Biological Evaluation of Selected Subwatersheds in the Lower Green River Watershed 2001: Final Report

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Kentucky Department for Environmental Protection
Division of Water
Watershed Management Branch
Nonpoint Source Section

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Cover photograph descriptions, clockwise from top left: acid mine drainage, channelized stream, channelized stream with no riparian zone, tile drain.

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Biological Evaluation of Selected Subwatersheds in the Lower Green River Watershed 2001: Final Report

By

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Acknowledgments

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EXECUTIVE SUMMARY

To more effectively evaluate the status of Kentucky's waterbodies and to improve restoration coordination, the Kentucky Division of Water (KDOW) initiated the Kentucky Watershed Management Approach. This approach follows a five-year cycle to evaluate current conditions, prioritize waterbodies, develop and implement strategies to remedy identified problems and finally to again assess water quality conditions. Because of the number of waterbodies in the state, it was necessary to focus water quality monitoring on fourth-order watersheds. However, it has proven difficult to implement BMPs and show demonstrable changes in water quality in fourth-order watersheds. To more effectively evaluate nonpoint source (NPS) impacts and remediation in Kentucky, it is necessary to concentrate on smaller watersheds. Problem watersheds within the larger drainages need to be identified in order to establish NPS grant funding priorities under §319(h) of the Clean Water Act. NPS Section biologists used data from previous monitoring in the Green River Basin Management Unit to determine watersheds impacted by nonpoint source pollution and the degree to which these impacts occurred. With this information, a list of priority watersheds for NPS assessment and monitoring was developed in consultation with the Green River Basin coordinator and TMDL coordinator. Within a select number of these larger watersheds, smaller tributary watersheds were monitored for the various suspected NPS impacts (e.g., agriculture, silviculture, etc.) in the watershed.

Sites were located in Daviess, Hancock, Ohio, McLean, Hopkins, Muhlenberg and Christian counties, Kentucky. Thirty-one sites were located in seven sub watersheds (Panther, Long Falls, Cypress, Render, Pond, Flat and Drakes). Sites ranged in size from 5 to 374 mi^2. Fish were collected following KDOW standard operating procedures. At each site, fish were collected with a backpack electrofisher, seine or a combination of seining and electrofishing. Sites (reach length 75-175m, $\bar{x}$ = 126m) were sampled with a single pass by working from downstream to upstream with all recognizable habitats thoroughly sampled. Electrofishing duration ranged from 451s to 1710s ($\bar{x}$ = 878s). Seine duration ranged from 20-90 min. ($\bar{x}$ =45 min). Fish were collected with dip nets or a seine and placed into a five-gallon bucket for preservation or identification. Macroinvertebrates were collected with the Rapid Bioassessment Protocols (RBPs) for low-gradient streams, which are based on recommendations of the Mid-Atlantic Coastal Plain Streams Workgroup. Macroinvertebrate sampling consisted of 20 jabs or kicks with a D-frame dip net (800×900 µm mesh) in a 100-meter reach at each sampling station, with the total area sampled approximately equal to 3.1 m^2. The available habitat types within the reach were sampled in proportion to their representation. The results of all 20 jabs or kicks were combined into a sieve bucket (600 µm mesh), and the sample was elutriated to remove large debris such as sticks, leaves and rocks. All organisms in the sample were identified to the lowest possible taxonomic level, usually genus or species. Habitat was assessed at each site using RBP habitat assessment protocols. A numerical score (0–20) was assigned to each of 10 parameters designed to measure habitat quality. The scores were summed to provide an overall habitat assessment score for each site. Water samples were analyzed for several bulk, nutrient and metal parameters. In situ field parameters such as temperature, dissolved oxygen, pH and conductivity were measured with a Hydrolab® Surveyor 4/MiniSonde.

No site within the sampled subwatersheds received a full-use designation for aquatic life use, eight sites received nonsupport, four received a threatened and remaining sites (n=18) received a partial support use designation. The fish community within the six subwatersheds in the lower Green River Watershed should be considered degraded. For fish communities, three sites scored excellent, four sites scored good, 14 sites scored fair, two sites scored poor, four sites scored very poor and two sites scored no fish. The aquatic macroinvertebrate community within the six subwatersheds in the lower Green River Watershed should be considered degraded. For macroinvertebrates, no site scored excellent or good, 22 sites scored fair, six sites scored poor and two sites scored very poor. The physical habitat within the six subwatersheds in the lower Green River Watershed should be considered degraded. For habitat, two sites scored full use support, five sites scored supporting but threatened, four sites scored partial support use support and the remaining sites (n=19) scored nonsupport for habitat. Aquatic life use determinations were included in the *2004 Kentucky Report to Congress on Water Quality* (KDOW 2004).

Although no one source can be identified as the cause of degradation, many causes (singular or a combination) stand out. For example, the aquatic fauna were degraded by a loss of habitat, chemical loadings and biological impairment. Although IBI scores were not related to total habitat, IBI scores were related to bank stability and MBI scores related to pool variability. Both pool variability and bank stability were related to channel alteration. This suggests that straightened channels resulted in poor pool habitat and unstable banks. Habitat degradation appears to be a major source of impairment in the lower Green River Watershed. Other sources of degradation include mining and to some extent urbanization. The main source of habitat degradation was channelization of streams and degraded riparian zones. This is apparent from RBP scores on channel alteration ($\bar{x}$ =10.4) and riparian zone ($\bar{x}$ =4.7).

Management Recommendation

1. Initiate Watershed Based Plans (WBP) in order to guide restoration activities and commit to long-term monitoring (7-10 yrs) in order to document changes in water quality.

   As part of the WBP:

   1. Encourage riparian zone BMP implementation on streams in the lower Green River Watershed. Width of buffer zones should be site specific. Buffers should be installed on ephemeral and intermittent streams as well.
   2. Limit stream maintenance projects. When maintenance projects occur, the source of the problem should be addressed.
   3. Investigate stream restoration projects as appropriate. Geomorphic assessments should be completed in order to identify if restoration is possible.
   4. Identify non-channelized streams and provide protection.
   5. Ensure that all mining activities are in compliance with permit requirements.
   6. Ensure that closed mine sites are in compliance before bond release.
   7. Abandoned mine (Pre Law) reclamations should proceed as funding is available.
   8. Initiate tile drain BMP research that may evaluate pollutant transport into streams.
   9. Initiate a water quality investigation in the Panther Creek Watershed to identify water quality impacts related to nutrients and pesticides.

INTRODUCTION

To more effectively evaluate the status of Kentucky's waterbodies and to improve restoration coordination, the Kentucky Division of Water (KDOW) initiated the Kentucky Watershed Management Approach. This approach follows a five-year cycle to evaluate current conditions, prioritize waterbodies, develop and implement strategies to remedy identified problems and finally to assess water quality conditions. Because of the number of waterbodies in the state, it was necessary to focus water quality monitoring on fourth-order watersheds. However, it has proven difficult to implement BMPs and show demonstrable changes in water quality in fourth-order watersheds (McMurray et. al in press). To more effectively evaluate nonpoint source (NPS) impacts and remediation in Kentucky, it is necessary to concentrate on smaller watersheds. Problem watersheds within the larger drainages need to be identified in order to establish NPS grant funding priorities under §319(h) of the Clean Water Act. NPS Section biologists used data from previous monitoring in the Green River Basin Management Unit (e.g., KDOW 1996, 1998 and 1999) to determine watersheds impacted by nonpoint source pollution, and the degree to which these impacts occurred. With this information, a list of priority watersheds for NPS assessment and monitoring was developed. Within a select number of these larger watersheds, smaller tributary watersheds were monitored for the various suspected NPS impacts (e.g., agriculture, silviculture, etc.) in the watershed.

METHODS

Study Area

The lower Green River watershed lies within the Wabash-Ohio Bottomland (72a) and the Green River - Southern Wabash Lowlands (72c) of the Interior River Valleys and Hills Ecoregion. Woods et al. (2002) characterized this ecoregion as nearly level lowlands that are dominated by agriculture and forested hills. This ecoregion also includes Kentucky's Western Coal Fields. Cropland, pastureland, and both underground and surface mining are extensive. Siltation from mining and agriculture has increased flooding and prompted remedial channelization projects. Channelization and ditching of streams are common (Woods et al. 2002).

Sites were located in Daviess, Ohio, McLean, Hopkins and Muhlenberg counties, Kentucky. Thirty-one sites were located in seven subwatersheds (Panther, Long Falls, Cypress, Render, Pond, Flat and Drakes) (Figure 1 and Table 1). Sites ranged in size from 5 mi^2 to 374 mi^2.

Fish

Collection

Fish were collected following KDOW standard operating procedures (KDOW 2002). At each, site fish were collected with a backpack electrofisher, seine or a combination of seining and electrofishing (Table 2). Sites (reach length 75m – 175m, $\bar{x}$ = 126m) were sampled with a single pass by working from downstream to upstream with all recognizable habitats thoroughly sampled (Barbour et al. 1999). Electrofishing duration ranged from 451s to 1710s ($\bar{x}$ = 878s). Seine duration ranged from 20 min – 90 min. ($\bar{x}$ =45 min). Fish were collected with dip nets or a seine and placed into a five-gallon bucket for preservation or identification.

Fish collections were preserved in the field with a 10%-15% buffered formaldehyde solution. Easily identified fish that were collected in large numbers (i.e., *Campostoma* spp.) or large specimens were recorded in the field and released. If possible, at least five specimens of each species released were retained as vouchers from each sample event. Fish were preserved in formaldehyde solution for at least 2 weeks. Fish were then rinsed and soaked for 1–2 d in tap water, transferred to 70% ethanol solution for long-term preservation, storage and identification. All fish were identified to the lowest possible taxonomic level, usually species.

Metric Selection

Fish assemblages in the state have shown strong correlation with ecoregion, basins, physiographic regions and stream size. Development of criteria for an IBI must be region- and stream size-specific to correspond with the differences within the ecoregion/basin framework (Angermeier et al. 2000 and Fausch et al. 1984). Therefore, several candidate metrics were tested and validated for their sensitivity and variation among each region and stream size following methodology found in Smogor and Angermeier (1999) and McCormick et al. (2001). Metrics were selected to demonstrate attributes of a fish community that show responsiveness to disturbances, predictability and uniformity throughout the state. The metric selection process uses statistical properties of redundancy and sensitivity to evaluate the discriminating power of a metric between impaired and relatively unimpaired sites (reference sites). After testing the candidate metrics, eight metrics were selected to structure the multimetric Index of Biotic

Integrity (IBI). The following list is an explanation of each metric used in the IBI (KDOW 2002):

1. Native Species Richness (NAT). This is the total number of native species present in a sample. Native richness is expected to decline with impairment. Non-native species are excluded since they tend to invade with impairment. This metric will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

2. Darter, Madtom and Sculpin Richness (DMS). This is the total number of the species in a sample within the tribe Etheostomatini (darters), the genus *Noturus* (madtoms) and the genus *Cottus* (sculpins). These groups are generally sensitive to pollution and are expected to decline with impairment. This metric will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

3. Intolerant Species Richness (INT). This metric represents the total number of intolerant species collected in a sample. Intolerant species are expected to decline with impairment. This metric will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

4. Water Column Species Richness (WC). This metric is a combination of four metrics. It is the total number of species, excluding tolerant members, from the family Cyprinidae along with the Sunfish, Top Carnivore and Sucker metrics used in KDOW (1997). This metric is expected to decline with impairment. This metric will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

5. Simple Lithophilic Spawning Species Richness (SL). This metric is the total number of simple lithophilic spawning species. It represents species that require relatively clean gravel and exhibit simple spawning behavior (Ohio 1987 and Simon 1999). The metric is considered a habitat metric and is expected to decline with impairment and be sensitive to siltation (Berkman and Rabeni 1987).

6. Proportion of Insectivorous Individuals (P_INS). This metric is the relative abundance of insectivorous individuals excluding tolerant individuals. It represents a proportion of

individuals that are fairly sensitive and feed primarily on insects. The metric is expected to decline with impairment. It will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

7. Proportion of Omnivorous Individuals (P_ OMN). This metric is the relative abundance of omnivorous individuals. It metric represents a proportion of individuals that are considered generalist in their feeding behavior. The metric is expected to increase with impairment. It metric will usually increase with decreasing water quality, habitat diversity and/or habitat suitability.

8. Proportion of Tolerant Individuals (P_TOL). This metric is the relative abundance of tolerant individuals. It represents a proportion of individuals that are pollution tolerant and invade with impairment. Therefore, this metric is expected to increase with impairment. It will usually increase with decreasing water quality, habitat diversity and/or habitat suitability.

IBI Scoring

Equations used to compute individual metrics (M. Compton personal communication):

$$NS = [[x - (9.1556(\log 10(catchment) + 4.5843) + 19.11] \div 25.74] \times 100$$

$$DMS = [[x - (2.7667(\log 10(catchment) + 1.4586) + 5.85] \div 9.39] \times 100$$

$$INT = [[x - (2.699(\log 10(catchment) + 0.3509) + 4.63] \div 7.6] \times 100$$

$$WC = [[x - (4.7932(\log 10(catchment) + -0.8669) + 6.74] \div 10.32] \times 100$$

$$SL = [[x - (3.9336(\log 10(catchment) + 1.5797) + 7.82] \div 12.33] \times 100$$

$$P\_INS = [[x - (-7.2142(\log 10(catchment)^2 + 39.688(\log 10(catchment)) + 11.05) + 55.86] \div 85.59] \times 100$$

$$P\_OMN = [[(100 - x) - (-18.458(\log 10(catchment)^2 + 73.028(\log 10(catchment)) + 17.625) + 84.29] \div 114.17] \times 100$$

$$P\_TOL = [[(100 - x) - (-9.2039(\log 10(catchment)^2 + 43.38(\log 10(catchment)) + 28.945) + 74.6] \div 100.74] \times 100$$

where:

x = raw metric score, and

catchment = drainage area in mi^2

Final IBI score was computed by the following equation (M. Compton, personal communication):

$$IBI=(NS+DMS+INT+WC+SL+P\_INS+P\_OMN+P\_TOL)\div 8$$

Sores for IBI calculation were rated according to the following criteria for the Interior Valley and Hills ecoregion (M. Compton, personal communication):

Excellent		≥	65.6
Good	52.0	-	65.5
Fair	34.7	-	51.9
Poor	17.3	-	34.6
Very Poor	0	-	17.2

Macroinvertebrates

Collection

Macroinvertebrates were collected with the Rapid Bioassessment Protocols (RBPs) for low-gradient streams, which are based on recommendations of the Mid-Atlantic Coastal Plain Streams Workgroup (Barbour et al. 1999, KDOW 2002 and MACS 1996). Macroinvertebrate sampling consisted of 20 jabs or kicks with a D-frame dip net (800 × 900 µm mesh) in a 100-meter reach at each sampling station, with the total area sampled approximately equal to 3.1 m^2. The available habitat types within the reach were sampled in proportion to their representation. For example, if root wads made up 20% of the available habitat, then 4 jabs were allocated to root wads in the 100-meter reach. The results of all 20 jabs or kicks were combined into a sieve bucket (600 µm mesh), and the sample was elutriated to remove large debris such as sticks, leaves and rocks. Samples were field processed until one pint or less of material remained. Samples were initially preserved in 95% ETOH, and returned to the laboratory for sorting and identification. All organisms in the sample were identified to the lowest possible taxonomic level, usually genus or species. However, when large numbers of midge larvae (Diptera: Chironomidae) were collected (i.e., >100 individuals), a 10% subsample was randomly chosen and identified to facilitate identification (KDOW 2002).

Metric Selection

The KDOW's metric selection process uses statistical properties of redundancy and sensitivity to evaluate the power of metrics that can discriminate between impaired and unimpaired sites. Metric scoring criteria are established using percentiles of the reference and non-reference data distribution. The following is a list and explanation of each metric.

1. Taxa Richness (GTR). This refers to the total number of distinct taxa present in the composited sample (both semi-quantitative and qualitative samples combined). In general, increasing taxa richness reflects increasing water quality, habitat diversity and/or habitat suitability.

2. Ephemeroptera, Plecoptera, Trichoptera Richness (GEPT). This is the total number of distinct taxa (both semi-quantitative and qualitative samples combined) within the generally pollution sensitive insect orders of Ephemeroptera, Plecoptera and Trichoptera found in the composite sample. This index value will usually increase with increasing water quality, habitat diversity and/or habitat suitability.

3. Modified Hilsenhoff Biotic Index (HBI2). The HBI was developed to summarize the overall pollution tolerance of a benthic arthropod community with a single value (Klemm et al. 1990). Hilsenhoff (1977), using a range of 0-5, originally developed the index for Wisconsin riffle/run streams experiencing organic pollution. Hilsenhoff (1982, 1987) later refined the index, expanding the scale to range from 0 to 10. Plafkin et al. (1989) modified the index to include non-arthropod benthic macroinvertebrates. Hilsenhoff (1987) developed tolerance values for a variety of macroinvertebrates from Wisconsin, and Plafkin et al. (1989) added additional tolerance values. However, KDOW uses tolerance values developed by North Carolina Division of Environmental Management (NCDEM) (Lenat 1993) as well as values developed from KDOW data. These HBI values have been regionally modified for streams of the southeastern United States. Both Hilsenhoff (1988) and NCDEM have developed seasonal correction factors for the HBI. Several states, including Kentucky, have used the mHBI to assess impacts other than organic enrichment and found the mHBI to be a valuable metric. An increasing mHBI value indicates decreasing water quality. The formula for the mHBI is as follows:

$$mHBI=(Sn_ixa_i)/N$$

where:

n_i = number of individuals within a species (maximum of 25),

a_i = tolerance value of the species,

N = total number of organisms in the sample (adjusted for $n_i > 25$).

