EPA/600/3-87/025
June 1987

THE OHIO STREAM REGIONALIZATION PROJECT: A COMPENDIUM OF RESULTS

by

Thomas R. Whittier[1]

David P. Larsen[2]

Robert M. Hughes[1]

Christina M. Rohm[1]

Alisa L. Gallant[1]

James M. Omernik[2]

[1]Northrop Services, Inc.
200 SW 35th St.
Corvallis, OR 97333

[2]Environmental Research Laboratory -- Corvallis
U. S. Environmental Protection Agency
200 SW 35th St.
Corvallis, OR 97333

DISCLAIMER

The information in this document has been funded in part by the United States Environmental Protection Agency under USEPA 205(j) funds awarded to the Ohio Environmental Protection Agency and USEPA contract no. 68-03-3124 to Northrop Services, Inc. It has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

Regional patterns in terrestrial characteristics can be used as a framework to monitor, assess and report the health of aquatic ecosystems. In Ohio, five ecological regions were delineated using combinations of spatial patterns in land-surface form, land use, soil and potential natural vegetation. We evaluated this framework by studying the water quality, physical habitat, and fish and macroinvertebrate assemblages of 109 minimally impacted representative streams. Water quality and fish assemblages showed clear regional differences. The highest quality water and fish assemblages were consistently found in the southeast ecoregion and the lowest quality in the northwest ecoregion. We found no clear regional patterns in macroinvertebrate assemblages and limited regional patterns in physical habitat.

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

A project of this size involves the effort of many people. We gratefully acknowledge their assistance. Jim Bland's insight and perseverance was instrumental in initiating and funding this study. The field and laboratory staff of the Ohio EPA provided the data; Chris Yoder, Dan Dudley and Dave Altfater provided many useful hours of discussion, planning and review of all phases of the study. The computer support staff of ERL-Corvallis, Peggy Walch, Joe Spitz, Margaret Spence, and Paula Jensen, performed the often thankless tasks of data management, analyses and document preparation. Sandra Henderson prepared the graphics for many of the figures.

SECTION 1

INTRODUCTION

State environmental protection agencies are faced with the responsibility of carrying out the mandates of the Clean Water Act (CWA, PL 95-217) through a variety of regulations (Federal Register 1983) promulgated by the United States Environmental Protection Agency (USEPA). The emphasis has been on management of water quality through establishment of chemical criteria that, if met, presumably provide for the protection and propagation of fish, shellfish, and wildlife. While this approach has improved water quality, state agencies increasingly need to address the goals of the CWA directly through setting biological objectives or criteria for water quality management.

In particular, the Ohio Environmental Protection Agency (OEPA) wished to determine the quality that was reasonably attainable in streams throughout Ohio. The OEPA staff recognized differences in streams in various parts of the state and also wished to obtain information about streams that were not impacted by point source discharges or substantial nonpoint sources. Their stream monitoring program concentrated on waterways that received municipal and industrial wastes; data were collected and analyzed on a case by case basis.

At about the same time, scientists at the Environmental Research Laboratory--Corvallis (ERL--Corvallis) were developing a method to identify and characterize regional patterns in aquatic ecosystems. The method delineated regions based on the commonality of a variety of geographic characteristics; these regions could be recognized by examining maps of land-surface form, soil, land use, and potential natural vegetation. They expected these ecoregions to provide a useful framework for examining attainable quality for various kinds of water bodies. Streams that occur within any particular region should reflect the characteristics of the land they drain and therefore be relatively similar to one another. Streams in different regions should differ.

This regional framework seemed a useful approach by which OEPA could obtain representative information to demonstrate what might be attainable in the streams it sampled. Water quality decision making could be improved by comparison of regional expectations to specific sites to evaluate the extent and degree of use impairment (or lack thereof). As a result, a memorandum of understanding among Region V (USEPA), ERL-Corvallis, and Ohio

EPA established a program to identify a regional framework for grading stream performance.

Briefly, the approach entailed delineating ecoregions in Ohio; identifying watersheds and streams that were representative of the ecoregions and were least disturbed by human activities; sampling these streams for a variety of physical, chemical, and biological characteristics; and determining the extent to which patterns in these characteristics reflected ecoregional patterns. The set of data obtained from the selected streams would form the basis for quantitatively expressing attainable uses in the various regions of Ohio. These attainable uses and other statements herein are limited to small streams having watershed areas of 10-300 mi^2. They may not be appropriate for larger streams and rivers. Also, because of the presence of row crop agriculture throughout much of the state, most of the sites were impacted to varying degrees by diffuse sources of pollution, primarily agricultural pesticides and fertilizers, sediment, and channel modifications.

