Based on differences in land cover (Table 1) and environmental variables and IBI (Figure 8), we considered models for each basin. The best model for the Raisin basin had an adjusted R^2 of 0.79 and included wetland buffer, and urban and agricultural land in the catchment in predicting IBI scores. In addition, MDEQ metrics representing flow stability, bank vegetative stability, and streamside cover were included as predictive variables (Table 3). The best model for the Huron basin had an adjusted R^2 of 0.76 and included multiple physical habitat variables, but did not include land cover/use.

DISCUSSION

Human alteration of landscapes through conversion of natural land to agriculture and urban lands is an important and widespread contributor to loss of integrity of aquatic ecosystems (Allan 2004). Throughout the Huron and Raisin basins, land cover/use varies greatly and appears to influence stream condition. In general, reach-scale habitat variables were included in regression models describing variation in biotic condition more frequently than were landscape variables. However, a number of physical habitat variables correlated with land use, wetlands, and the amount of relatively undisturbed versus disturbed land, showing strongest relationships with measures of flow stability, substrate, and riparian vegetation. These results suggest that land use and instream physical habitat both can influence the biotic condition of a stream.

Michigan Department of Environmental Quality's habitat scores documented a wide range of physical habitat quality across sample sites. Physical habitat metrics also were significantly correlated with field measures of physical habitat and substrate (Diana 2002). Performing visual assessment and using quantitative measurements of habitat may be redundant; however, some differences in correlations with the IBI were observed, and the use of both proved useful in predicting IBI scores. Nonetheless, Platts et al. (1983) and Kaufmann et al. (1999) found that the imprecision of qualitative physical habitat metrics made them highly suspect for general monitoring.

The IBI is expected to correlate with habitat indexes, which often are used together to provide a more comprehensive assessment of stream condition or to validate an IBI or habitat assessment protocol (Fausch et al. 1984; Berkman et al. 1986; Schleiger 2000). However, several MDEQ metrics formed stronger bivariate correlations with the IBI than did the MDEQ total habitat scores. Visually assessed flow stability was especially consistent in forming significant relationships with the IBI and with land cover/use.

Table 3. Multiple linear regression models that predict the IBI for all sites combined, and separately for the Huron and Raisin sites. Variables are listed in the order entered in a stepwise forward multiple regression.

Basin	Variables selected	*N*	R^2	Adjusted R^2
Combined	flow stability	48	0.58	0.52
	fine gravel (%)			
	embeddedness /siltation			
	riffle (%)			
	sand (%)			
Huron	fine gravel (%)	26	0.81	0.76
	bank stability			
	embeddedness / siltation			
	fine sediment (%)			
	pools:riffles:runs:bends			
Raisin	catchment agriculture	22	0.85	0.79
	bank vegetative stability			
	streamside cover			
	catchment urban			
	flow stability			
	buffer wetland			