4. Modified Percent EPT Abundance (P_EPT). This metric measures the abundance of the generally pollution-sensitive insect orders of Ephemeroptera, Plecoptera and Trichoptera. The relatively tolerant and ubiquitous caddisfly *Cheumatopsyche* is excluded from the calculation. Increasing values indicate increasing water quality and/or habitat conditions.

5. Percent Chironomidae+Oligochaeta (P_CO). This metric measures the relative abundance of these generally pollution tolerant organisms. Increasing abundance of these groups suggests decreasing water quality conditions.

6. Percent Primary Clingers (P_Clng). This habit metric measures the relative abundance of those organisms that need hard, silt-free substrates to "cling" to. Merritt and Cummins (1996) and Barbour et al. (1999) list habits for most insect genera. Habit information for non-insect taxa can be determined from Pennak (1989), Thorp and Covich (1991) and Barbour et al. (1999).

MBI Scoring

Equations used to compute individual metrics (KDOW 2002):

TR=(x/95th%ile)*100
EPT=(x/95th%ile)*100
PEPT=(x/95th%ile)*100
HBI2=((10-x)/95th%ile)*100
P_Clng=(x/95th%ile)*100
P_CO=((100-x)/(100-5th%ile))*100

where:
x = raw metric score, and
%ile provided by (G. Pond, personnel communication)

Final MBI score was computed by the following equation:

MBI=((TR+EPT+PEPT+HBI2+P_Clng+P_CO)/6)*100

Scores for MBI calculation were rated according to the following criteria for the Interior Valley and Hills ecoregion (G. Pond, personal communication):

Excellent		>	58
Good	57	-	48.1
Fair	48	-	24.1
Poor	24	-	12.1
Very Poor		≤	12

Habitat

Habitat was assessed at each site using RBP habitat assessment protocols described in Barbour et al. (1999) and KDOW (2002). Evaluated habitat parameters included epifaunal substrate/available cover (EpiFauSub), pool substrate characterization (PoolSubChar), pool variability (PoolVar), sediment deposition (SedDep), channel flow status (ChaFlowS), channel alteration (ChanAlter), channel sinuosity (ChanSin), bank stability (BankSta), bank vegetative protection (BankVegP) and riparian vegetative zone width (RipVegZW) (Barbour et al. 1999). Values for the habitat parameters BankSta, BankVegP and RipVegZW represented combinations of the scores from left and right bank to facilitate data analysis. For consistency, scores for each category were determined by the same investigator(s) at all of the monitoring stations. A numerical score (0–20) was assigned to each of 10 parameters designed to measure habitat quality. The scores were summed (0–200) to provide an overall habitat assessment score for each site, with higher scores indicating better habitat features (KDOW 2002).

Chemical and Physicochemical Characteristics

Water samples for physicochemical analyses were collected with protocols described in the KDOW standard operating procedures manuals (KDOW 1993 and 1995). Water samples were analyzed for several bulk (alkalinity, total suspended solids, organic carbon, sulfate), nutrient (total phosphorus, nitrate, total kjeldhal nitrogen and ammonia) and metal parameters (aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium and zinc) following standard methodology (APHA et al. 1998, KDOW 1993 and 1995). In situ field parameters such as temperature, dissolved oxygen, pH and conductivity were measured with a Hydrolab® Surveyor 4/MiniSonde (Hydrolab-Hach Company, Loveland, CO).

Data Analysis

Simple correlation analysis was used to analyze the relationships between biological, chemical and physical habitat conditions within the lower Green River Watershed. Linear regression and forward stepwise multiple regressions were used to identify cause and affect relationships and a t-test was used in order to compare means. All analysis was considered significant if $\alpha \leq 0.1$. All data analysis was performed with statements written for the Statistical Analysis System (SAS 1987).

RESULTS

Fish

A total of 3,813 individuals were collected from 29 sites within six separate watersheds (Cypress n=3, Drakes n=1, Flat n=1, Long Falls n=2, Panther n=15 and Pond n=7) (Table 3 and Appendix A) in the lower Green River Watershed during June, July and August 2001. Two sites in Renders Creek Watershed (03010002 and 0301003) were not sampled for fish because of severe acid mine drainage (AMD) impacts (i.e. “red dog” and high conductivity). A visual search for fish was conducted and no fish were observed. Even though these sites were not sampled for fish by KDOW methods (KDOW 2002), these sites should be rated as very poor based on chemical data (i.e. conductivity) (Table 4). Two sites were sampled where no fish were collected (03003003 and 03004005), and at one site (03011009) only one fish was collected (Appendix A). These sites were scored as no fish, no fish and very poor, respectively (Table 5). Fish communities were correlated with biological, physical and chemical stressors within the lower Green River Watershed. All quality assurance/quality control (QA/QC) checks (5% of samples re-identified) were passed (M. Compton, personal communication).

All fish metrics (Tables 6 and 7) were positively correlated with MBI ($p \leq 0.05$) (Figure 2) except for DMS, INT and SL. Degraded invertebrate communities directly affect fish communities within the lower Green River Watershed. For example, GTR, GEPT, and %EPT were all positively correlated with the total number of fish individuals collected and IBI scores ($p \leq 0.05$). As these invertebrate diversity indices decrease, so did the total number of fish individual and IBI scores (Figure 3), suggesting that fish communities need diverse invertebrate communities.

Overall, IBI scores and total habitat scores were not related (*p*>0.1) (Figure 4), and only one individual parameter (riparian zone width) correlated with total IBI score (r =-0.4, *p*=0.03). However, several individual IBI metrics and habitat metrics were significantly correlated (*p*<0.1). NAT, INT, SL and WC species richness was positively correlated with sediment deposition (*p*<0.1), but IBI, DMS and INT were negatively correlated with riparian zone width (*p*<0.05) (Figure 5). IBI, DMS and INT species richness should respond positively to increasing riparian zone widths (KDOW 2002). In the lower Green River Watershed, riparian zone width negatively affected these scores, suggesting other factors are driving the system (i.e., conductivity). In order to separate abiotic factors (mining) on the fisheries, correlations were performed on sites (n=17) with conductivity less than 1000 µs/cm and pH greater than 6. Excluding these sites negated the influence of mining. When mining sites were excluded from the analysis, IBI and metric scores versus riparian zone width, and IBI versus total habitat score were not significantly correlated (*p*>0.1). However, bank stability significantly correlated with IBI and all metric scores (*p*<0.1) except P_OMN and P_INST (*p*=0.18).

Fish communities correlated with several chemical parameters within the lower Green River Watershed. Parameters that were significantly correlated (*p*≤0.05) with fish metrics include: conductivity, pH, ammonia, and sulfates. Conductivity significantly affected IBI scores (*p*≤0.0001, R^2=0.52, IBI=56.1-0.019(conductivity)) (Figure 6). When subwatersheds were analyzed separately, two watersheds (Panther and Pond) contained sufficient observations for analysis. IBI scores and conductivity were not significantly correlated (*p*>0.1) within the Panther Creek Watershed, but IBI scores and conductivity were significantly correlated (*p*=0.005) in the Pond Creek Watershed. However, mean conductivity was not significantly different (*p*=0.9, TTEST) between Panther and Pond Creek Watershed (Figure 7). In all watersheds sulfate and chloride concentration seem to be driving conductivity (forward stepwise multiple regression, p = 0.0001, R^2=0.97, Conductivity = 137.1+10.3(chloride) +1.2(sulfates)).

Chemical parameters that were significantly correlated (*p* ≤ 0.01) with the IBI included pH, ammonia and sulfates. Water quality was impacted by pH (<6.0) at the following sites: 03003003, 03004005 and 03011009 (Table 4). Although pH was positively correlated (*p*≤0.005) with IBI, TNI, NAT, WC, P_OMN, P_INST and P_TOL, the three sites with pH<6.0 probably influenced this relationship. At all other sites, pH scores were within the acceptable range (pH=6.2–8.5) (401 KAR 5:031). Nitrate and sulfate concentration relationships should be of concern. Both ammonia and sulfates were negatively correlated with IBI scores (*p*=0.01, r=-0.46). Sulfate concentrations were significantly (*p*<0.1) negatively related to all IBI metric scores except for INT and P_OMN (Figure 8). Although ammonia and IBI scores were negatively correlated, high numbers of non-detects and low numbers of high concentrations (>0.5 mg/L) influenced this relationship. However, high ammonia (>0.6 mg/L) concentrations attributed to poor IBI scores (Figure 9).

Macroinvertebrate

A total of 11,494 individuals were collected from 30 sites within seven separate watersheds (Cypress n=3, Drakes n=1, Flat n=1, Long Falls n=2, Panther n=15, Pond n=7 and Renders n=1) (Table 3 and Appendix B) in the lower Green River Watershed during June, July and August 2001. Invertebrate communities were correlated with biological, physical and chemical stressors within the lower Green River Watershed.

Overall MBI and metric scores (Table 8 and 9) and total habitat and individual scores were not correlated (*p*>0.1). However, mHBI and P_Clng were positively correlated with total habitat (*p*<0.1) and MBI and pool variability were correlated (*p*<0.1). In addition mHBI was correlated with several individual habitat metrics. The mHBI was significantly correlated with epifaunal substrate/available cover, pool substrate characterization, pool variability, bank vegetative protection and riparian zone width (*p*<0.1). P_Clng was also correlated with channel alteration, pool variability and riparian zone width (*p*<0.1) and PCO was negatively correlated with bank stability and channel flow status (*p*=0.1).

Invertebrate communities correlated with several chemical parameters within the lower Green River Watershed. MBI scores were positively related to pH (*p*=0.09) and negatively related to ammonia and TKN (*p*=0.06). GTR and GEPT was negatively related to conductivity, ammonia and sulfates (p=0.04) and positively related to pH (p=0.09). The mHBI was negatively related to ammonia, chloride, TKN and TOTP (*p*=0.07). PEPT was correlated to pH, nitrate and TOTP (*p*=0.09). PCO was negatively correlated with ammonia and TKN (*p*=0.03), and P_Clng was negatively correlated with chloride (*p*=0.02).

Habitat

Habitat data was collected at all sites (n=30) with biological collections (Table 3 and 10). Although all individual habitat parameters were correlated with total habitat (p=0.01), channel alteration and epifaunal substrate/available cover had the highest correlation coefficient (r= 0.74 and 0.75 respectively). Channel alteration and epifaunal substrate/available cover may be driving habitat conditions in the lower Green River Watershed.

Channel alteration and epifaunal substrate/available cover were not directly correlated with IBI, but the IBI and bank stability were correlated (p=0.0009). Epifaunal substrate/available cover significantly correlated with NAT, SL and WC (p<0.5). Channel alteration significantly correlated with bank stability (p<0.01), which was the only habitat variable that significantly correlated with IBI (p=0.0009), indicating that channelized streams are resulting in degraded fish communities. Channel alteration and epifaunal substrate/available cover were not directly correlated with MBI, but the MBI and pool variability were correlated (p=0.09). Pool variability was correlated to Channel alteration, epifaunal substrate/available cover and pool substrate characterization (p=0.01), also indicating that channelized streams are resulting in degraded invertebrate communities.

Use Designation

Fish

Overall, three sites scored excellent, four sites scored good, 14 sites scored fair, two sites scored poor, four sites scored very poor and two sites scored no fish (Table 5 and Appendix A). The fish community within the six subwatersheds in the lower Green River Watershed should be considered degraded.

Macroinvertebrates

Overall, no site scored excellent or good, 22 sites scored fair, six sites scored poor and two sites scored very poor (Table 5 and Appendix B). The aquatic macroinvertebrate community within the six subwatersheds in the lower Green River Watershed should be considered degraded.

Habitat

Overall, two sites scored full support, five sites scored supporting but threatened, four sites scored partial support and the remaining sites (n=19) scored nonsupport (Table 5). The overall physical habitat within the six subwatersheds in the lower Green River Watershed should be considered degraded.

Overall Use Designation

No sites within the sampled subwatersheds received a full use designation, eight sites received nonsupport, four received a threatened and remaining sites (n=18) received a partial support use designation (Table 5 and Appendix C).

DISCUSSION

Although no one source can be identified as the cause of degradation, many causes (singular or a combination) stand out. For example, the aquatic fauna were degraded by a loss of habitat, chemical loadings and biological impairment. Although IBI scores were not related to total habitat, IBI scores were related to bank stability, and MBI scores related to pool variability. Both pool variability and bank stability were related to channel alteration. This suggests that straightened channels resulted in poor pool habitat and unstable banks. Habitat degradation appears to be a major source of impairment in the lower Green River Watershed. Other sources of degradation included mining and some urbanization. The main source of habitat degradation was channelization of streams and degraded riparian zones. This is apparent from RBP scores on channel alteration ($\bar{x}$ =10.4, Table 10) and riparian zone scores ($\bar{x}$ =4.7, Table 10).

Channelization occurred at many of the sites sampled in the lower Green River Watershed. As is often the case in low-gradient agricultural streams, channelization is a severe impact (Wang et al. 1997). Channelization is often a sought-out solution for drainage and flooding problems. However, this is a short-term solution that leads to long-term damage to streams (Wenger 1999). Dredging and channelization reduce both the quantity and quality of instream habitat and geomorphic units (Lee et al. 2001). Impacts occur not only downstream (Shields et al. 1994) but upstream as well (i.e., headwater erosion and downcutting) (Pringle 1997). Channel straightening can abruptly increase a stream’s sediment transport capacity (Shields et al. 1994). Channelization increases gradient, which increases the power of the stream. Increased power increases the stream’s ability to transport sediment (Nakamura et al. 2000). Degradation of the streambed by channelization may make banks unstable and set up bank failure (Nakamura et al. 2000). Bank failure causes an estimated $250 million in damages each year in the United States (Gore et al. 1995). Holtrop and Fischer (2002) found in the Embarras River, Illinois, that a straightened channel not connected to floodplain exerted significant energy to stream banks and that bank failure and an unstable bed was the likely source of fine sediment. Shields et al. (1994) reported that an incised channel produced fewer fish and had lower species richness.

Agricultural practices in riparian zones can result in the loss of stream corridor vegetation and stream bank integrity, directly causing bank erosion and destabilization of the stream channel (Wang et al. 2002). Agriculture has been identified as the leading nonpoint source of water quality impacts on surveyed rivers and lakes in the United States. Sources of impairment include sediment, nutrients, pathogens, pesticides, metals and salts (USEPA 2003). In Pennsylvania, habitat quality decreased when agriculture land use reached 40% (Genito et al. 2002). Wang et al. (1997) demonstrated in Wisconsin that even in areas with high agriculture land use (80%), sites with good habitat still supported healthy fish populations. However, these areas were typically higher gradients and not channelized.

Sources of sediment include runoff from upland areas (rowcrops and construction sites) or the channel itself (unstable banks and scouring of streambed). Channel sediment may originally be from upland sources (Wenger 1999). High sediment loads can fill interstitial spaces and reduced microhabitat (Genito et al. 2002). Mebane (2001) reported that invertebrate scores decreased and salmonid and sculpin age class declined with increases in fine sediment. If upstream sources (i.e. agriculture, urban areas) are significant, then the habitat can be lost for a long distance downstream (Diamond et al. 2002).

Consequences of riparian removal are increased sediment input in streams (Jones et al. 1999). Bank erosion and fine substrates in a channel are influenced by adjacent riparian land use (Lyons et al. 2000). In Midwestern agricultural streams, riparian zones with mature trees provided bank stability, roots, shade, overhanging cover and rootwad habitat (Shields et al. 2000). Stewart et al. (2001) reported that EPT richness was positively influenced by a forested riparian zone and watershed and negatively influenced by near stream agriculture and grasslands. Hanson (1997) indicated that the fish community was influenced by physical habitat condition that was strongly related to wooded riparian cover. Streams in Wisconsin with increased IBI, species richness, diversity and percent benthic invertebrates were in streams with wooded riparian zones (Stauffer et al. 2000). Riparian land use can be the best predictor of biotic integrity (Whiles et al. 2000).

Shields et al. (1994) characterized unstable habitat as variable and harsh. Woody debris and overhanging vegetation provide cover, temperature stability, a food source and reduce fine sediment (Shields et al. 2000). Cover is any structure that protects aquatic organisms from mechanical damage by high velocities and predation (Gore et al. 1995). Stable habitat facilitates reproduction and YOY fish survival (Freeman et al. 2001) and increased invertebrate scores (Mebane 2001). Darters have been found to be more common in relatively stable, non-incised reaches with tree-lined banks (Shields et al. 1995). Etnier (1972) attributed unstable habitat to the decline of fish populations in a channelized stream that underwent annual reworking in a Tennessee stream. Low-gradient streams without wooded riparian zone lack instream habitat (i.e. woody debris, root wads) (Stauffer et al. 2000).

An important role for riparian buffer zones is bank stabilization (Wenger 1999 and Gore et al. 1995). These zones reduce bank erosion and the introduction of fine sediment into a channel (Lyons et al. 2000). However, riparian buffers will not be effective if the underlying problem is not resolved (i.e. increased storm flow from urban runoff, agricultural operations and channelization) (Wenger 1999). Protection of vegetative riparian zones may help mitigate effects of agriculture and urbanization and sustain species (Diamond et al. 2002). Roots and other vegetation stabilize banks and reduce erosion (Lee et al. 2001). Riparian BMPs have been shown to significantly improve overall stream habitat quality, bank stability, instream cover for fish and abundance of fishes (Wang et al. 2002).

In order for buffers to be effective, bank vegetation should have good, deep root structures that hold soil (i.e. native woody species) (Wenger 1999). Buffers should be wide enough to permit channel migration and should be wider on steeper slopes. Ephemeral and intermittent channels should be protected as well (Wenger 1999). Gaps in riparian vegetation can lead to degradation of fish and invertebrate communities (Stewart et al. 2001). Jones et al. (1999) reported that fish did not tolerate disruptions much more than 1 km in length.