Our purpose here is to present a general overview of this project and its results. This report will be of interest to a diverse group of readers: aquatic scientists, resource managers, and regulatory personnel. This document describes: (1) the five ecoregions in Ohio and the distinguishing features of each; (2) the selection of candidate watersheds and study sites representative of these ecoregions; (3) the field sampling and analyses; (4) the results summarized in a way that makes them useful as a reference data set indicating attainable quality.

The following references should be consulted for more detail about various phases of this project: ecoregion concept development (Bailey 1976, 1983, Hughes and Omernik 1981, Hughes et al. 1986, Larsen et al. 1986, Omernik et al. 1982, Omernik 1987, Rowe and Sheard 1981, Warren 1979); regional reference sites (Hughes et al. 1986); Ohio fish assemblages (Larsen et al. 1986); Ohio water quality (Larsen and Dudley 1987); ecoregions in other states (Hughes et al. 1987, Omernik and Gallant 1986, Rohm et al. 1987, Whittier et al. MS).

SECTION 2

ECOREGIONS OF OHIO

We studied maps of land-surface form, land use, potential natural vegetation, soil, surficial geology, climate, and hydrology for obvious regional patterns of homogeneity in combinations of these factors. This analysis revealed five ecoregions (Table 1) defined by certain characteristics in land use (Anderson 1970), land-surface form (Hammond 1970), potential natural vegetation (Kuchler 1970), and soils (USDA 1957, USGS 1970). Cursory examination reveals a gradual transition in these characteristics from northwest to southeast Ohio.

Through a map analysis and overlay process, we defined the most typical portions of each ecoregion as those areas where all four of its characteristic components occurred in combination. One region and some of the most typical areas of the ecoregions are discontinuous. Lines distinguishing the major regions are less precise than those defining the most typical areas and were drawn to include areas where most, but not all, of the characteristics typifying a region occurred in combination. Such areas were considered generally typical of their ecoregions (Figure 1).

Descriptions of the ecoregions (below) provide a synopsis of the watershed characteristics that affect aquatic ecosystems. Each description is an amplification of the combination of features that give the ecoregion its identity (Table 1) and includes the regionally important human impacts, particularly those that are diffuse or nonpoint in nature. We obtained this information from a variety of sources. The most helpful of these was Land Resource Regions and Major Land Resource Areas of the United States (Austin 1965, USDA 1981). We estimated watershed sizes necessary to support perennial stream flow by interpolating from USGS Water Resources Data and 1:250,000 scale maps.

Several land uses that impact stream quality occur statewide. Much of the natural forest vegetation has been removed in Ohio. Land clearing and soil compaction amplify the intensity and frequency of flood and drought flows. General agriculture near streams is a source of nutrients (fertilizer), toxic chemicals (pesticides), and sediments from increased erosion. These affect the chemistry and oxygen carrying capacity of the water and erosion affects the physical habitat by increasing turbidity and sedimentation. Farmers and foresters often remove the natural riparian vegetation thereby speeding runoff, reducing shade (increasing water temperature and increasing photosynthetic

Table 1. Summary of the terrestrial characteristics of the five ecoregions of Ohio as shown on the four component maps used to delineate ecoregion boundaries (Omernik 1987).

	Huron/Erie Lake Plain	Eastern Corn Belt Plains	Erie/Ontario Lake Plain	Western Allegheny Plateau	Interior Plateau
Land-Surface Form (Hammond 1964)	flat plains	smooth plains	irregular plains	low to high hills	plains with hills, open hills, tablelands with moderate relief
Land Use (Anderson 1967)	cropland	cropland	cropland with pasture, woodland, and forest, urban	woodland and forest with some cropland and pasture forest and woodland mostly ungrazed	mosaic of cropland, pasture, woodland, and forest
Soils (USDA 1957, USGS 1970)	Humic-Gley, Low Humic Gley, Gray-Brown Podzolic/Humic Gley	Alfisols, Gray-Brown Podzolic/ Humic Gley	Alfisols	Alfisols	Udalfs and Udults
Potential Natural Vegetation (Kuchler 1970)	elm/ash forest	beech/maple forest	beech/maple, northern hardwoods (maple, birch, beech, hemlock)	mixed mesophytic forest (maple, buckeye, beech, tuliptree, oak, linden), Appalachian oak	oak/hickory forest

activity), decreasing cover and increasing erosion. These effects are further increased by ditching, field tile drainage, and channelizing and clearing stream beds. Livestock along or in streams increase nutrient loads (manure), increase turbidity and sedimentation by eroding banks, and remove riparian vegetation by browsing and trampling. Oil field operations may affect water quality by spills of brine and petroleum, by seepage from sweetening plant ponds and by sludge from drilling sites. Quarries and gravel pits may increase turbidity and sedimentation in nearby streams. Mining may severely degrade streams both chemically (acidification) and physically.