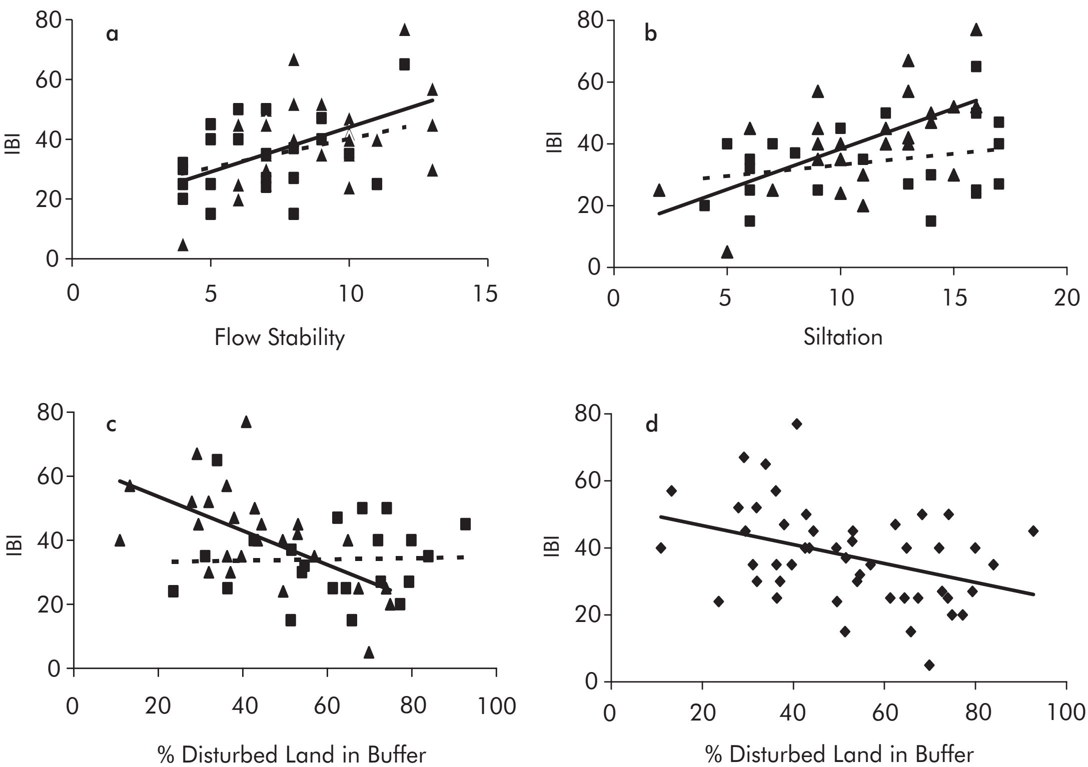

Figure 8. Relationships between the IBI and environmental variables. Huron basin: triangles, solid line; Raisin basin: squares, dashed line, combined: diamonds, solid line.

Agricultural land use was expected to alter stream physical habitat quality, and in this study, agricultural land was negatively correlated with a number of physical habitat variables. Fine substrates increased and gravel substrate decreased as agriculture increased. Agriculture has been shown to increase sedimentation rates in other basins (Waters 1995; Walser and Bart 1999). Agriculture was also negatively correlated with flow stability, leading to decreased bank and bank vegetation stability. Richards et al. (1996) identified variables highly correlated to row-crop agriculture as having the strongest influence on flood ratio in the Saginaw basin of east-central Michigan. Catchments with a high proportion of agriculture were associated with fine geology, and relatively undisturbed lands were associated with catchments with coarser geology (Diana 2002).

Urban land was associated with greater amounts of gravel and large substrate and a decrease in fine substrate. Urbanization of a basin has been shown to increase the imperviousness of the basin and therefore to increase the magnitude of high flows, the flashiness of the stream, and channel erosion (Klein 1979; Paul and Meyer 2001). However, urban land was not strongly correlated with flow stability or other measures of flashiness in our study. To minimize the potential for streams with severely altered stream chemistry or thermal regimes to interfere with our ability to detect links among the landscape, stream habitat, and the IBI, we eliminated sites with catchments containing large amounts of commercially or industrially developed areas. Consequently, the weak relationship between urban land and flow regimes may be due to the fact that variation in urbanized areas in this study is due primarily to residential developments.

The proportion of wetland in the subcatchments was the only individual land cover component significantly correlated to the IBI. The amount of wetland in a catchment has a direct influence on stream water quality and flow variability and may affect fish assemblages. Roth et al. (1996) found higher IBI scores in areas of higher wetland and forest and lower agriculture within the Raisin River basin. Richards et al. (1996) showed that agriculture and the presence of wetlands were the most important land cover variables influencing instream habitat features. Roth et al. (1996) also reported that higher habitat index scores were associated with streams located in areas of less agriculture and higher wetland. Correlations in the present study indicate that the relative amount of wetland influences the physical habitat quality of streams.