Maintaining woody riparian cover along streams can be effective in maintaining or improving fish community composition in streams draining heavy agricultural areas (Lee et al. 2001).

In the lower Green River Watershed, fish and macroinvertebrate scores did not relate directly to habitat scores. This relationship was probably confounded by poor water quality. Although water quality samples were collected, these were one-time samples that may not adequately characterize water quality within the watershed. It is speculated that elevated nutrients, conductivity and sulfates are factors that limit the aquatic fauna in the lower Green River Watershed. Shields et al. (1995) reported that IBI scores were generally not reflective of physical habitat conditions in Mississippi and that water quality may have confounded relationships between physical habitat and fish metrics. Lammert and Allan (1999) also reported that fish did not have a well-defined association to habitat. Invertebrate impairment was attributed to poor water quality in Nebraska streams although habitat scores were high (Whiles et al. 2000). Nonpoint source impacts from agriculture pesticides are a potential source of toxic stress on aquatic fauna (Diamond et al. 2002). Tile drains with open inlets deliver runoff laden with sediment, nutrients and pesticides directly to the stream and bypass the riparian zone (Meador et al. 2003). Tile drains were common at sample sites in the lower Green River Watershed. Meador et al. (2003) reported that degraded fish communities were related to increased nutrients, suspended sediments and total solids and that these relationships may be more important than other relationships (i.e., agricultural land cover).

Mining impacts can be detrimental to aquatic communities, either through toxic stressors (acidic conditions and high conductivity) or through habitat degradation. For example, Nichols and Bulow (1973) reported in Tennessee that no fish were collected below a mining impact area, and characteristic invertebrates within the impacted zone were *Chironomus* and *Sialis*. Although not a mining impact, acid impact (low pH) from acid deposition significantly affected invertebrate density in the southern Appalachian Mountains (Rosemond et al. 1992). Garcia-Criado et al. (1999) reported that variables most related to biological parameters were those indicating mining impacts (conductivity and sulfates). Kennedy et al. (2003) also reported that conductivity levels impair sensitive aquatic fauna. Copper was the most likely component causing mortality of juvenile salmon impacted by AMD in British Colombia (Barry et al. 2000). A major factor affecting the benthic community seemed to be ferric hydroxide deposition (yellow boy) in a southwestern Pennsylvania stream (Moon and Lucostic 1979). Mining impacts were evident in several watersheds within the lower Green River Watershed. For example, low pH and high conductivity affected several sites (Table 4).

Past land use may result in long-term modifications and reductions in aquatic diversity, and recovery may take decades (Harding et al. 1998). However, multiple authors support reforestation of riparian zones as an effective way of maintaining and improving aquatic communities (Meador et al. 2003, Shields et al. 1995, Stauffer et al. 2000 and Wilchert and Rapport 1998). Channelized streams tend to return to a natural condition through time. However, periodic maintenance of channels for drainage preclude recovery (Lee et al. 2001). Complete restoration of pre-European settlement conditions may not be practical, and decisions have to be made regarding the selection of habitat characteristics for restoration (Shields et al. 1995). It should also be noted that there might be a substantial lag time between reclamation and changes in stream water quality (Wang et al. 2002).

Management Recommendation

1. Initiate Watershed Based Plans (WBP) in order to guide restoration activities and commit to long-term monitoring (7-10 yrs) in order to document changes in water quality.

    As part of the WBP:

    1. Encourage riparian zone BMP implementation on streams in the lower Green River Watershed. Width of buffer zones should be site specific. Buffers should be installed on ephemeral and intermittent streams as well.
    2. Limit stream maintenance projects. When maintenance projects occur, the source of the problem should be addressed.
    3. Investigate stream restoration projects as appropriate. Geomorphic assessments should be completed in order to identify if restoration is possible.
    4. Identify non-channelized streams and provide protection.
    5. Ensure that all mining activities are in compliance with permit requirements.
    6. Ensure that closed mine sites are in compliance before bond release.
    7. Abandoned mine (Pre Law) reclamations should proceed as funding is available.
    8. Initiate tile drain BMP research that may evaluate pollutant transport into streams.
    9. Initiate a water quality investigation in the Panther Creek Watershed to identify water quality impacts related to nutrients and pesticides.

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FIGURES

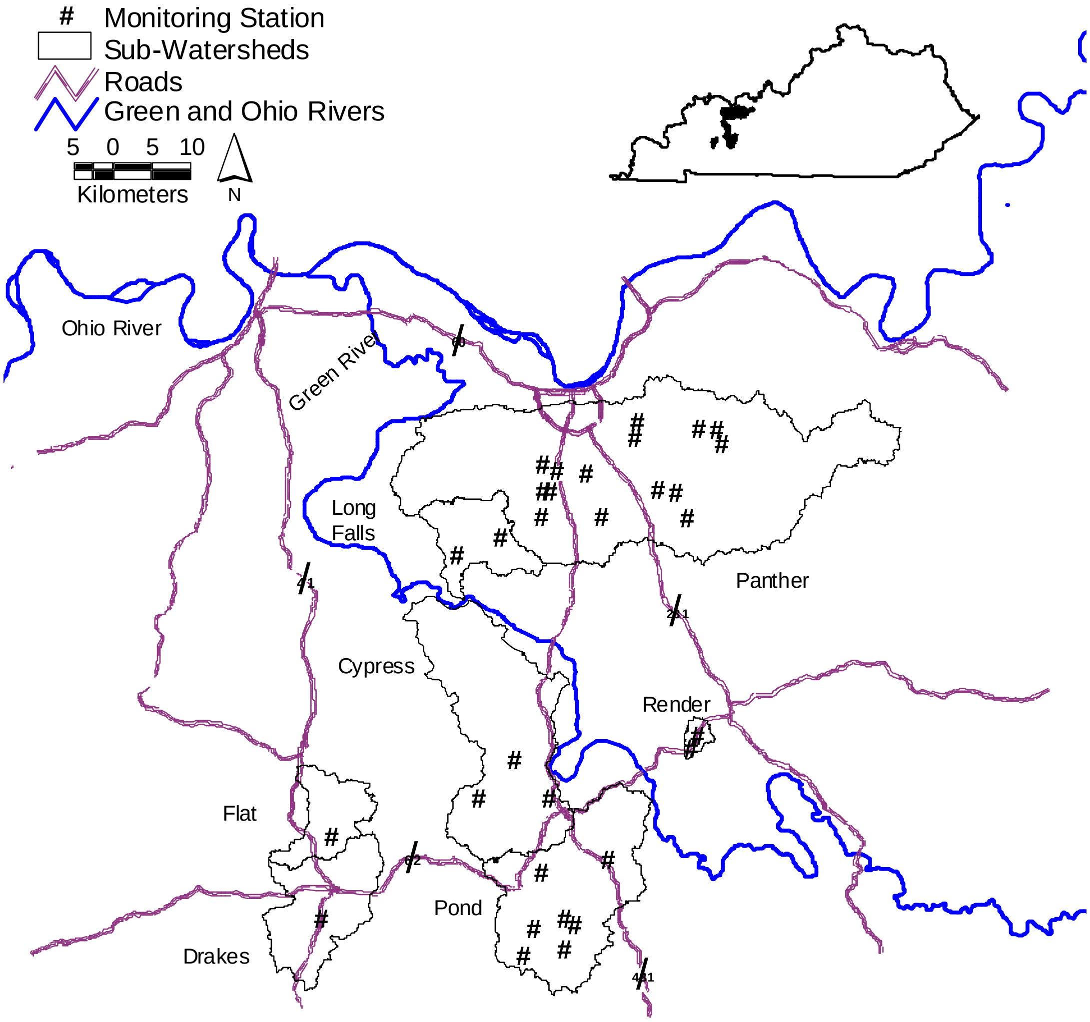


Figure 1. Location of subwatersheds monitored in the lower Green River, Kentucky. Monitoring locations represented by “●”.

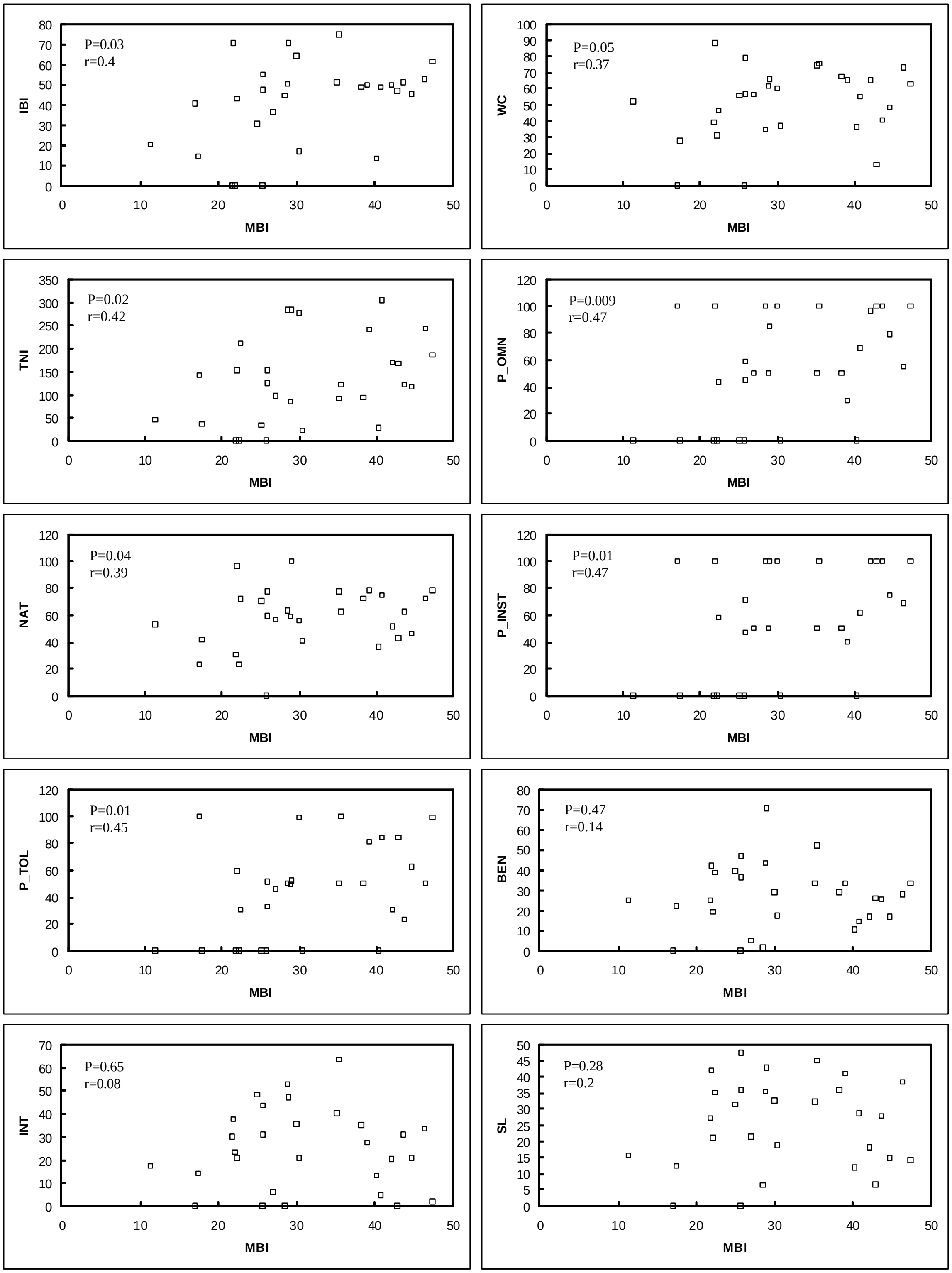


Figure 2. Relationship between fish metric scores and the MBI

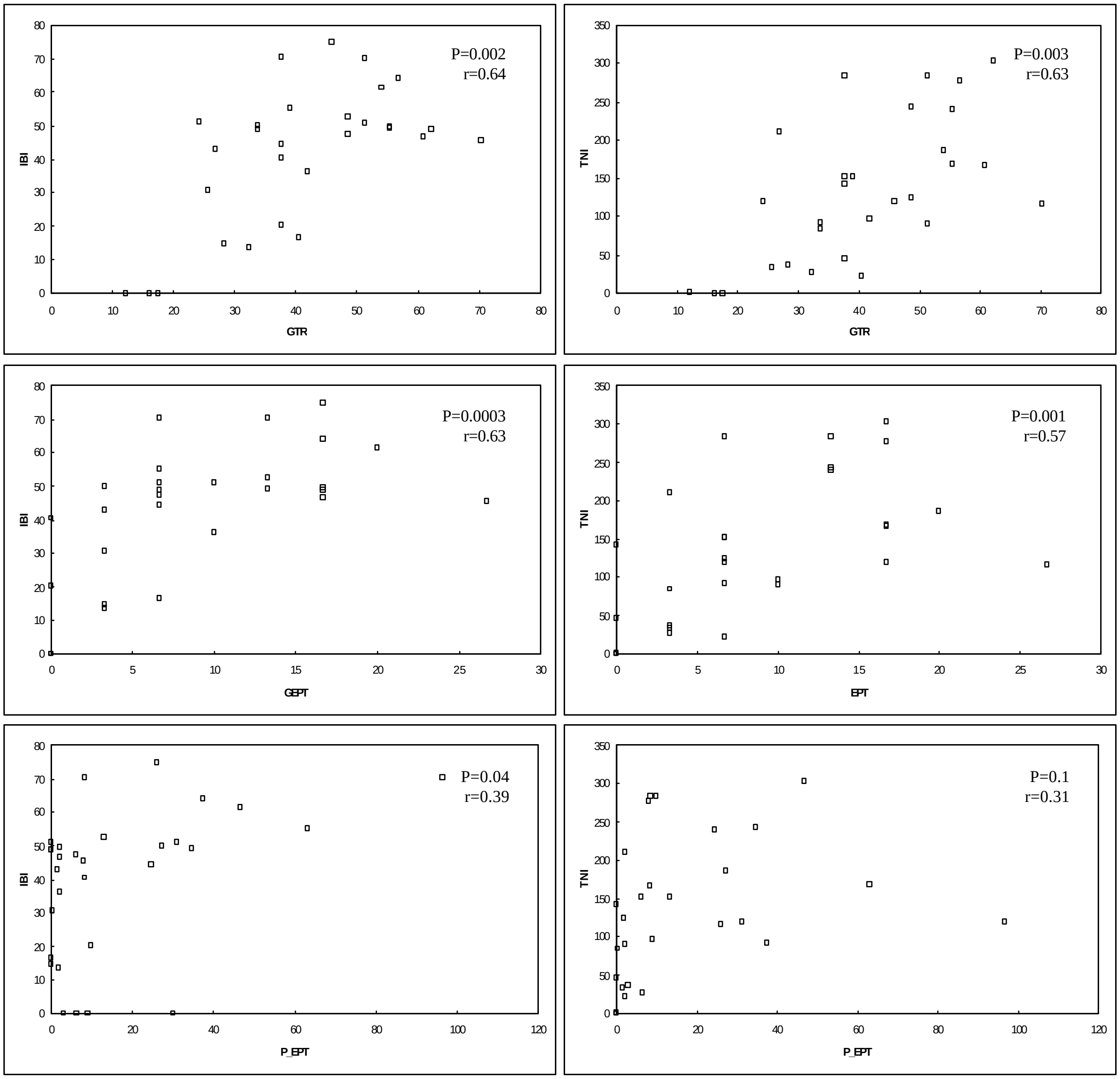


Figure 3. Relationship between P_EPT, GEPT, and GTR with IBI and TNI.

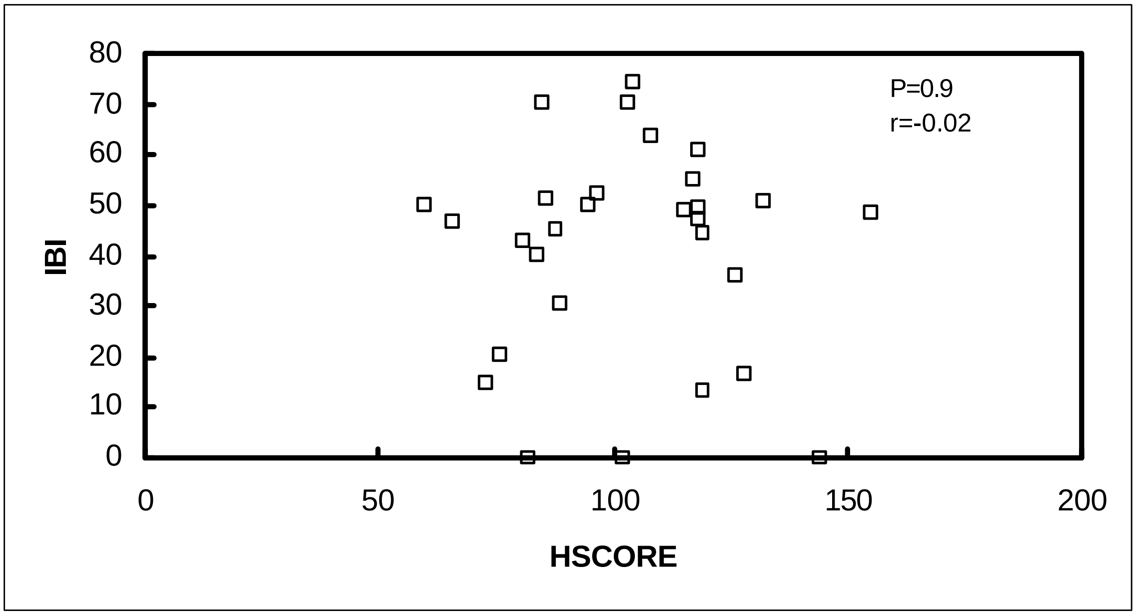


Figure 4. Relationship between total habitat scores and IBI scores.