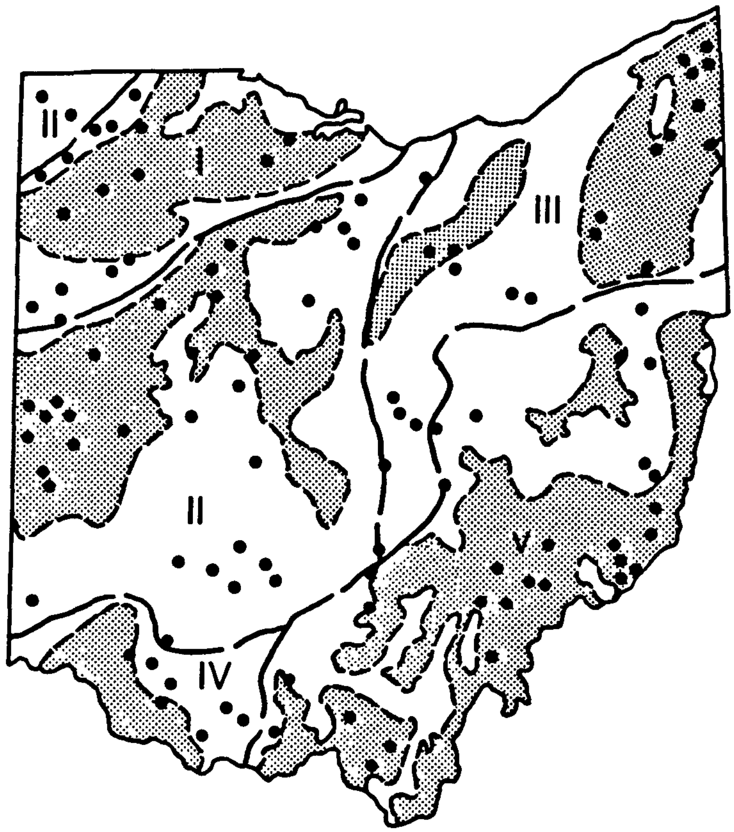

Figure 1. The five ecoregions of Ohio. Darker tones denote most typical areas. I = Huron/Erie Lake Plain (HELP), II = Eastern Corn Belt Plains (ECBP), III = Erie/Ontario Lake Plain (EOLP), IV = Interior Plateau (IP), V = Western Allegheny Plateau (WAP). Dots indicate location of sampling sites.

HURON/ERIE LAKE PLAIN

The Huron/Erie Lake Plain ecoregion is distinguished from surrounding ecoregions primarily by features related to poor soil drainage. The ecoregion is a nearly level, broad lake plain, somewhat interrupted by beach ridges and low moraines. Much of the area was covered by forested wetlands in presettlement times. The elevation is generally around 600 feet, rising to 800 feet on some moraines. Local relief is generally only a few feet.

Typically in this ecoregion, mapped small streams and drainage ditches are intermittent, while medium to larger streams are perennial. Larger streams contained entirely within the ecoregion drain as much as 400 to 500 mi^2. The majority of streams however, drain watersheds of less than 100 mi^2 (larger streams generally originate in adjacent ecoregions). The few lakes and reservoirs are small, having surface areas of < 0.25 mi^2. Average annual precipitation ranges from 31 to 35 inches, fairly evenly distributed throughout the year and generally adequate for crop production.

The extensive, nearly level plains and numerous depressions in morainal areas have contributed to the formation of poorly drained soils, primarily Aqualfs or Aquepts. Ochraqualfs and Haplaquepts formed in lacustrine and glacial drift. Udipsamments and Hapludalfs occur on beach ridges and other well drained sites.

These poorly drained soils support swampy elm/ash forest vegetation. Major forest constituents are black ash (replaced by white ash where drainage is slightly better), American elm and red maple. Forest species also include silver maple, sycamore, pin oak, swamp white oak, black tupelo and eastern cottonwood. Only small remnants of these forests exist in this ecoregion.