While individual land cover categories were weakly correlated with the IBI, when they were combined as relatively undisturbed versus disturbed land, the relationships were much stronger. This was also seen with a number of physical habitat variables. This implies that the biotic condition of fish assemblages is affected by whether land is altered for human use or left as relatively undisturbed forest and wetland. Agricultural and urban land have each been shown to have negative effects on fish assemblages (Walser et al. 1999; Brown 2000; Schleiger 2000; Wang et al. 2000, 2001) and there may not be major differences in their negative influence, at least in the present study. Although Wang et al. (1997, 2000) reported much more negative effects of urbanization than agriculture on IBI scores, Mebane et al. (2003) and Van Sickle et al. (2004) projected similar effects of urbanization and irrigated agriculture on the IBI.

The IBI was associated with physical habitat variables that were negatively correlated with disturbed land and positively correlated with wetland in a catchment. Higher IBI scores were observed in streams with a high proportion of gravel, low sedimentation, and low flow variability. High levels of sedimentation and the lack of exposed gravel have been shown to negatively affect stream fish in other studies. Nerbonne and Vondracek (2001) reported a negative correlation between IBI and embeddedness in the Whitewater River in Minnesota. Belliard et al. (1999) also found the IBI to be significantly related to substrate clogging in headwater streams of the Seine. Substrate was identified as a major factor influencing fish assemblages in a northeast Missouri stream where Berkman and Rabeni (1987) found that exposed gravel substrate was important to certain fish species and, as silt covered gravel, fish species that use gravel for feeding and reproduction were negatively affected. This supports the interpretations that exposed gravel substrate associated with lower levels of embeddedness promotes higher IBI scores in the Huron and Raisin basins. However, because substrate size is naturally affected by stream power and geology, such evaluations must be tempered pending evaluation of relative bed stability (Kaufmann and Hughes 2006, this volume). In addition, flow stability was significantly correlated with IBI score and the amounts of disturbed and natural land in a catchment.

The multiple linear regression model for combined basins identified the variables just discussed as best able to explain a large proportion of the variance in IBI. Flow stability and the relative amounts of fine sediment and gravel in a stream were selected, and no land-use variables remained in the model created for both basins. However, the instream physical habitat variables selected were related to land use, as discussed earlier, lending support to the idea that land cover/use may alter physical habitat features that are important to fish assemblages. When models were developed to predict the IBI separately for the Raisin and Huron rivers, different factors were related to biotic condition in the two basins and model explanatory power was increased. The Raisin model included land cover variables, while the Huron model included only variables related to physical habitat. In basins such as the Raisin, with large amounts of altered land, the negative effects of land cover/use on stream fish assemblages may be more apparent. Because the Huron basin has more relatively undisturbed land and a smaller extent of agriculture in the study subcatchments, land cover/use may be less likely to be identified as a primary factor. Thus instream habitat and land cover may play different roles in these basins, suggesting the benefit of forming separate models for individual basins when sufficient data are available.

Instream physical habitat metrics were better predictors of IBI than land use. Substrate conditions, especially sedimentation, and flow stability were important correlates of biotic condition in two watersheds of southeastern Michigan. High IBI scores were associated with exposed gravel substrate and low levels of embeddedness as well as more stable flows. Sedimentation and flow stability were also closely related to land use in a watershed. High levels of sedimentation and decreased flow stability were found in watersheds with low wetland and high agricultural land. A disturbed land-use category combining agriculture and urban land was more closely associated with IBI scores and physical habitat components, suggesting that the relative amount of land that is altered for human use may have a greater effect on stream assemblages than do specific types of land use. In addition, percent disturbed land had higher correlations with IBI score than did most physical habitat variables (Table 2). Specific land uses were not highly correlated with IBI score, but were related to physical habitat metrics that were closely related with IBI score. Like Richards et al. (1996), this study provides evidence that some instream physical habitat scores are more directly related to the IBI than is specific land cover, but that land cover in turn influences instream physical habitat.

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