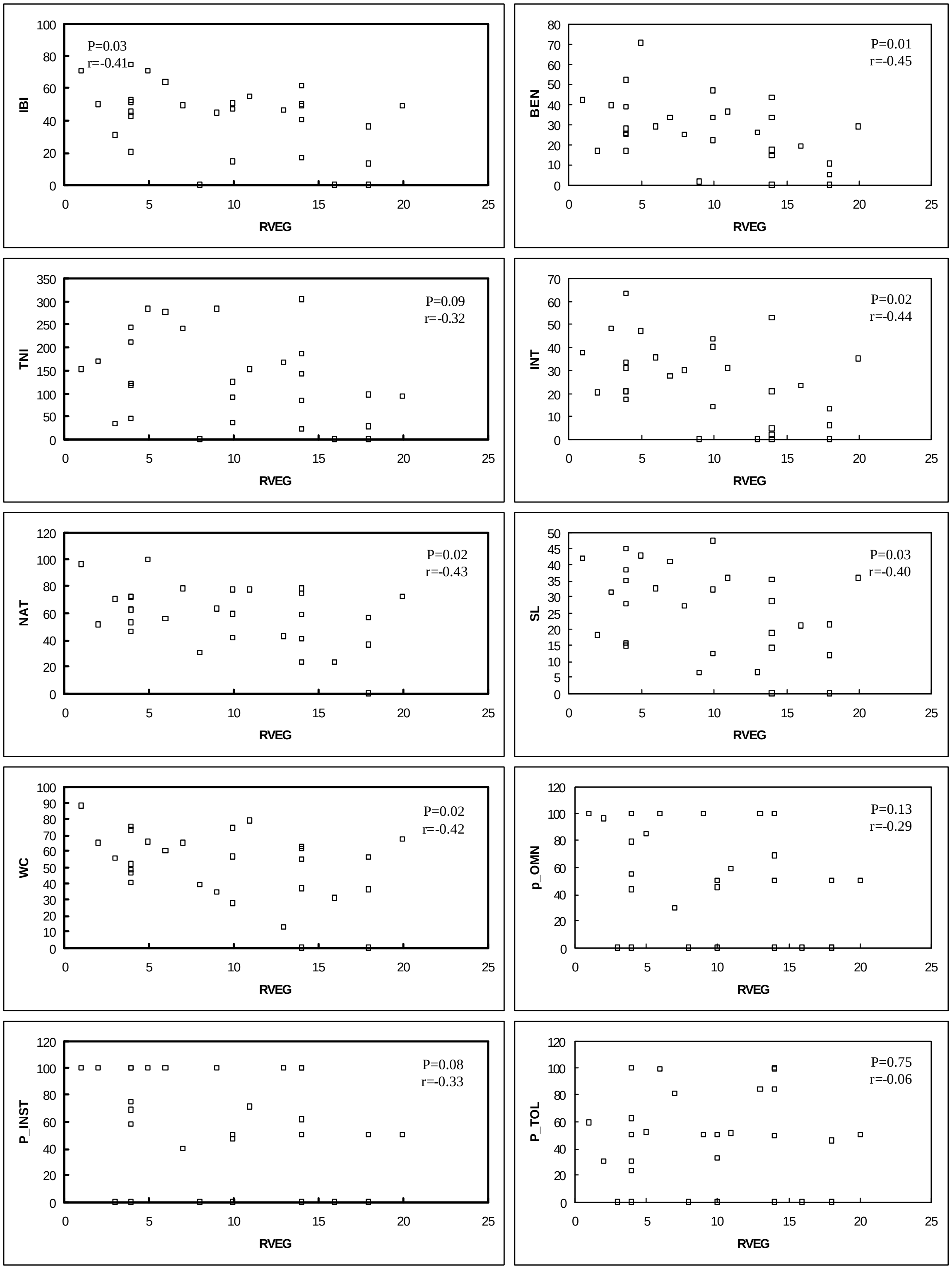


Figure 5. Relationship between IBI metrics and riparian zone width (RVEG).

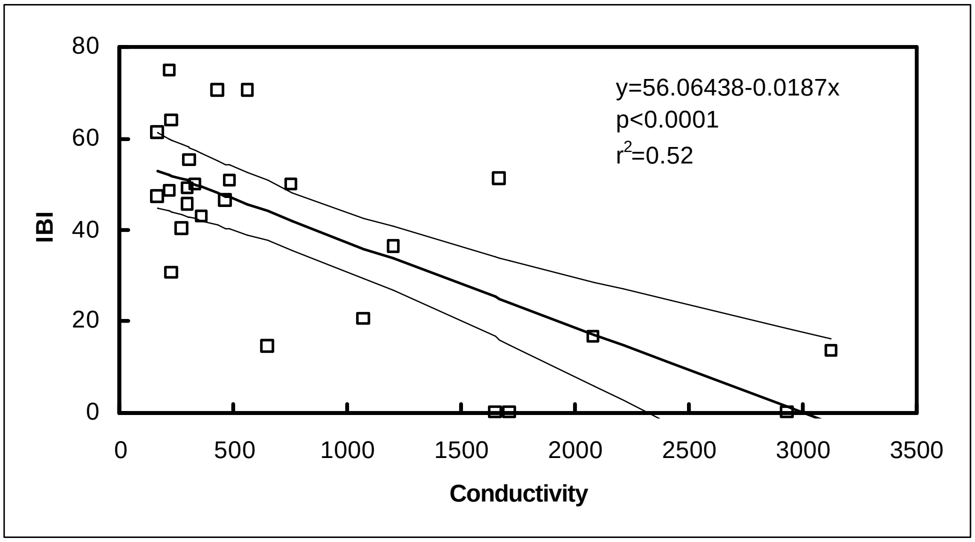


Figure 6. Relationship between conductivity and IBI. Regression line and 95% confidence intervals shown.

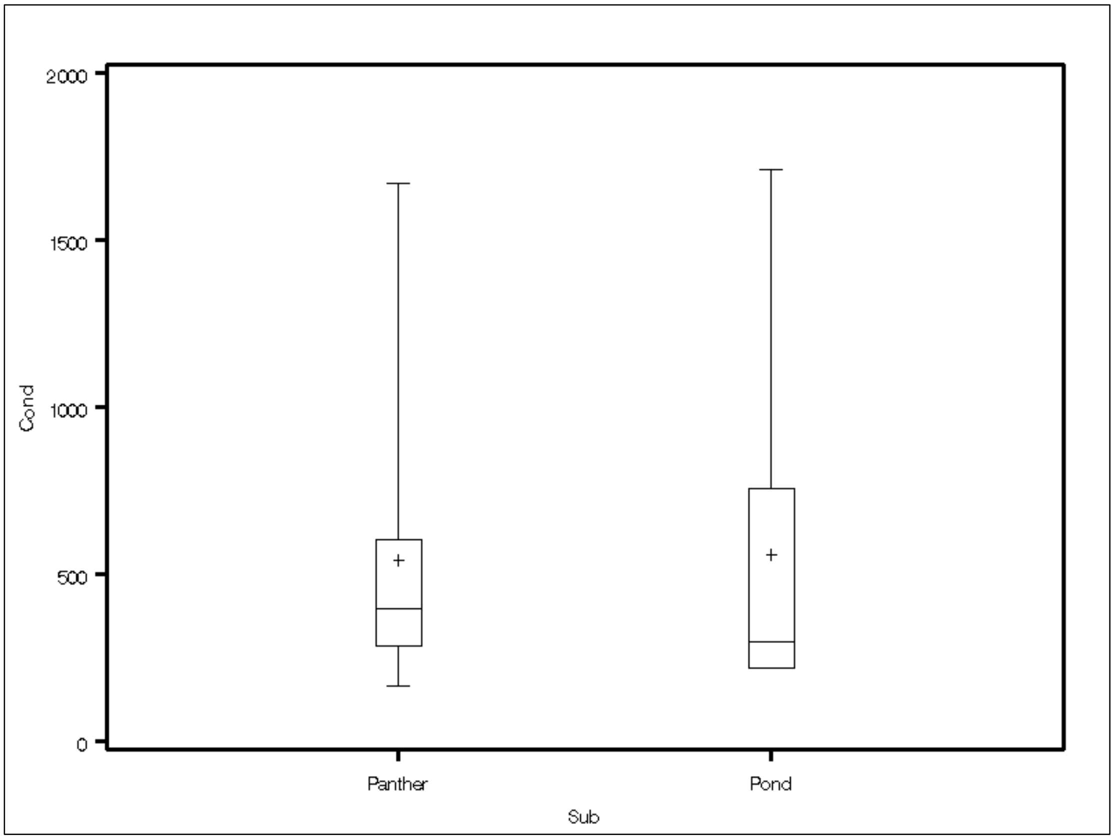


Figure 7. Box plot of conductivity in the Panther and Pond Creek Watersheds in the lower Green Watershed, 2001.

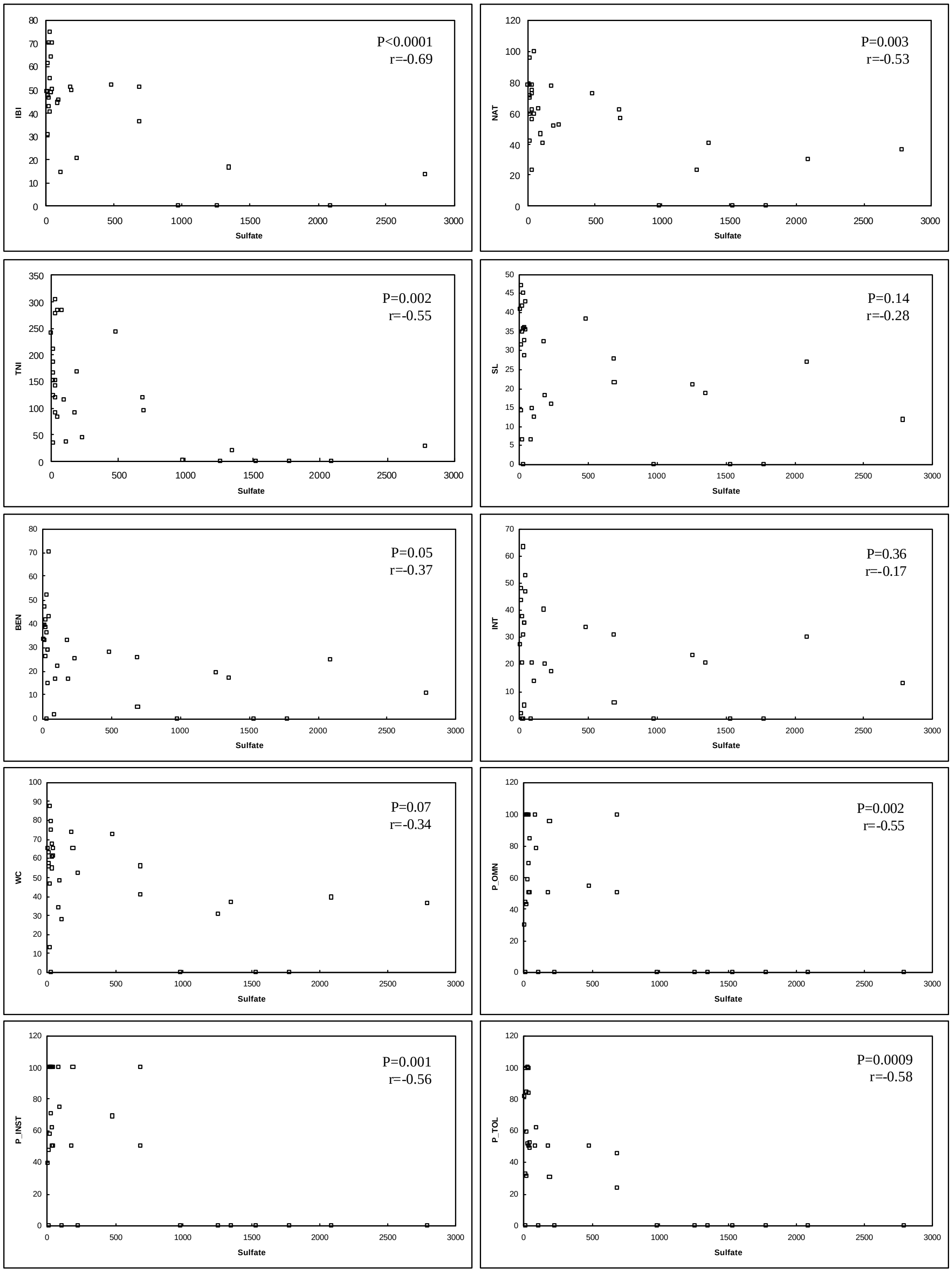


Figure 8. Relationship between IBI metrics and sulfate concentrations (mg/L).

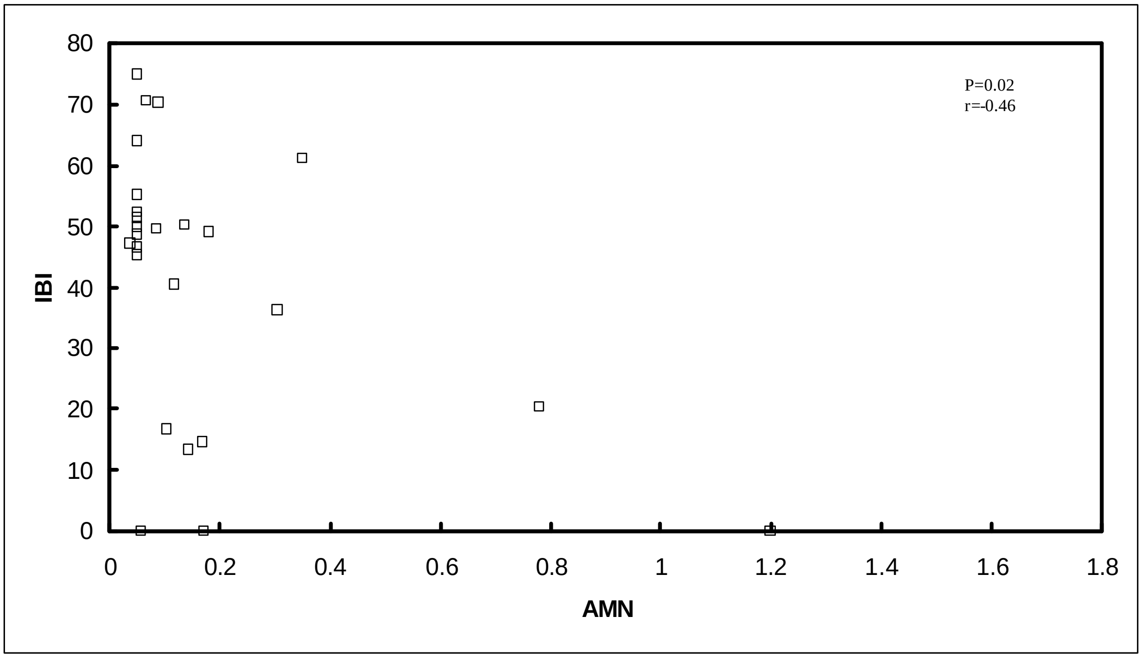


Figure 9. Relationship between IBI and ammonia concentration (AMN) (mg/L).

TABLES

1. Site location information for sampling sites in the lower Green River Watershed, Kentucky.

2. Fishing effort for site in the lower Green River Watershed, KY, 2001.

3. Sample data, time, subwatershed and parameter collected at sample locations in the lower Green River Watershed, Kentucky. 1=parameter collected 0=parameter not collected.

4. Raw chemical parameters collected. Temperature (°C), Conductivity (µs/cm), turbitity (NTU), all others mg/L

5. Use designations for streams in the lower Green River Watershed, Kentucky.

6. Raw fish metric scores from the lower Green River Watershed, Kentucky.

7. Calculated fish metric scores from the lower Green River Watershed, Kentucky.

8. Raw invertebrate scores from the lower Green River Watershed, Kentucky.

9. Calculated invertebrate metric scores from the lower Green River Watershed, Kentucky.

10. Raw habitat data collected in the lower Green River Watershed, Kentucky.

Table 1. Site location information for sampling sites in the lower Green River Watershed, Kentucky.