Agriculture forms the economic base of this area. Corn, winter wheat, soybeans, and hay are the principal crops, along with sugar beets, field and seed beans, and a variety of canning crops. Fruit and truck crops are grown on more coarse-textured soils. Some farmland is in pasture and small woodlots. Principal livestock include swine, poultry, and (near large cities) dairy cattle.

Stream water quality in this ecoregion is affected primarily by crop and livestock production practices. Channelization of streams, construction of ditches, drainage of natural woodland swamps and extensive removal of forests result in reduced quantity and quality of habitat for stream biota throughout the area.

EASTERN CORN BELT PLAINS

The gently sloping glacial till plain comprising the Eastern Corn Belt Plains ecoregion is broken by hilly moraines, kames, and outwash terraces. Elevations range from about 600 feet near Lake Erie to greater than 1,100 feet. Local relief is generally less than 50 feet except in some of the moraines in west central Ohio, where relief reaches 200 feet. Valleys are typically narrow and shallow.

Streams in the larger watersheds contained completely within the ecoregion drain on the order of thousands of square miles, e.g. the Great Miami River drains 3,500 mi^2. Most mid-sized streams are perennial; many smaller streams have been channelized. Some larger streams are regulated to inhibit flooding. There are relatively few reservoirs or natural lakes. Average annual precipitation ranges from 34 to 38 inches, mostly occurring during the growing season, and is generally adequate for crop production.

This ecoregion supports hardwood vegetation characterized by a predominance of American beech and sugar maple. White, black, and northern red oaks, yellow-poplar, hickory, white ash and black walnut accompany these in forested areas. On wetter sites hardwood forests include white, pin, and northern red oaks, sweetgum and yellow-poplar as major constituents; shingle and black oaks, and hickory may occur. Silver maple, cottonwood, sycamore, pin oak, and elm occur along streams. Most of the forests have been cleared.

Soils of this ecoregion were formed predominantly under deciduous forests. They derived from calcareous glacial loam till overlain by loess deposits in some southern portions. Many of the soils are affected by poor internal drainage. Hapludalfs and Ochraqualfs formed on broad flat uplands and are the dominant soil groups. Argiaquolls, Haplaquolls, and Medisaprists formed in flats and depressions.

The ecoregion is almost entirely farmland. Approximately 75% of the area is in cropland; the remainder is permanent pasture, small woodlots or urbanized. Corn and soybeans are the principal crops. Feed grains and hay for livestock are also grown. Truck and canning crops, and tobacco are grown locally. Swine, beef and dairy cattle, and poultry are raised throughout the area. There are numerous quarries and gravel pits.

Stream quality in the Eastern Corn Belt Plains is subject to the influences of a highly agricultural economy. Quarries and instream mining of gravel may impose local effects on stream habitats.

ERIE/ONTARIO LAKE PLAIN

The gently to strongly rolling dissected glacial plateau of the Erie/Ontario Lake Plain ecoregion is underlain mostly by sandstone and siltstone. Local relief varies from a few feet, in gently rolling terrain, to as much as 200 or 300 feet in steeper stream valleys. Local relief is greater here than in the two northwestern and western Ohio ecoregions, but less than the Western Allegheny Plateau. The elevation ranges from about 600 feet near Lake Erie to 1,200 feet on the uplands.

The majority of mapped streams in the ecoregion are perennial and not deeply dissected. The larger watersheds contained entirely within the ecoregion drain 400-600 mi^2. There are many lakes and reservoirs and some well developed wetlands. Average annual precipitation is 35-40 inches, generally adequate for crop production.

This ecoregion supports northern hardwood forest vegetation. The predominant beech/maple/yellow birch forest in many parts is similar to those in the Eastern Corn Belt Plains, while on wetter soils, the forest composition more closely resembles the swamp forests of the Huron/Erie Lake Plain. In mesophytic areas associated trees are basswood, American elm, red maple, hemlock, white ash, black cherry, white pine, northern red oak, balsam fir, and white spruce. On moist sites American elm, black ash and red maple dominate with constituents of silver maple, pin, and swamp white oak, sycamore, tupelo and cottonwood.

Soils are mostly Udalfs and Aqualfs. Aquepts are predominant along the Lake Erie shore. Soils are derived mainly from glacial till and lacustrine sediments. Fragiudalfs, Ochraqualfs, Fragiaqualfs, and Fragiudults formed on uplands. Haplaquepts, Fragiaquepts, and Hapludalfs formed in lacustrine sediments. Ochraqualfs formed in lower glacial till plains.