SiteID	StreamName	Location	County	Lat_Dec	Long_Dec	River Mile	Strm_Order	Catchment Area
03002003	RHODES CREEK	@ SR 554 BRIDGE	DAVIESS	37.67940	-87.13500	0.6	4	15.8
03002004	RHODES CREEK	at Hwy 1207	DAVIESS	37.62803	-87.15540	5.0	4	12.4
03002005	TWOMILE CREEK	at Browns Valley-Red Hill Road	DAVIESS	37.62852	-87.06874	2.0	3	10.3
03002006	SOUTH FORK PANTHER CREEK	at Hwy 298	DAVIESS	37.67936	-87.09069	24.3	5	139.0
03002007	BURNETT FORK	at Hwy 54	DAVIESS	37.73775	-87.01917	1.2	1	10.1
03002008	SWEEPSTAKES BRANCH	at Bratcher Hill Road	DAVIESS	37.66008	-86.98630	1.2	2	4.0
03002009	CANE RUN	at Hwy 762	DAVIESS	37.65800	-86.96172	1.3	2	3.0
03002010	SOUTH FORK PANTHER CREEK	at Hwy 762	DAVIESS	37.62820	-86.94351	35.2	5	80.3
03002011	NORTH FORK PANTHER CREEK	at Haynes Station Road	DAVIESS	37.71495	-86.89522	11.2	4	28.3
03002012	PANTHER CREEK	At Hwy 2127 (Todd Bridge Road)	DAVIESS	37.68759	-87.15498	18.7	5	292.8
03002013	NORTH FORK PANTHER CREEK	at Millers Mill Road	DAVIESS	37.71998	-87.02303	4.0	4	78.3
03002014	JOES BRANCH	at Monarch Road	DAVIESS	37.73266	-86.92763	1.4	2	6.5
03002015	JOES RUN	at Jack Hinton Road	DAVIESS	37.73109	-86.90363	1.7	2	4.4
03002016	WOLF BRANCH DITCH	at Fitts Road	DAVIESS	37.65717	-87.15553	0.4	3	3.4
03002017	FORD DITCH	at Burns Road	DAVIESS	37.65640	-87.14223	0.2	1	5.2
03003003	BRUSH FORK	at Hwy 140	MCLEAN	37.60337	-87.21493	1.0	2	5.5
03003004	LONG FALLS CREEK	at Scotts Bridge Road	MCLEAN	37.58127	-87.27737	4.1	3	26.6
03004004	CRABORCHARD CREEK	at US Hwy 41	HOPKINS	37.15767	-87.46374	1.0	3	10.1
03004005	FLAT CREEK	0.1 km above Pennyrile Parkway	HOPKINS	37.25282	-87.45163	5.2	3	8.5
03005003	LITTLE CYPRESS CREEK	at Whitmer Road	MUHLENBERG	37.30189	-87.13723	3.0	3	16.6
03005004	CYPRESS CREEK	UT at Ridge Drive	MUHLENBERG	37.30082	-87.24022	1.1	2	2.3
03005005	MUDDY FORK	at Hwy 81	MUHLENBERG	37.34587	-87.19042	1.7	1	5.2
03010002	RENDER CREEK	at Middle Road	OHIO	37.36197	-86.93359	1.2	3	.
03010003	RENDER CREEK	at McHenry Park	OHIO	37.37666	-86.92357	2.4	1	1.5
03011001	CANEY CREEK	AT KY 1380 BRIDGE	MUHLENBERG	37.21530	-87.14750	2.4	3	10.4
03011004	SANDLICK CREEK	at Johnson Road	MUHLENBERG	37.14993	-87.15729	0.2	2	6.7
03011005	SALTLICK CREEK	at John Moore Road	MUHLENBERG	37.11897	-87.17018	2.3	1	1.5
03011006	POND CREEK	at Hwy 1163	MUHLENBERG	37.16286	-87.11259	17	4	23.9
03011007	BAT EAST CREEK	at Hwy 1163	MUHLENBERG	37.15656	-87.09751	1.3	3	21.4
03011008	BAT EAST CREEK	at Three Creeks Road	MUHLENBERG	37.12854	-87.11128	3.8	3	9.3
03011009	POND CREEK	at Hwy 2107	MUHLENBERG	37.23228	-87.05338	10.2	5	86.4

Table 2. Fishing effort for sites in the lower Green River Watershed, KY, 2001.

SiteID	StreamName	length	Shocking Seconds	Seine Minutes
03002003	RHODES CREEK	125	1710	
03002004	RHODES CREEK	125	827	
03002005	TWOMILE CREEK	150	880	
03002006	SOUTH FORK PANTHER CREEK	100	591	
03002007	BURNETT FORK	150	963	
03002008	SWEEPSTAKES BRANCH	100	587	
03002009	CANE RUN	150	1078	
03002010	SOUTH FORK PANTHER CREEK	150	1318	
03002011	NORTH FORK PANTHER CREEK	100	723	
03002012	PANTHER CREEK	100	861	45
03002013	NORTH FORK PANTHER CREEK	150	1012	30
03002014	JOES BRANCH	75	655	
03002015	JOES RUN	125	950	
03002016	WOLF BRANCH DITCH	150	1091	
03002017	FORD DITCH	100		45
03003003	BRUSH FORK	100		30
03003004	LONG FALLS CREEK	175	1006	
03004004	CRABORCHARD CREEK			45
03004005	FLAT CREEK			20
03005003	LITTLE CYPRESS CREEK			60
03005004	CYPRESS CREEK	120	453	
03005005	MUDDY FORK	125	785	
03011001	CANEY CREEK	150		60
03011004	SANDLICK CREEK	175	968	
03011005	SALTLICK CREEK	100	451	
03011006	POND CREEK	100	751	
03011007	BAT EAST CREEK	150		90
03011008	BAT EAST CREEK	100	776	30
03011009	POND CREEK	125		45
	Min	75	451	20
	Max	175	1710	90
	Mean	126	878	46

Table 3. Sample data, time, subwatershed and parameter collected at sample locations in the Lower Green River Watershed, Kentucky. 1=parameter collected 0=parameter not collected.

SiteID	StreamName	Sub Watershed	Date	Time	P-Chem	Invert	Fish	Habitat
3002003	RHODES CREEK	Panther	07/11/01	15:30	1	1	1	1
3002004	RHODES CREEK	Panther	07/12/01	8:45	1	1	1	1
3002005	TWOMILE CREEK	Panther	07/12/01	14:00	1	1	1	1
3002006	SOUTH FORK PANTHER CREEK	Panther	07/12/01	16:30	1	1	1	1
3002007	BURNETT FORK	Panther	07/24/01	12:35	1	1	1	1
3002008	SWEEPSTAKES BRANCH	Panther	07/24/01	14:50	1	1	1	1
3002009	CANE RUN	Panther	07/25/01	9:00	1	1	1	1
3002010	SOUTH FORK PANTHER CREEK	Panther	07/25/01	14:00	1	1	1	1
3002011	NORTH FORK PANTHER CREEK	Panther	07/25/01	15:50	1	1	1	1
3002012	PANTHER CREEK	Panther	08/06/01	15:55	1	1	1	1
3002013	NORTH FORK PANTHER CREEK	Panther	08/06/01	16:30	1	1	1	1
3002014	JOES BRANCH	Panther	08/07/01	9:15	1	1	1	1
3002015	JOES RUN	Panther	08/07/01	11:45	1	1	1	1
3002016	WOLF BRANCH DITCH	Panther	07/11/01	12:30	1	1	1	1
3002017	FORD DITCH	Panther	07/12/01	11:15	1	1	1	1
3003003	BRUSH FORK	Long Falls	06/28/01	9:20	1	1	1	1
3003004	LONG FALLS CREEK	Long Falls	07/13/01	9:00	1	1	1	1
3004004	CRABORCHARD CREEK	Drakes	06/19/01	14:22	1	1	1	1
3004005	FLAT CREEK	Flat	06/19/01	16:34	1	1	1	1
3005003	LITTLE CYPRESS CREEK	Cypress	06/20/01	9:28	1	1	1	1
3005004	CYPRESS CREEK	Cypress	06/20/01	12:45	1	1	1	1
3005005	MUDDY FORK	Cypress	06/20/01	14:41	1	1	1	1
3010002	RENDER CREEK	Renders	06/27/01	12:00	1	0	0	0
3010003	RENDER CREEK	Renders	06/27/01	12:35	1	1	0	1
3011001	CANEY CREEK	Pond	06/26/01	12:07	1	1	1	1
3011004	SANDLICK CREEK	Pond	06/21/01	9:15	1	1	1	1
3011005	SALTLICK CREEK	Pond	06/21/01	12:00	1	1	1	1
3011006	POND CREEK	Pond	06/22/01	9:00	1	1	1	1
3011007	BAT EAST CREEK	Pond	06/26/01	14:00	1	1	1	1
3011008	BAT EAST CREEK	Pond	06/26/01	16:45	1	1	1	1
3011009	POND CREEK	Pond	06/27/01	9:16	1	1	1	1

Table 4. Raw chemical parameters collected. Temperature (^{o}C), Conductivity (µs/cm), turbitity (NTU), all others mg/L.

SiteID	Temperature	Specific Conductance	pH	DO	% Saturation	Alkalinity	Ammonia	Chloride	Nitrate	Sulfate	TKN	Total P	TSS	Turbidity
03002003	27.5	646	7.3	5.5	72.8	168.0	0.167	34.4	0.307	112.0	1.050	0.232	28	.
03002004	21.6	1074	7.2	1.5	17	245.0	0.780	62.6	0.014	231.0	1.750	0.395	26	.
03002005	22.4	433	7.4	5.9	70.6	122.0	0.090	32.6	0.081	47.8	0.735	0.041	20	.
03002006	23.7	466	7.4	6.0	73.4	187.0	0.051	23.3	0.048	19.4	1.350	0.176	164	.
03002007	25.8	357	7.5	5.2	65.6	129.0	.	.	.	23.7	1.490	0.118	52	.
03002008	25.9	230	6.5	1.2	14.5	63.2	.	.	.	14.9	.	.	290	.
03002009	23.7	329	7.2	3.0	36.8	89.4	0.137	.	0.051	46.9	1.030	0.083	52	.
03002010	26.0	167	6.9	4.4	55.3	43.6	0.349	.	0.963	14.2	1.680	0.200	280	.
03002011	31.9	295	7.3	7.3	103	66.4	0.180	.	0.362	36.3	1.230	0.125	28	.
03002012	29.0	274	.	.	.	78.9	0.118	11.9	0.278	34.0	1.100	0.152	96	.
03002013	.	.	.	.	.	67.0	.	15.0	0.043	86.5	0.579	0.024	260	.
03002014	.	.	.	.	.	93.3	0.086	10.1	0.065	5.6	1.060	0.046	42	.
03002015	.	.	.	.	.	69.5	BD	9.0	0.077	483.0	0.699	BD	10	.
03002016	27.1	558	7.3	3.5	45.4	192.0	0.067	47.4	0.017	19.5	1.380	0.128	62	.
03002017	20.9	1669	7.7	5.0	58.1	236.0	BD	42.5	0.212	687.0	0.930	0.126	100	.
03003003	19.6	2930	3.1	7.5	85	BD	1.200	23.5	0.948	2090.0	1.710	0.006	5	5.2
03003004	20.0	1200	7.3	5.9	68	25.5	0.306	24.9	0.747	691.0	0.906	0.043	26	.
03004004	24.8	2080	6.9	4.3	54	64.3	0.105	6.5	0.152	1350.0	1.090	BD	96	.
03004005	25.8	1650	4.2	6.4	81.2	BD	0.173	7.2	0.594	1260.0	0.277	BD	1	.
03005003	24.8	3120	7.3	4.3	53.2	281.0	0.143	5.2	0.826	2790.0	0.576	BD	1	.
03005004	21.3	166	7.1	6.4	74	50.7	0.038	8.4	0.288	17.6	0.186	BD	36	.
03005005	27.0	306	8.3	10.6	134	91.3	BD	23.7	BD	31.1	1.380	0.033	72	.
03010002	17.1	2210	6.5	7.1	76.3	20.2	1.510	4.9	0.178	1530.0	2.130	BD	20	32.1
03010003	17.8	2420	6.2	6.5	70.8	38.4	1.670	3.7	0.047	1780.0	2.120	BD	28	31.5
03011001	26.4	757	8.5	11.2	144.5	49.4	BD	49.8	16.300	192.0	0.862	0.716	4	.
03011004	21.2	481	7.1	5.2	59.8	46.8	.	11.4	0.585	181.0	0.381	.	21	.
03011005	22.4	219	7.1	8.4	101.8	62.0	BD	10.5	0.289	32.3	0.262	BD	2	.
03011006	20.5	299	7.4	6.9	79	40.5	BD	12.4	0.321	94.8	0.353	BD	7	.
03011007	23.5	231	7.1	6.5	78	59.6	BD	.	0.167	35.3	0.753	BD	72	.
03011008	22.0	219	7.1	6.1	72	44.0	BD	5.6	0.032	37.7	0.316	BD	34	.
03011009	23.3	1710	3.8	7.7	93.1	BD	0.056	16.3	3.220	977.0	BD	BD	2	.

Table 5. Use designations for streams in the lower Green River Watershed, Kentucky.

SiteID	StreamName	IBI	Score	MBI	Score	Habitat	Score	Aquatic Life	Overall
03002003	RHODES CREEK	14.62	VP	17.46	P	73	NS	NS	NS
03002004	RHODES CREEK	20.36	P	11.38	VP	76	NS	NS	NS
03002005	TWOMILE CREEK	70.21	EX	29.05	F	103	NS	T	T
03002006	SOUTH FORK PANTHER CREEK	46.52	F	42.99	F	66	NS	PS	PS
03002007	BURNETT FORK	42.87	F	22.5	P	81	NS	PS	PS
03002008	SWEEPSTAKES BRANCH	30.57	P	25.07	F	89	NS	PS	PS
03002009	CANE RUN	50.04	F	28.89	F	95	NS	PS	PS
03002010	SOUTH FORK PANTHER CREEK	61.15	G	47.37	F	118	PS	T	T
03002011	NORTH FORK PANTHER CREEK	48.88	F	40.83	F	115	PS	PS	PS
03002012	PANTHER CREEK	40.39	F	17.09	P	84	NS	NS	NS
03002013	NORTH FORK PANTHER CREEK	44.41	F	28.48	F	119	S BUT T	PS	PS
03002014	JOES BRANCH	49.45	F	39.12	F	118	PS	PS	PS
03002015	JOES RUN	52.29	G	46.42	F	97	NS	PS	PS
03002016	WOLF BRANCH DITCH	70.44	EX	22.01	P	85	NS	PS	PS
03002017	FORD DITCH	51.29	F	43.69	F	86	NS	PS	PS
03003003	BRUSH FORK	0	NO FISH	21.85	P	82	NS	NS	NS
03003004	LONG FALLS CREEK	36.22	F	27.08	F	126	S BUT T	PS	PS
03004004	CRABORCHARD CREEK	16.66	VP	30.37	F	128	S BUT T	NS	NS
03004005	FLAT CREEK	0	NO FISH	22.19	P	144	FS	NS	NS
03005003	LITTLE CYPRESS CREEK	13.53	VP	40.36	F	119	S BUT T	PS	PS
03005004	CYPRESS CREEK	47.28	F	25.86	F	118	PS	PS	PS
03005005	MUDDY FORK	55.04	G	25.86	F	117	NS	T	T
03010002	RENDER CREEK	.	.	.	.	.	.		
03010003	RENDER CREEK	.	.	6.19	VP	104	NS	NS	NS
03011001	CANEY CREEK	49.76	F	42.23	F	60	NS	PS	PS
03011004	SANDLICK CREEK	50.9	F	35.21	F	132	S BUT T	PS	PS
03011005	SALTLICK CREEK	74.68	EX	35.45	F	104	NS	T	T
03011006	POND CREEK	45.25	F	44.74	F	88	NS	PS	PS
03011007	BAT EAST CREEK	63.97	G	29.99	F	108	NS	PS	PS
03011008	BAT EAST CREEK	48.73	F	38.38	F	155	FS	PS	PS
03011009	POND CREEK	0	VP	25.72	F	102	NS	NS	NS

VP=VERY POOR
P=POOR
F=FAIR
G=GOOD
EX=EXCELLENT

NS= NOT SUPPORT
PS= PARTIAL SUPPORT
FS= FULL SUPPORT
T=THREATENED
S BUT T = SUPPORT BUT THREATENED

Table 6. Raw fish metric scores from the lower Green River Watershed, Kentucky.

SiteID	TNI	NAT	DMS	INT	WC	SL	P_INS	P_OMN	P_TOL
03002003	36	7	1	0	1	0	94.44	5.56	63.89
03002004	45	9	1	0	3	0	73.33	13.33	55.56
03002005	283	21	5	2	4	3	84.81	15.19	58.66
03002006	166	16	4	1	4	3	90.96	7.83	84.34
03002007	211	13	2	0	2	2	36.97	62.56	80.57
03002008	34	9	1	1	1	0	94.12	5.88	61.76
03002009	84	5	1	1	1	0	39.29	60.71	78.57
03002010	186	23	4	1	8	3	80.65	16.67	31.72
03002011	303	18	1	0	5	3	47.85	51.49	23.43
03002012	142	14	1	1	4	0	96.48	2.11	87.32
03002013	283	19	1	0	5	2	84.81	14.13	79.86
03002014	240	13	1	0	3	2	16.25	83.75	34.58
03002015	243	10	0	0	3	1	36.21	63.79	71.60
03002016	152	15	1	0	4	1	84.21	9.87	66.45
03002017	120	8	0	0	0	0	98.33	1.67	95.83
03003003	0	0	0	0	0	0	0.00	0.00	0.00
03003004	96	13	0	0	5	2	55.21	34.38	61.46
03004004	21	5	0	0	1	0	95.24	0.00	28.57
03004005	0	0	0	0	0	0	0.00	0.00	0.00
03005003	27	6	0	0	2	0	96.30	0.00	7.41
03005004	125	4	1	0	0	1	8.00	92.00	99.20
03005005	152	12	1	0	4	1	40.13	55.92	67.76
03010002	.	.	.	.	.	.	.	.	.
03010003	.	.	.	.	.	.	.	.	.
03011001	168	8	0	0	4	0	95.83	2.38	80.36
03011004	90	13	1	1	4	1	68.89	28.89	53.33
03011005	120	3	1	1	1	0	90.83	9.17	9.17
03011006	116	10	1	1	4	1	58.62	31.90	44.83
03011007	277	12	2	2	5	3	92.06	3.97	7.22
03011008	92	13	1	1	4	2	86.96	8.70	11.96
03011009	1	1	0	0	0	0	0.00	0.00	0.00

Table 7. Calculated fish metric scores from the lower Green River Watershed, Kentucky.