This ecoregion exhibits a mosaic of cropland, pasture, livestock and poultry production, woodland and forest. Approximately one fourth of the ecoregion provides pasture for cattle. Cropland covers about one third and is interspersed with pasture, woodland, and forest. Cropland emphasis is on feed grains and forage, principally hay and corn, for dairy cattle, which are important near large cities. Cash crops include wheat, potatoes, canning and truck crops, e.g. sweet corn, beans, cabbage, peas, and onions, over most of the area, and vineyards, orchards, small fruits along Lake Erie. Forests cover about one third of the ecoregion, used primarily as woodlots, also for saw logs and pulpwood. About 20% of the area is urbanized. There is some oil and gas drilling in the southern arm of the ecoregion.

Stream quality in this ecoregion is primarily affected by agricultural practices. In urbanized areas streams are often channelized, regulated and used for industrial purposes. Numerous gravel pits and quarries, and oil and gas drilling may have local effects on nearby streams.

INTERIOR PLATEAU

Characteristics of the Interior Plateau ecoregion are transitional between the adjacent Eastern Corn Belt Plains and Western Allegheny Plateau ecoregions. This ecoregion includes undulating to steep terrain formed from Illinoian glacial drift materials. Elevations vary from about 500 feet near the Ohio River, to more than 1,200 feet in hilly areas. Average annual precipitation is about 42 inches, ordinarily adequate for crop production, but less than half occurs during the growing season.

The majority of mapped streams in this ecoregion are perennial. Streams in the largest watersheds contained completely within the ecoregion drain from 200 to 500 mi^2. The ecoregion contains few lakes, most of which are constructed.

As with soils of the Western Allegheny Plateau, many of the soils in the Interior Plateau formed in residuum of from sedimentary rocks overlain by varying amounts of loess. Some soils are derived from calcareous loam till materials with localized mantlings of loess. Ochraqualfs formed on broad flat uplands. Hapludalfs, Glossaqualfs, and Fragiaqualfs occur on nearly level to gently sloping uplands. Hapludalfs occur on steeper upland slope, Fragiudalfs on side slopes. Udifluvents and Fluvaquents formed in silty alluvium on relatively narrow floodplains. Hapludolls formed in shaly limestone materials. Movement of moisture through a number of soils in this area is impeded by claypans or fragipans. Limestone is present to within 5 feet of the surface over the eastern portion of the region.

This ecoregion supports mainly hardwood forest vegetation. The ecoregion can be distinguished overall as having oak-hickory forest vegetation. Other tree associates are yellow-poplar, sugar maple, white and green ashes, sweetgum and black walnut. Honeylocust is dominant on soils that formed in shaly limestone. Riparian forests include silver maple, cottonwood, sycamore, pin oak, elm and sweetgum.

Most of this ecoregion is farmland. About half the area is cropland, primarily corn, soybeans, other feed grains, hay for cattle and tobacco. The remaining farmland is in pasture. One fifth of the area is forested. Influences on stream quality are mainly from livestock and crop production. In cropland areas, many rivers have been dammed for flood control.

WESTERN ALLEGHENY PLATEAU

The Western Allegheny Plateau ecoregion, which consists of a dissected plateau comprised of horizontally bedded sandstone, siltstone, shale and limestone, is characterized by steeper, more rugged terrain than neighboring ecoregions to the north and west. Elevation ranges from about 600 feet along the Ohio river to over 1,300 feet in the higher ridges. Local relief is between 300 to 500 feet in most of the Ohio portion of the ecoregion.

Most streams in the larger watersheds contained entirely within the ecoregion drain 200 to 400 mi^2. However, some drain > 650 mi^2. Most mapped streams are perennial, and a few in smaller agricultural valleys are channelized. The few natural lakes are small, usually < 0.5 mi^2. Reservoirs, though few, outnumber natural lakes, and are generally < 5 mi^2.

This ecoregion supports mixed mesophytic forest vegetation in which, characteristically, dominance is shared by greater numbers of species than in the rest of Ohio. The composition of this forest changes with moisture availability and soil fertility. Major forest species are oak (white, black, northern red, scarlet) and hickory (shagbark, bitternut, pignut, and mockernut). Oak, blackgum, flowering dogwood, and pine (Virginia, pitch, shortleaf) occur mainly on ridgetops and shallower soils. Yellow-poplar, black walnut, red oak, and red maple grow in more sheltered locations.