SiteID	IBI	SCORE	TNI	NAT	BEN	INT	SL	WC	P_OMN	P_INST	P_TOL
03002003	14.62	VERY POOR	36	40.99	22.10	13.74	12.37	27.73	0.00	0.00	0.00
03002004	20.36	POOR	45	52.51	25.20	17.47	15.73	52.00	0.00	0.00	0.00
03002005	70.21	EXCELLENT	283	100.00	70.17	46.65	42.63	65.43	84.67	100.00	52.14
03002006	46.52	FAIR	166	42.37	26.22	0.00	6.57	12.94	100.00	100.00	84.09
03002007	42.87	FAIR	211	71.21	38.47	20.64	34.79	46.44	43.32	57.48	30.58
03002008	30.57	POOR	34	69.98	39.68	48.08	31.40	55.44	0.00	0.00	0.00
03002009	50.04	FAIR	84	58.89	43.36	52.52	35.39	61.24	50.00	50.00	48.91
03002010	61.15	GOOD	186	78.04	33.24	1.82	14.18	62.76	100.00	100.00	99.14
03002011	48.88	FAIR	303	74.72	14.64	4.75	28.63	54.73	68.37	61.52	83.72
03002012	40.39	FAIR	142	23.09	0.00	0.00	0.00	0.00	100.00	100.00	100.00
03002013	44.41	FAIR	283	62.89	1.62	0.00	6.42	34.20	100.00	100.00	50.19
03002014	49.45	FAIR	240	78.02	33.46	27.43	40.90	65.02	30.00	39.47	81.29
03002015	52.29	GOOD	243	72.40	27.81	33.45	38.19	72.89	54.67	68.99	49.94
03002016	70.44	EXCELLENT	152	95.80	41.76	37.43	41.77	87.79	100.00	100.00	58.97
03002017	51.29	FAIR	120	62.05	25.67	30.88	27.77	40.46	100.00	100.00	23.49
03003003	0.00	NO FISH	0	30.10	24.95	30.01	26.99	39.32	0.00	0.00	0.00
03003004	36.22	FAIR	96	56.26	4.78	5.70	21.37	55.98	50.00	50.00	45.68
03004004	16.66	VERY POOR	21	40.13	17.18	20.64	18.57	36.75	0.00	0.00	0.00
03004005	0.00	NO FISH	0	23.37	19.38	23.30	20.96	30.54	0.00	0.00	0.00
03005003	13.53	VERY POOR	27	36.34	10.82	12.97	11.69	36.42	0.00	0.00	0.00
03005004	47.28	FAIR	125	59.11	46.76	43.46	47.18	56.91	44.78	47.32	32.75
03005005	55.04	GOOD	152	77.59	36.32	30.88	35.88	79.21	58.27	70.85	51.36
03010002	0.00	NO COLLECT	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03010003	0.00	NO COLLECT	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03011001	49.76	FAIR	168	51.34	16.80	20.19	18.16	65.23	95.83	100.00	30.51
03011004	50.90	FAIR	90	77.55	33.08	40.13	32.37	74.10	50.00	50.00	50.00
03011005	74.68	EXCELLENT	120	61.82	52.23	63.21	44.99	75.22	100.00	100.00	100.00
03011006	45.25	FAIR	116	46.25	16.80	20.51	14.75	48.45	78.60	74.73	61.89
03011007	63.97	GOOD	277	55.73	28.87	35.37	32.50	60.37	99.77	100.00	99.15
03011008	48.73	FAIR	92	72.49	28.88	35.07	35.93	67.49	50.00	50.00	50.00
03011009	0.00	VERY POOR	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 8. Raw invertebrate scores from the lower Green River Watershed, Kentucky.

SiteID	TR	EPT	P_EPT	HBI2	P_Clng	P_CO
03002003	21	1	2.3	2.2	0.0	18.4
03002004	28	0	0.0	1.9	1.6	-3.6
03002005	38	4	7.3	2.0	1.3	34.1
03002006	45	5	6.0	2.6	33.6	44.0
03002007	20	1	1.5	1.9	3.1	34.7
03002008	19	1	1.1	1.9	0.6	44.9
03002009	25	1	0.4	2.1	4.8	48.4
03002010	40	6	20.0	3.2	29.6	47.4
03002011	46	5	34.1	2.2	4.4	40.0
03002012	28	0	0.0	1.8	5.8	15.1
03002013	28	2	6.2	2.3	8.1	36.3
03002014	41	4	18.1	2.7	9.9	43.3
03002015	36	4	25.3	2.7	37.5	44.9
03002016	28	2	9.7	1.6	0.0	25.2
03002017	18	2	70.5	2.5	0.0	48.3
03003003	13	0	0.0	2.6	7.5	32.5
03003004	31	3	6.6	1.9	3.3	34.0
03004004	30	2	1.6	2.2	12.8	40.9
03004005	12	0	0.0	2.7	1.0	37.1
03005003	24	1	4.6	2.9	45.2	47.5
03005004	36	2	1.4	2.9	6.8	23.0
03005005	29	2	4.4	1.9	0.4	31.9
03010003	12	0	0.0	1.1	3.6	-22.7
03011001	41	5	46.2	1.6	1.2	46.0
03011004	38	3	1.6	2.8	26.0	34.9
03011005	34	5	22.8	2.5	12.2	32.3
03011006	52	8	19.0	2.8	14.2	42.0
03011007	42	5	5.9	2.2	10.3	25.9
03011008	25	2	27.3	3.0	30.3	33.3
03011009	9	0	0.0	2.4	5.9	50.0

Table 9. Calculated invertebrate metric scores from the lower Green River Watershed, Kentucky.

SiteID	MBI	SCORE	TR	EPT	P_EPT	HBI2	P_Clng	P_CO
03002003	17.46	POOR	28.38	3.33	3.09	32.37	0.00	37.59
03002004	11.38	VPOOR	37.84	0.00	0.00	28.27	2.19	0.00
03002005	29.05	FAIR	51.35	13.33	10.01	28.33	1.80	69.50
03002006	42.99	FAIR	60.81	16.67	8.27	37.14	45.35	89.71
03002007	22.50	POOR	27.03	3.33	2.09	27.52	4.13	70.88
03002008	25.07	FAIR	25.68	3.33	1.56	27.47	0.77	91.60
03002009	28.89	FAIR	33.78	3.33	0.54	30.41	6.44	98.80
03002010	47.37	FAIR	54.05	20.00	27.44	45.98	40.02	96.71
03002011	40.83	FAIR	62.16	16.67	46.75	31.81	5.94	81.66
03002012	17.06	POOR	37.84	0.00	0.00	25.79	7.86	30.85
03002013	28.48	FAIR	37.84	6.67	8.51	32.78	10.91	74.15
03002014	39.12	FAIR	55.41	13.33	24.73	39.52	13.38	88.35
03002015	46.42	FAIR	48.65	13.33	34.67	39.57	50.68	91.65
03002016	22.01	POOR	37.84	6.67	13.23	22.94	0.00	51.37
03002017	43.69	FAIR	24.32	6.67	96.60	35.90	0.00	98.67
03003003	21.85	POOR	17.57	0.00	0.00	37.08	10.14	66.33
03003004	27.08	FAIR	41.89	10.00	9.05	27.77	4.46	69.31
03004004	30.37	FAIR	40.54	6.67	2.17	32.10	17.34	83.41
03004005	22.19	POOR	16.22	0.00	0.00	39.81	1.34	75.77
03005003	40.36	FAIR	32.43	3.33	6.36	41.94	61.08	96.99
03005004	25.86	FAIR	48.65	6.67	1.87	41.72	9.22	47.02
03005005	24.15	FAIR	39.19	6.67	6.06	27.39	0.60	65.02
03010003	6.19	VPOOR	16.22	0.00	0.00	16.02	4.91	0.00
03011001	42.23	FAIR	55.41	16.67	63.22	22.64	1.64	93.78
03011004	35.21	FAIR	51.35	10.00	2.20	41.32	35.08	71.30
03011005	35.45	FAIR	45.95	16.67	31.21	36.44	16.54	65.87
03011006	44.74	FAIR	70.27	26.67	25.96	40.66	19.24	85.65
03011007	29.99	FAIR	56.76	16.67	8.11	31.77	13.85	52.76
03011008	38.38	FAIR	33.78	6.67	37.36	43.48	40.95	68.03
03011009	25.72	FAIR	12.16	0.00	0.00	34.19	7.95	100.00

Table 10. Raw habitat data collected in the lower Green River Watershed, Kentucky.

SiteID	BankSta	BankVegP	ChaFlowS	ChanAlter	ChanSin	EpiFauSub	PoolSubChar	PoolVar	RipVegZW	SedDep	Score
03002003	4	10	14	6	5	3	7	7	10	7	73
03002004	12	12	8	8	5	6	10	8	4	3	76
03002005	14	14	11	10	5	9	13	12	5	10	103
03002006	8	8	8	6	1	4	6	10	13	2	66
03002007	8	10	11	9	8	9	8	7	4	7	81
03002008	8	10	10	11	4	13	6	11	3	13	89
03002009	8	12	7	8	8	10	16	6	14	6	95
03002010	8	10	14	13	7	14	15	16	14	7	118
03002011	14	16	8	14	8	11	11	16	14	3	115
03002012	10	4	16	9	3	6	8	6	14	8	84
03002013	8	14	16	12	3	13	15	15	9	14	119
03002014	10	14	10	12	8	16	13	15	7	13	118
03002015	8	6	7	13	14	13	11	16	4	5	97
03002016	14	10	11	7	6	11	12	5	1	8	85
03002017	14	16	8	6	8	5	11	6	4	8	86
03003003	11	10	8	9	5	7	10	8	8	6	82
03003004	12	6	16	10	7	17	16	16	18	8	126
03004004	12	12	18	14	14	11	13	10	14	10	128
03004005	16	17	10	15	13	15	16	15	16	11	144
03005003	16	16	18	13	8	6	8	8	18	8	119
03005004	16	16	14	12	8	16	15	6	10	5	118
03005005	12	14	16	9	9	12	12	12	11	10	117
03010003	15	14	18	16	15	7	6	8	3	2	104
03011001	5	5	15	8	1	3	10	6	2	5	60
03011004	10	14	15	14	8	18	14	16	10	13	132
03011005	16	18	15	11	6	9	5	5	4	15	104
03011006	8	10	14	6	5	14	13	9	4	5	88
03011007	14	10	16	12	5	8	12	13	6	12	108
03011008	12	14	18	13	13	16	18	16	20	15	155
03011009	6	12	15	7	2	10	8	16	18	8	102

APPENDICES

Appendix A. Raw fish data collected in the lower Green River Watershed, Kentucky.
Appendix B. Raw invertebrate data collected in the lower Green River Watershed, Kentucky.
Appendix C. 305b Aquatic life use.

Appendix A. Raw fish data collected in the lower Green River Watershed, Kentucky.

SiteID	StreamName	*Ameiurus natalis*	*Amia calva*	*Aphredoderus sayanus*	*Campostoma oligolepis*	*Carpiodes cyprinus*	*Catostomus commersoni*	*Cyprinella spiloptera*
03002003	RHODES CREEK	2		9				
03002004	RHODES CREEK		3	9				
03002005	TWOMILE CREEK	9		18			2	
03002006	SOUTH FORK PANTHER CREEK	1		3				
03002007	BURNETT FORK			1				
03002008	SWEEPSTAKES BRANCH	1		4				
03002009	CANE RUN							
03002010	SOUTH FORK PANTHER CREEK	5		12	1			
03002011	NORTH FORK PANTHER CREEK			5		1	1	1
03002012	PANTHER CREEK			3				
03002013	NORTH FORK PANTHER CREEK	9	1	3		1		
03002014	JOES BRANCH	2		4				
03002015	JOES RUN	5						
03002016	WOLF BRANCH DITCH		4	26				
03002017	FORD DITCH			1				
03003003	BRUSH FORK							
03003004	LONG FALLS CREEK							
03004004	CRABORCHARD CREEK			1				
03004005	FLAT CREEK							
03005003	LITTLE CYPRESS CREEK			1				
03005004	CYPRESS CREEK							
03005005	MUDDY FORK	4						
03011001	CANEY CREEK							
03011004	SANDLICK CREEK	3		2				
03011005	SALTLICK CREEK							
03011006	POND CREEK	3		3				
03011007	BAT EAST CREEK							
03011008	BAT EAST CREEK	1		2			2	
03011009	POND CREEK							

Appendix A. Continued

SiteID	*Cyprinella whipplei*	*Cyprinus carpio*	*Dorosoma cepedianum*	*Ericymba buccata*	*Erimyzon oblongus*	*Esox americanus vermiculatus*	*Etheostoma gracile*	*Etheostoma nigrum*	*Etheostoma squamiceps*	*Fundulus notatus*
03002003							3			
03002004		4			4	3	1			
03002005					55		8	3	17	2
03002006		1				1	4	1		
03002007				7	11		7			
03002008					8				1	
03002009					17				1	
03002010	12	1		5	8	3	1	3	4	2
03002011	3	1		119	42					30
03002012		1	1			1				3
03002013		14	3	7						3
03002014				124	12					6
03002015		1		22	29					
03002016		1			10	3	3			2
03002017										2
03003003										
03003004	1			2	8					
03004004										
03004005										
03005003						1				2
03005004										
03005005		74			38	3				
03011001	1	1			6					20
03011004					12	1			6	6
03011005					5				104	
03011006					5	11			6	6
03011007	1								1	
03011008					17	3			6	2
03011009										

Appendix A. Continued

SiteID	*Fundulus olivaceus*	*Gambusia affinis*	*Hybognathus nuchalis*	*Labidesthes sicculus*	*Lepisosteus oculatus*	*Lepomis cyanellus*	*Lepomis gulosus*	*Lepomis macrochirus*	*Lepomis megalotis*	*Lepomis sp_*	*Lythrurus fumeus*
03002003		6				7		8	1		
03002004		8				3		8			
03002005		58				45	1	14	2		4
03002006		127				2		1			6
03002007		28				14					3
03002008		3				8		7			1
03002009						15					
03002010		1				13	1	8	68		11
03002011		19				3		12	26		
03002012		28		3		7	3	55	1		33
03002013		18		7	1	10	3	26	24		143
03002014						5		1	7		
03002015						15		26	7	2	
03002016		33				10		25			18
03002017		50				6		57		2	
03003003											
03003004		22	6			6			4		
03004004	12							6	1		
03004005											
03005003				12				2	9		
03005004						1		8			
03005005		4				9		5	3		
03011001		131							3		
03011004						6		16	12		
03011005											
03011006								15	27		
03011007		1		2				8	2		
03011008						1			29		
03011009											

Appendix A. Continued

SiteID	*Lythrurus umbratilis*	*Micropterus punctulatus*	*Micropterus salmoides*	*Minytrema melanops*	*Moxostoma erythrurum*	*NO FISH*	*Notemigonus crysoleucas*	*Noturus gyrinus*	*Percina maculata*	*Phenacobius mirabilis*
03002003										
03002004										
03002005							14	4	1	6
03002006		1		2				2	1	2
03002007			1						2	12
03002008										
03002009							2			
03002010	4	1							1	1
03002011			2				1		1	2
03002012								1		
03002013			1		2				1	
03002014							1		2	2
03002015										9
03002016			2	1			1			
03002017							1			
03003003						x				
03003004			4	1						11
03004004			1							
03004005						x				
03005003										
03005004									1	
03005005		1	2				3		2	
03011001		3					1			
03011004	2		1							
03011005										
03011006	6									
03011007	231		11	2	6			1		
03011008	21		1							
03011009			1							

Appendix A. Continued

SiteID	*Pimephales notatus*	*Pimephales promelas*	*Pimephales vigilax*	*Pomoxis annularis*	*Semotilus atromaculatus*
03002003					
03002004					2
03002005	8	2			10
03002006		2	9		
03002007	58	42			25
03002008					1
03002009					49
03002010	17				3
03002011	29				5
03002012			1	1	
03002013	6				
03002014	38				36
03002015	24				103
03002016	1				12
03002017					1
03003003					
03003004	1	2			28
03004004					
03004005					
03005003					
03005004					115
03005005					4
03011001					2
03011004	1				22
03011005					11
03011006	34				
03011007	11				
03011008	4				3
03011009					

Appendix B. Raw invertebrate data collected in the lower Green River Watershed, Kentucky.