Soils of this ecoregion formed predominantly from unglaciated clay, shale, and siltstone, and include a capping of loess in some areas. Soils are mainly Udalfs, Udults, and Ochrepts. Hapludalfs formed in residuum from shale and siltstone. Hapludults formed in residuum from acid siltstone, shale, and sandstone. Dystrochrepts are common on steep slopes and ridges.

Land use in this ecoregion is limited by poor soils, steep topography and high erosion hazard. Thus, most of the area is forested and timber harvest is important. A large portion has been strip-mined for coal. Less than 20% is cropland, which occurs on valley floors, usually in alfalfa and small grains for beef and dairy cattle. Fruit and vegetables are farmed on a local scale. Urban growth continually infringes on farmland areas.

Stream water quality is primarily affected by mining operations. Numerous oil and gas fields also affect stream water quality. Though agriculture accounts for a relatively small proportion of land use, it occurs primarily in stream valleys, resulting in loss of riparian vegetation and increased sedimentation.

SECTION 3

SELECTION OF CANDIDATE WATERSHEDS AND STUDY SITES

First, we outlined all watersheds that fell completely within the most typical or generally typical portions of each ecoregion. This prevented aggregation of characteristics from different ecoregions or portions of ecoregions. We drew the watershed outlines on a 1:500,000 scale topographic map of the state and estimated the area of each watershed.

The smallest watersheds selected were those expected to have permanent streams. In Ohio mean annual runoff is about 15 inches (varying from about 10 inches in the northwest to about 20 inches in the extreme northeast) with minor seasonal differences in precipitation. Thus minimum watershed size was about 10 square miles. The largest watersheds (100 to 300 mi^2) were contained entirely within a generally typical or most typical portion of an ecoregion. Also, to better understand the stream-ecosystem quality attainable in watersheds straddling two ecoregions, or the most typical and generally typical portions of ecoregions, we selected a few least-impacted watersheds in these locations.

Using general information on point and nonpoint pollution sources, we eliminated those watersheds and streams with a relatively heavy human impact. The source materials that were used for this sorting process included:

1. Maps of human population density and census data. These provided a rough approximation of the sewered and unsewered population in each watershed, as well as the number and sizes of large cities where point source impacts were more likely.
2. Maps of land use, past and present strip mining, and streams impacted by strip mines. These maps helped reveal the watersheds that were heavily impacted by strip mining, urbanization, and agriculture. Although land use maps were not available for the western fifth of the state, the land use there is generally limited to cropland or urban areas.
3. A watershed disturbance ranking compiled from the land use and strip mining maps. For each watershed, we calculated a disturbance ranking by multiplying the percent area in each land use class by a disturbance value arbitrarily assigned to each class. In the absence of an appropriate precedent, we based the ranking on our estimate of relative probable impact (for example, strip mining was assigned a value of 10; forest 0; cropland 4; industrial 7; and residential, 4). In the Eastern Corn Belt Plains and the Huron/Erie Lake Plain, watershed rankings differed little because of the uniform influence of agricultural land use. In the other three ecoregions, where there were great differences in

agricultural land use, urbanization, forest cover, and strip mining, the least- and most-impacted watersheds were obvious from their rankings.

4. A list of important point sources occurring in the candidate watersheds. The Ohio EPA compiled this list from their files of known municipal and industrial point sources. This list was purposely general to expedite plotting of point sources with notations about their relative importance. By using the receiving stream name and river mile index, we plotted the point source information on an overlay of the candidate watersheds. In watersheds, ecoregions, or portions of ecoregions where there were few point sources, it was important to know the location and type of each point source to avoid them or disregard them if they were determined to be unimportant. On the other hand, in a watershed littered with point sources, that knowledge alone was sufficient to eliminate it.

Using this approach, we selected sets of least-impacted candidate watersheds in the most typical and generally typical areas of each ecoregion and in some areas that straddled regional and most typical boundaries. We stress that these watersheds are not pristine or undisturbed, but they represent the least-impacted conditions in an area (by being outside the influence of identifiable point and nonpoint sources), and they should therefore represent potentially attainable conditions from a regional viewpoint.

FINAL SELECTION OF STUDY SITES

We based final selection on field examination of each of the candidate watersheds and streams. Each candidate stream site, and the watershed immediately upstream from the site, was photographed from altitudes approximately 2,000 and 5,000 feet above the ground. These photos were used to: (1) assess typical watershed and riparian characteristics in each region; (2) detect significant disturbances not found by other means; (3) select candidate sampling sites; and (4) provide visual aids for briefings on the project. Finally, we inspected from the ground each candidate site and two or three additional locations one to two miles upstream or downstream to determine: (1) the representative nature of the site; (2) the ease of access to the water; and (3) the least-impacted sites. Factors examined included the amount and age of stream channelization, amount and size of riparian canopy, channel morphology, water volume, bottom substrate size and heterogeneity, obvious color and odor problems, and the amount of large woody debris in the channel.

Locations of the candidate watersheds, and the most typical and generally typical portions of the aquatic ecoregions are shown in Figure 1. Table 2 is a regional summary of the number of sites, their average watershed areas, and their type.

Table 2. Distribution of sampling sites.

	Huron/Erie Lake Plain	Eastern Corn Belt Plains	Erie/Ontario Lake Plain	Interior Plateau	Western Allegheny Plateau	Cross Ecoregion Boundary
Number of Sites						
Most Typical (MT)	7	14	14	0	14	
Generally Typical (GT)	6	15	5	6	7	12
On MT/GT Boundary	1	4	0	0	4	
					Total Sites = 109	
Watershed Sizes (mi^2)						
Mean	50	75	59	134	108	117
Median	42	65	44	134	104	81
Range	10-114	8-197	9-168	51-233	7-280	35-272

SECTION 4

FIELD SAMPLING AND ANALYSES

The OEPA sampled water quality characteristics approximately monthly from July 1983--November 1984, including: temperature, conductivity, alkalinity, hardness, pH, dissolved oxygen, nitrite, nitrate, ammonia-nitrogen, Kjeldahl nitrogen, total phosphorus, total organic carbon, total residue, magnesium, calcium, cadmium, chromium, nickel, zinc, iron, copper, and lead. Subsurface samples were taken midstream, directly collected in 1-liter disposable polyethylene cubitainers or using a plastic bucket and then pouring into the cubitainers. Nitrogen and phosphorus were preserved with 2 ml concentrated nitric acid; alkalinity and conductivity samples were iced. Samples for total organic carbon were collected in acid-rinsed 25-ml polypropylene vials, preserved with mercuric chloride and shipped to ERL-Corvallis for analysis. All samples were analyzed according to methods summarized in Table 3.

Quality assurance procedures for all samples included: field blanks and duplicates collected at a 5 percent frequency; and replicates, spiked samples and blanks analyzed at a 5 to 10 percent frequency for laboratory analyses (OEPA 1984a). Samples not meeting precision and accuracy goals specified in Table 3 were rejected.

The OEPA sampled half the sites during each of two consecutive summers (1983, 1984) for physical habitat, fish and macroinvertebrate assemblages. We selected sites to be sampled each summer to represent each region and to prevent spatial bias in the results. The physical habitat (percent canopy; mapped gradient; dominant riparian vegetation; percent cobble, gravel, sand, silt, muck, bedrock; percent instream cover provided by macrophytes, stumps, brush, snags, undercut banks; mean, maximum, and minimum depth and width of riffles, runs, and pools) was assessed twice, once during midsummer when crews sampled the fish assemblages and again during macroinvertebrate sampling.

The OEPA sampled for fish at each site two to three times at approximately one-month intervals from late July to October. Rivers too deep to wade were sampled with a boat-mounted electrofisher. Small, shallow creeks were sampled with a backpack electrofisher and the other streams were sampled with a towed electrofisher. Whenever possible the towed unit was used because of its greater effectiveness. Sites sampled by boat, towed unit

Table 3. Summary of analytical methods, precision and accuracy goals, and minimum detection limits for chemical analyses used in this study (USEPA 1979).

Variable	Method	Precision[1]	Accuracy[2]	MDL[3]
Alkalinity	Automated Titration	±10%	±15%	5.0 MG/L
Calcium	Atomic Absorption	±10%	±10%	1.0 MG/L
Carbon, Total Organic	Coulometric Carbon Analyzer	±10%	±15%	1.0 MG/L
Conductivity	Wheatstone Bridge	± 5%	± 5%	1.0 S/CM
Copper	Atomic Absorption	±10%	±10%	0.5 MG/L
Iron	Atomic Absorption	±10%	±10%	0.05 MG/L
Lead	Graphite Furnace	±10%	±10%	2.0 MG/L
Magnesium	Atomic Absorption	±10%	±10%	0.5 MG/L
Nitrogen				
Nitrate	Automated Cadmium Reduction	±10%	±10%	0.10 MG/L
Nitrite	Automated Analyzer	±10%	± 5%	0.02 MG/L
Ammonia	Nesslerization	±10%	±15%	0.05 MG/L
Total Kjeldahl	Automated Phenate Block Digester	±10%	±10%	0.20 MG/L
Phosphorus, Total	Automated Ascorbic Acid Reduction	±10%	±10%	0.05 MG/L