SiteID	Ablabesmyia	Acerpenna	Aeshna	Agabus	Anax	Ancyronyx	Anopheles	Apedilum	Argia	Axarus	Baetis	Basiaeschna
03002003	14											
03002004	10								1			
03002005	4											1
03002006	19					1			51	6		
03002007												
03002008												
03002009			1				1				1	
03002010	7						2		49			6
03002011	16						5		28			5
03002012												
03002013	2								2			4
03002014	5						1	1	9			2
03002015	9						8		36			4
03002016	1								2			
03002017												
03003003			8									
03003004	18		1									
03004004	3						1				2	
03004005			19	1								
03005003	1								31			1
03005004	31		1		3				1			
03005005	3						4					
03010003							2					
03011001	5		1	2								31
03011004	12						1				4	
03011005	8											
03011006	8	7					2		2			38
03011007	5						1		8			
03011008	1											
03011009									4			

Appendix B. Continued

SiteID	Belostoma	Berosus	Boyeria	Branchiura	Caecidotea	Caenis	Callibaetis	Calopteryx	Cambarus	Celina	Centroptilum	Ceraclea
03002003		22	1			3			3			
03002004		4		18								
03002005					8	10	4		1			
03002006				3	6	32	1		1			
03002007					36							
03002008	1				2	2						
03002009			3		2				2			
03002010	1	22	3		2	70			1		20	
03002011		100	1			440	4		1			
03002012	3			4	2							
03002013		47		3		5						
03002014		1			272	99		10	1			
03002015		3	1		13	91			1			
03002016		1		10		9	5		1			
03002017				1		296			6			
03003003												
03003004			2			11	3	9	3			
03004004			10		136	10			5			
03004005					1							
03005003			10		5	15			4	1		
03005004			22		85			7	15		4	
03005005	1		4	1	3	3	7		1			
03010003												
03011001	4	38		2	34	4	81		5		10	
03011004			25		44				1			
03011005			9		16				11		27	
03011006	1	3		1	34	40			9		29	
03011007		10	7	1	38	14	6		4		3	1
03011008			5		20	5			2			
03011009									3			

Appendix B. Continued

SiteID	Cernotina	Chaoborus	Chauloides	Cheumatopsyche	Chironomus	Choroterpes	Clinotanypus	Copelatus	Corbicula	Cordulegaster
03002003					2					
03002004					61		10			
03002005					13					
03002006				8	3			1	1	
03002007					10					
03002008										
03002009		1								
03002010				3					20	
03002011				1	6		12			
03002012					8				1	
03002013					3					
03002014			1							
03002015				5	4					
03002016					5		5	1	1	
03002017										
03003003					3					
03003004			1	5	1			1		
03004004					8					1
03004005			1							
03005003					1				16	
03005004			1	1						1
03005005										
03010003			1		35					
03011001					5		2	1	2	
03011004				13						
03011005					18			1		2
03011006			1			11			16	
03011007	2				1					
03011008					5					
03011009			2							

Appendix B. Continued

SiteID	Corydalus	Crangonyx	Cryptochironomus	Culex	Cyphon	Dicrotendipes	Dineutus	Dixella	Djalmabatista	Dubiraphia	Eclipidrilus
03002003							5				3
03002004				1							5
03002005						7	6				
03002006			1			1	3			91	
03002007						4				1	
03002008						3				1	
03002009		3		1	1					9	
03002010							1			83	
03002011						8				31	
03002012						2	1			1	10
03002013						2	2			4	
03002014					3	8				42	
03002015						5				218	
03002016											4
03002017											
03003003						1					
03003004				1			4				
03004004						15				93	
03004005							2				
03005003						1				146	
03005004						3		1		2	
03005005					1	4				1	
03010003											
03011001			1			1				8	
03011004	1									55	
03011005					1	3				3	
03011006				2	1		2		2	100	
03011007					8					38	2
03011008						1				6	
03011009											

Appendix B. Continued

SiteID	Enallagma	Endochironomus	Enochrus	Epicordulia	Epitheca	Erythemis	Fallicambarus	Ferrissia	Gammarus	Gerris	Glyptotendipes
03002003	27										
03002004	1										
03002005			1						4		2
03002006	22	1		1				1			3
03002007									10		
03002008	1										
03002009								1			
03002010	80				4						
03002011	71										
03002012	1			2		1					2
03002013									3		
03002014	2								1		3
03002015	29			9							
03002016	2										
03002017	5										
03003003											
03003004	6										
03004004											
03004005											
03005003	4										
03005004											
03005005	10										1
03010003									1		
03011001	27										
03011004	1										
03011005							1				1
03011006	19									3	
03011007	2	4									12
03011008											
03011009											

Appendix B. Continued

SiteID	Gomphus	Gyraulus	Gyrinus	Helichus	Helisoma	Helochares	Hemerodromia	Hetaerina	Hyalella	Hydrocanthus	Hydrochus
03002003		7									
03002004		4	1		4						
03002005		5			1						
03002006	3	66							103		
03002007											
03002008											
03002009				1							
03002010				7	11				29		
03002011	1	10		24		9					
03002012											
03002013				9	1						
03002014		3		5					2		
03002015				4				13	1		
03002016					9						
03002017									2		
03003003											
03003004	1								1		
03004004	3								282		
03004005									1		
03005003	1										1
03005004				4			2				
03005005											
03010003				1							
03011001								1			
03011004				1			1		41		
03011005				2							
03011006	6			8	145				172		1
03011007		16							66		
03011008				1	2						
03011009			1							1	

Appendix B. Continued

SiteID	Hydrometra	Hydroporus	Hydropsyche	Ilybius	Ischnura	Kiefferulus	Laccophilus	Larsia	Libellula	Limnodrilus	Limnophila
03002003											
03002004					14	10	1		7		
03002005					1		1		1		
03002006	2				39		1				
03002007					5						
03002008									7		
03002009							2		14		
03002010											
03002011					27		3		11		3
03002012					2		2		1		
03002013					2				5		
03002014					5				4		
03002015											
03002016					35		2				
03002017					8						
03003003								1			
03003004					19				40		
03004004					42				22		
03004005									2		
03005003									1		
03005004											
03005005	1				42		1		1		
03010003		1									
03011001	6			4	6		5		2		
03011004	1	1	1		7				25		
03011005					2						
03011006	2				22			2		51	
03011007					18		1		18		
03011008									5		
03011009									2		

Appendix B. Continued

SiteID	Limnoporus	Lioporeus	Lirceus	Lymnaea	Macromia	Macronychus	Metrobates	Microtendipes	Microvelia	Musculium	Natarsia
03002003					1						
03002004				1							
03002005			6				1				
03002006			8	6							
03002007				1							
03002008			2								
03002009											
03002010				4	3						
03002011			1	8						3	
03002012				1							
03002013		2		3							
03002014			55	1		6					
03002015			16	4							
03002016											
03002017			72								
03003003							2				
03003004			3		1						
03004004			6								
03004005											
03005003				3	2						
03005004						1					
03005005	1		3								
03010003											
03011001											2
03011004			1	1					1		
03011005									3		
03011006									2		
03011007			1	4							
03011008								1			
03011009	1										

Appendix B. Continued

SiteID	Nectopsyche	Neoperla	Neophylax	Neoplea	Neoporus	Neurocordulia	Nigronia	Notonecta	Oecetis	Ophiogomphus	Orconectes
03002003											
03002004											
03002005						4		2	1		3
03002006					5				3		
03002007					3	2					4
03002008					4						1
03002009					128						4
03002010					2	2				12	6
03002011				1	21						
03002012					1						2
03002013											1
03002014					10						3
03002015	1				2	6					1
03002016											6
03002017					4	1					11
03003003					2						
03003004					3						
03004004					1						
03004005					3						
03005003											
03005004					6	24					
03005005					6						10
03010003											
03011001					5						11
03011004					6						3
03011005		1	6		37	13					2
03011006					2	23	1		2		3
03011007					6						1
03011008					7						4
03011009								2			

Appendix B. Continued

SiteID	Orthocladius	Palaemonetes	Parachironomus	Paracloeodes	Paracymus	Paramerina	Paratanytarsus	Peltodytes	Pentaneura
03002003								2	
03002004									
03002005							1	1	
03002006		5							
03002007							2		
03002008									
03002009									3
03002010		1						1	
03002011								104	
03002012		3	3						
03002013								1	
03002014							2	3	
03002015							2	2	
03002016								7	
03002017								4	
03003003	1								
03003004									
03004004								8	
03004005									
03005003									
03005004							11		
03005005									
03010003									
03011001				246				2	
03011004						2	4		
03011005					1		3	4	
03011006								8	
03011007								7	
03011008								1	
03011009									

Appendix B. Continued

SiteID	Phaenopsectra	Physella	Pisidium	Polycentropus	Polypedilum	Procambarus	Procladius	Procloeon	Progomphus	Promoresia
03002003		15			6		1			
03002004		46			50					
03002005		100			3	1	10			
03002006	5	24			2					
03002007		18								
03002008		37					1			
03002009		66	1							
03002010		3		1	1		1			
03002011		213			4		12	13	1	
03002012		2								
03002013	1	27			2			5		
03002014	3	21						6	2	
03002015		27			2					
03002016		17	1		2					
03002017		1			3					
03003003		2								1
03003004		11			3		4			
03004004	1	11			1		10			
03004005					11					
03005003		44			2					
03005004	3	1			10		2		2	
03005005		52			1					
03010003					1					
03011001		115			5		5			
03011004		4			6		2			
03011005	6	18						6		
03011006	1	27			3		1	6	1	
03011007		34			4		16			
03011008		18			1					
03011009										

Appendix B. Continued

SiteID	Psectrotanypus	Pseudochironomus	Pseudolimnophila	Pseudosuccinea	Ptilostomis	Ranatra	Rheotanytarsus	Sepedon	Sialis
03002003									
03002004	10						10		
03002005									
03002006									2
03002007							1		
03002008		2							
03002009								1	
03002010									12
03002011				2					2
03002012									
03002013									
03002014					5				1
03002015									9
03002016									
03002017									1
03003003									15
03003004									47
03004004							4		19
03004005									58
03005003									26
03005004									16
03005005									1
03010003			1						6
03011001						1			
03011004									17
03011005									
03011006							3		18
03011007							4		7
03011008							1		
03011009									18

Appendix B. Continued

SiteID	Simulium	Somatochlora	Sphaerium	Stenacron	Stenelmis	Stenonema	Stictochironomus	Stratiomys	Tabanus	Tanypus	Tanytarsus
03002003			3								
03002004			175							90	
03002005						3	5				
03002006			208	27	223						
03002007							1				
03002008											
03002009			2		2				1		
03002010				3	73						1
03002011			1		2	1		6			
03002012			2		4						
03002013			2								
03002014					3	3					
03002015					14						2
03002016			3				1			6	
03002017											
03003003					2		1				
03003004					1						
03004004			31						1		6
03004005											1
03005003											
03005004		1					3				5
03005005							28				
03010003											
03011001						1		1			
03011004	3		1		3		1				2
03011005		2				14					1
03011006						20					
03011007											5
03011008					1	31					
03011009											

Appendix B. Continued

SiteID	Thienemanniella	Thienemannimyia	Tipula	Trepobates	Triaenodes	Tribelos	Tropisternus	UIW/OCS	Unid_ Ancylidae	Unid_ Baetid
03002003		5				2				
03002004			1				2			
03002005		1	2							
03002006		4	5							
03002007										2
03002008										
03002009										
03002010										
03002011		8		4			16			
03002012							1			
03002013		3								
03002014		13					1			
03002015		9								
03002016		1								
03002017		3								3
03003003			1							
03003004		4	2				2			
03004004							1			
03004005		1								
03005003										
03005004	1		1							
03005005								1		
03010003								3		
03011001		1					21			
03011004		7	1			3				
03011005		2		1						
03011006				2	1			1	1	
03011007		3				32	1			
03011008						7	1			
03011009										

Appendix B. Continued

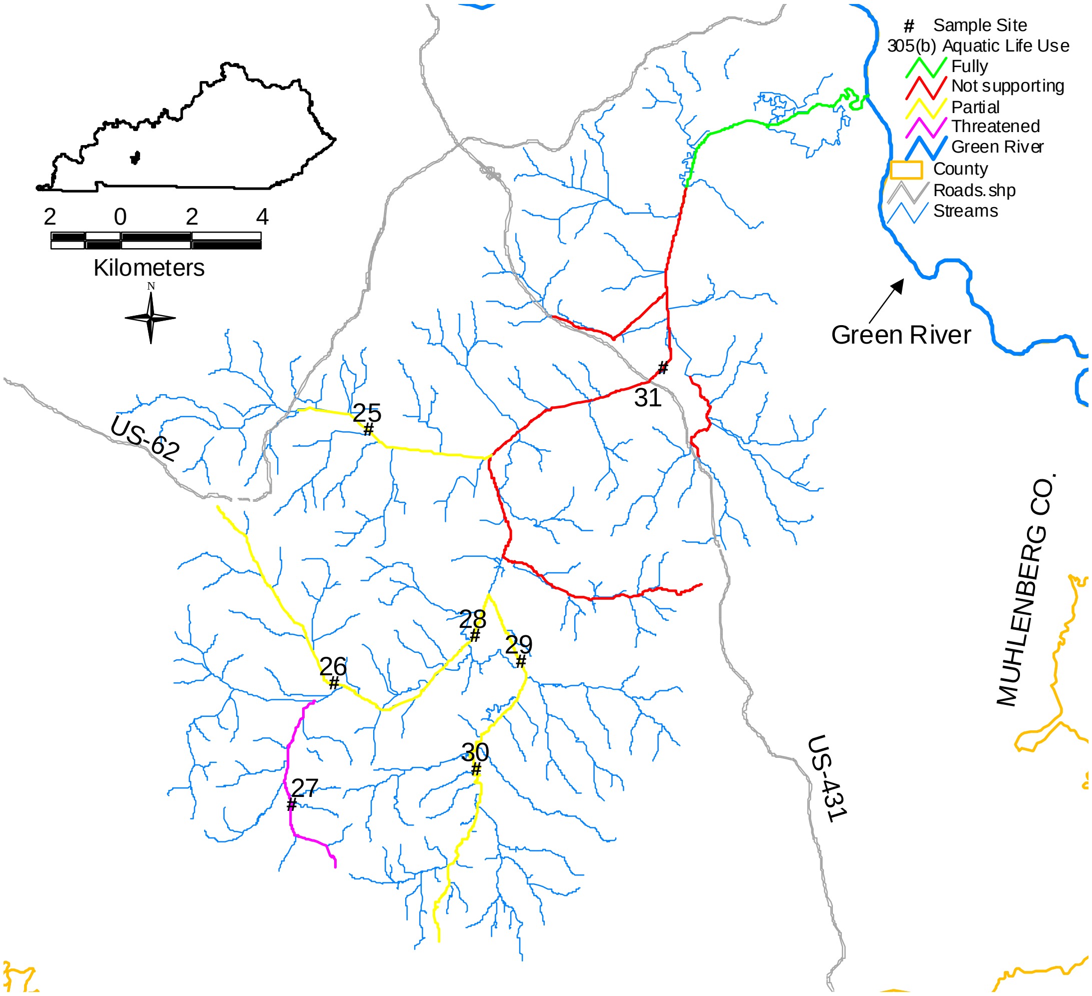
SiteID	Unid_ Chironomid	Unid_ Corduliid	Unid_ Corixid	Unid_ Curculionid	Unid_ Glossiphoniid	Unid_ Gomphid	Unid_ Leptocerid
03002003	8		1		1		
03002004	37		13		10		
03002005			3			1	
03002006	6		25		5		
03002007	1	1					
03002008				2			
03002009	1						
03002010							1
03002011	64		1		1		
03002012	1		21		2		
03002013	3		11		3		
03002014	7			1			
03002015						1	1
03002016	1		6		1		
03002017							
03003003							
03003004	3						
03004004	13						
03004005							
03005003	1					1	
03005004				9			
03005005					1		
03010003				1			
03011001			4	5			
03011004	3						
03011005			9				
03011006			1				
03011007	13		7		2		
03011008	4						
03011009							

Appendix B. Continued

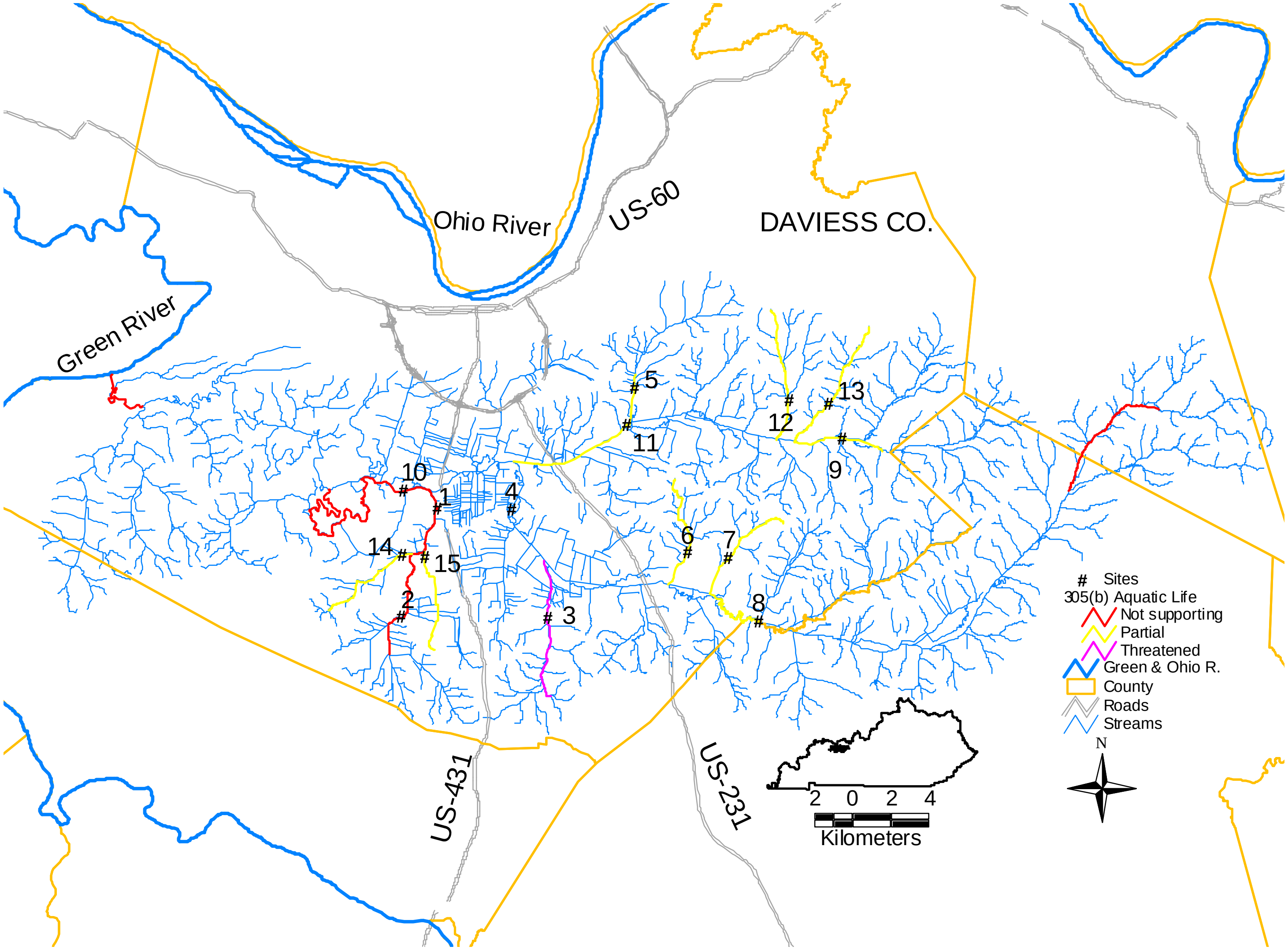
SiteID	Unid_ Libellulid	Unid_ Lumbriculid	Unid_ Lymnaeid	Unid_ Naidid	Unid_ Planariid	Unid_ Planorbid	Unid_ Sciomyzid
03002003							
03002004							
03002005							
03002006							
03002007			1	1		26	
03002008						45	1
03002009							
03002010							
03002011							
03002012							
03002013							
03002014							
03002015	14					8	
03002016							
03002017			1				
03003003							
03003004							
03004004		3					
03004005							
03005003	3						
03005004			1				
03005005							
03010003							
03011001							
03011004							
03011005							
03011006							
03011007							
03011008		1			1		
03011009							

Appendix B. Continued

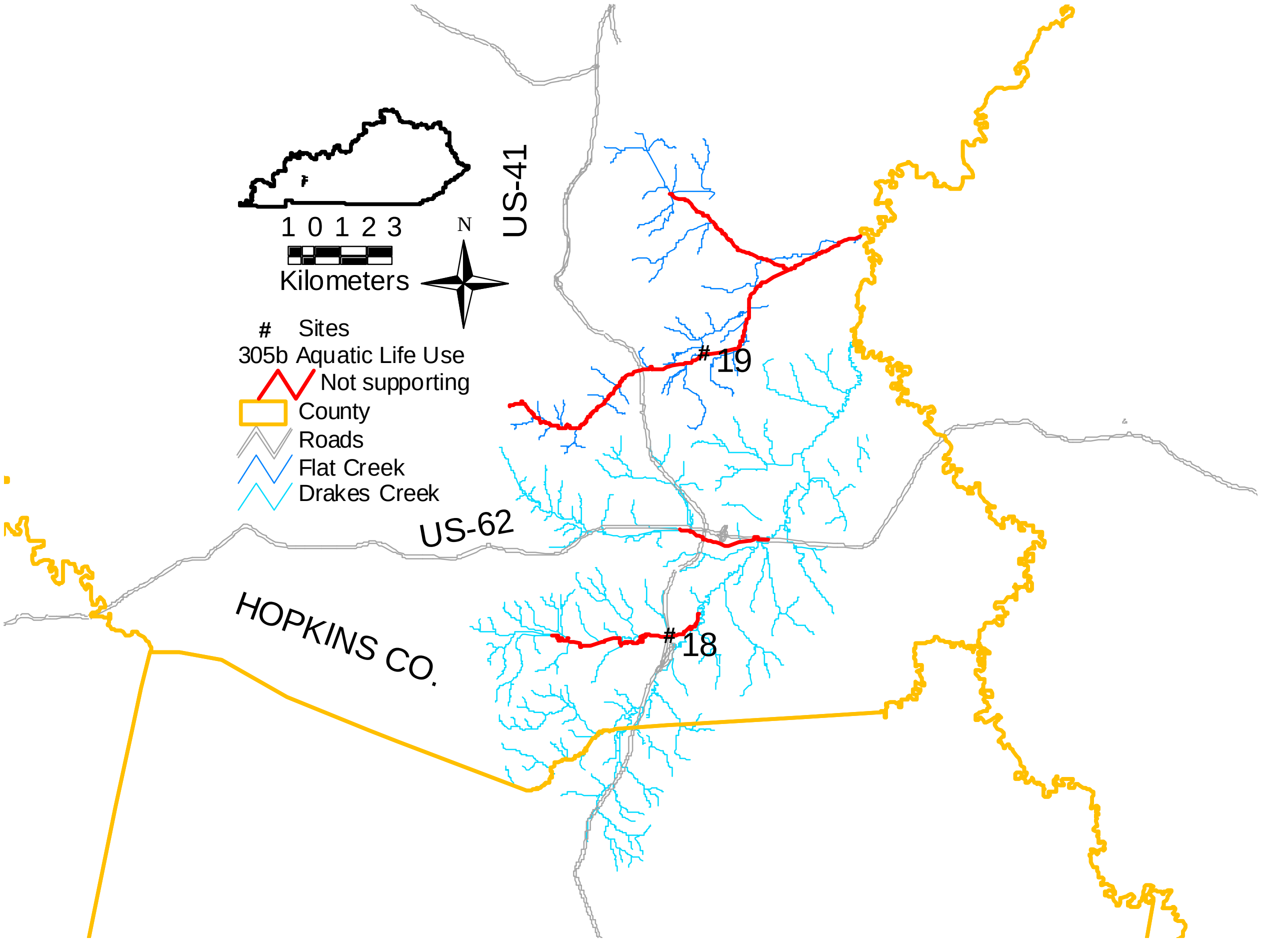
SiteID	Unid_ Scirtid	Unid_ Sphaerriid	Unid_ Tabanid	Unid_ Tanypodinae	Unid_ Tubificidae	Unid_ Veliid	Xylotopus	Zavrelimyia
03002003								
03002004								
03002005	1	76					2	
03002006								
03002007								
03002008	1	56	1		3			
03002009								
03002010		1		3	2			
03002011								
03002012								
03002013								
03002014								
03002015								
03002016								
03002017		2						
03003003								
03003004								1
03004004								
03004005								
03005003								
03005004		2					2	
03005005		30						
03010003						1		
03011001								
03011004								
03011005		1						
03011006								
03011007								
03011008								
03011009								



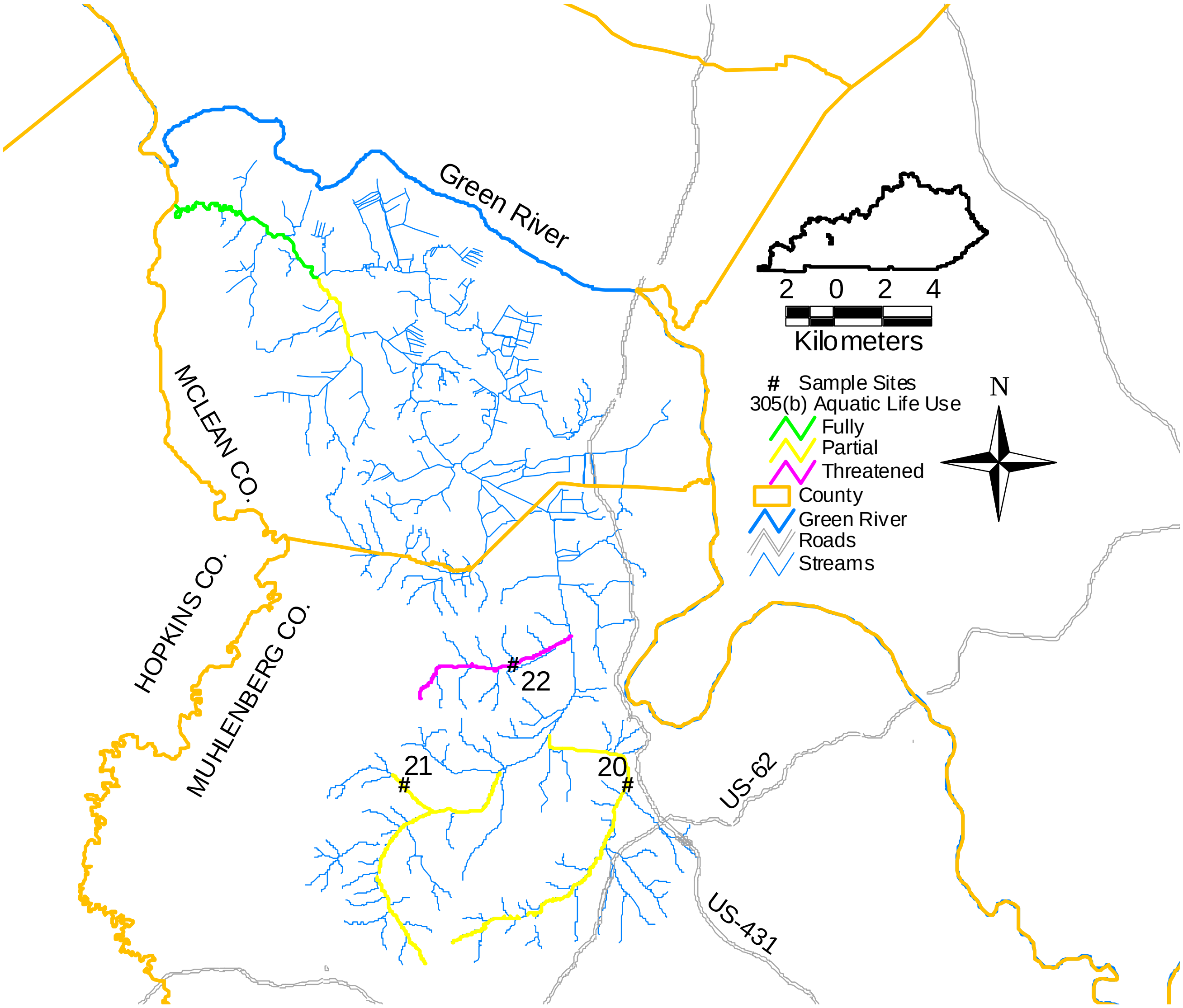
Appendix C-1. 305(b) Aquatic life assessments for the Pond River, Muhlenburg, County, Kentucky. Sample stations represented by "●". Station numbers: 25=03011001, 26=03011004, 27=03011005, 28=03011006, 29=03011007, 30=03011008, and 31=03011009.



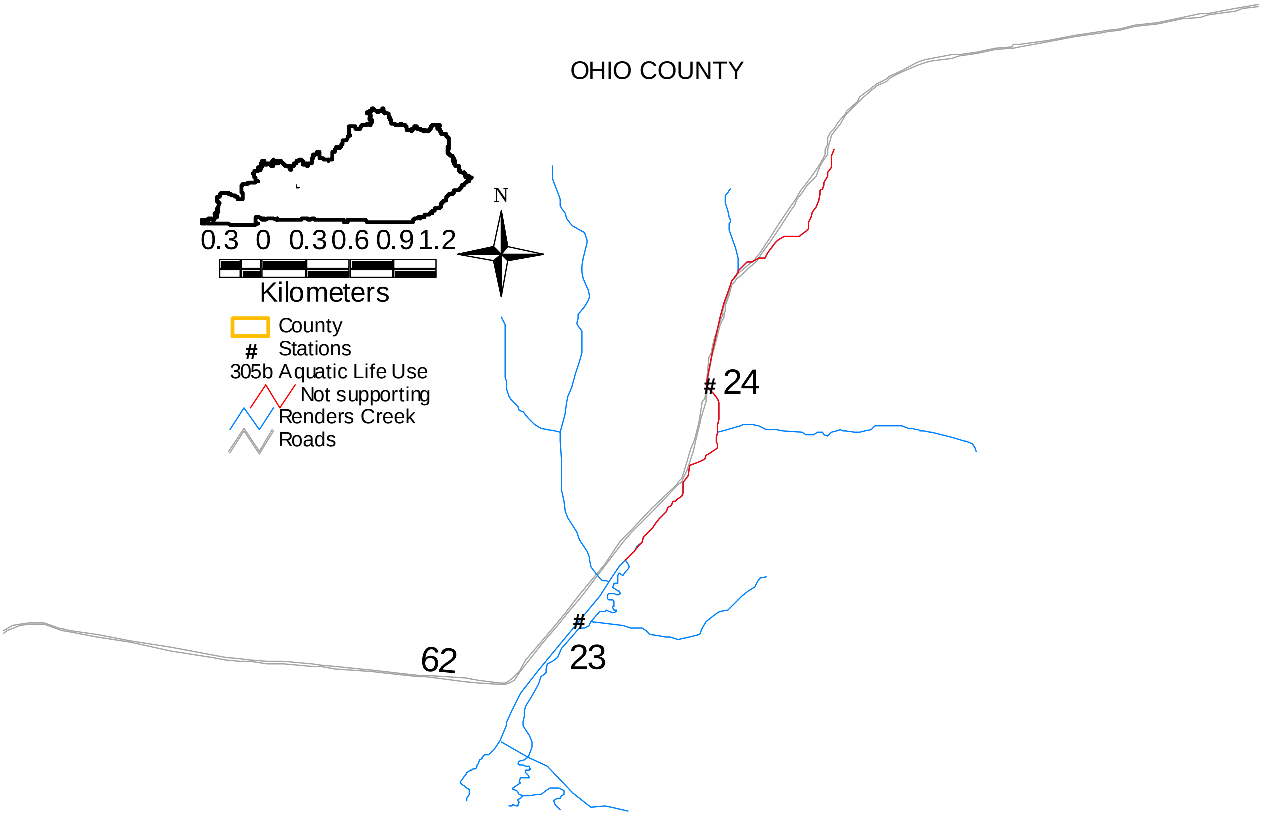
Appendix C-2. 305(b) Aquatic life assessments for Panther Creek, Daviess, County, Kentucky. Sample stations represented by "●". Station numbers: 1=03002003, 2=03002004, 3=03002005, 4=03002006, 5=03002007, 6=03002008, 7=03002009, 8=03002010, 9=03002011, 10=03002012, 11=03002013, 12=03002014, 13=03002015, 14=03002016, and 15=03002017.



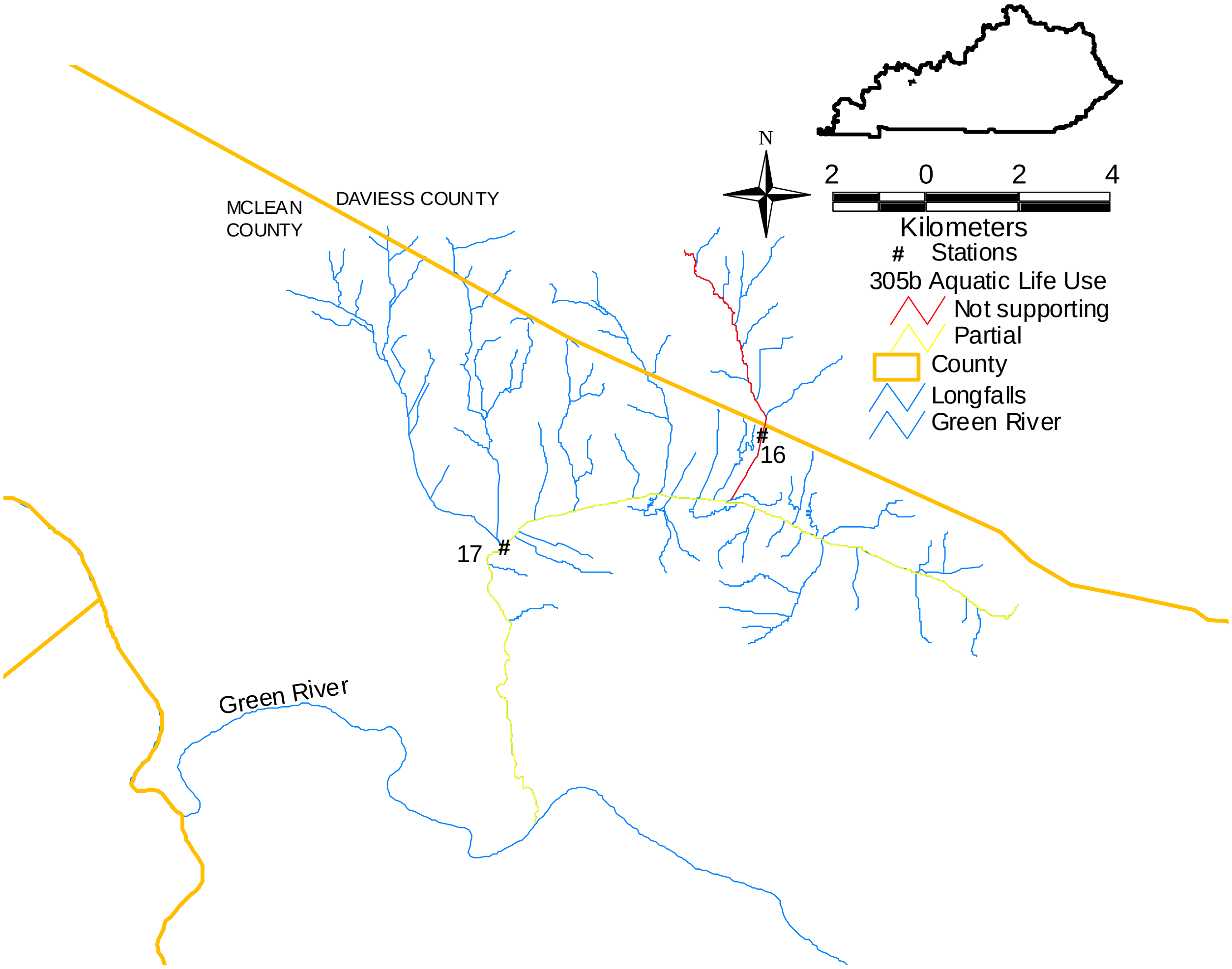
Appendix C-3. 305(b) Aquatic life assessments for Drakes and Flat Creek, Hopkins, County, Kentucky. Sample stations represented by “●”. Station numbers: 18=03004004 and 19=03004005.



Appendix C-4. 305(b) Aquatic life assessments for Cypress Creek, Muhlenburg and McLean, Counties, Kentucky. Sample stations represented by "●". Station numbers: 20=03005003, 21=03005004, and 22=03005005.



Appendix C-5. 305(b) Aquatic life assessments for Renders Creek, Ohio County, Kentucky. Sample stations represented by “●”. Station numbers: 23=03010002 and 24=03010003.



Appendix C-6. 305(b) Aquatic life assessments for Long Falls Creek, McLean and Daviess Counties, Kentucky. Sample stations represented by "●". Station numbers: 16=03003003 and 17=03003004.