[1]standard deviation among duplicates
[2]degree of difference between a series of measurements and standards
[3]Minimum Detection Level

or backpack were fished for a distance of approximately 500, 300 or 200 meters, respectively, with the availability of micro-habitats determining the actual distance fished. All captured fish were identified, counted and weighed in the field. Selected specimens were preserved to confirm field identifications. They sampled macroinvertebrates once in the summer with modified Hester-Dendy multiple plate samplers and kick net transects in riffles or areas of greatest habitat diversity where riffles were absent (Pollard and Kinney 1979). Samples were preserved in formalin in the field, identified later to the lowest taxonomic level that keys permitted, and quantified by number and size per time and area sampled.

SECTION 5

DATA ANALYSES AND RESULTS

The results are organized by sections on fish, macroinvertebrates, water quality, and physical habitat. They are summarized primarily graphically because visual displays are easiest to grasp. We used box plots to summarize many of the results (Reckhow 1980). Box plots contain sample sizes, medians, ranges, and 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles. Box plots have the advantage over other methods of presentation, such as means, standard deviations and standard errors, because they do not assume a particular data distribution. They provide more information about the data distribution, such as central tendencies, outliers and skewness.

Our purpose is to show how the regional framework is useful for examining and characterizing the range of conditions in a geographic area and for distinguishing major differences among regions. This is an important basic step toward determining attainable water quality. We do not present statistical tests to determine whether the characteristics of one region differ significantly from those of another. For many variables, two of the regions have little or no overlap, making statistical tests of difference unnecessary. The other three regions show varying degrees of overlap. From a management viewpoint it may be appropriate to combine data for some variables and regions. However, the regions are geographically distinguishable and for some variables this distinction might be important, particularly if stream characteristics are to be related to land management practices.

Data from sites in the most typical and generally typical areas have been combined for each region. The differences among regional characteristics in Ohio are not as distinct as in some parts of the country (e.g. the mountainous West), so that the transitional nature of the generally typical areas is subtle. Although the data may display similar values among the regions, the factors that cause them to be similar might be different, e.g. two very different types of soils may produce similar nutrient chemical conditions in streams.

FISH

We present a variety of measures to characterize and summarize the fish assemblages, including dominance, species richness, species diversity, Karr's index of biotic integrity (Karr 1981, Fausch et al. 1984), a composite index or index of well being (Gammon 1980), and the fraction of the fish community that is tolerant of turbidity, sedimentation and low dissolved oxygen.

After consulting with OEPA biologists, we omitted several sites and samples from the analyses. We excluded six sites because, subsequent to the design and sampling phases, watershed and stream characteristics were discovered that indicated these sites were not representative of least-impacted conditions. In addition, we excluded 17 individual samples (out of 312 remaining) due to identifiable sampling problems (Table 4). We calculated all indices for each sample. For each index, we examined both the maximum and median scores at each site. Mostly this report uses site maxima. For species richness and percent intolerant individuals, we also combined all fish caught at each site for a composite sample. Hybrids are not counted as "species" in the following indices: IBI, species richness, and percent intolerant individuals. For composite index, species diversity, and site composite species richness, hybrids are treated as "species." Sites on regional boundaries have been excluded from most analyses.

Dominant Species by Ecoregions

We used two approaches to describe the dominant fish species for each ecoregion. First, we listed the species that were among the numerically dominant in any sample (> 10% of sample). For each region, we calculated the fraction of samples in which each of those species were dominant (Table 5). Histograms of the same data show ecoregional differences in the dominance of these 23 species (Figure 2).

The second approach to dominant species is a regional signature based on relative abundance of species. We selected all species that had a mean relative abundance of > 2% for any region. For each region, we constructed box plots of relative abundances of only those species that occurred in at least half of that region's samples (Figure 3).

Species Richness

Species richness (the total number of different species sampled) is a simple and direct measure of the variety of species present in a community. In general, species richness in small- to medium-sized streams increases as the size of a stream increases. Because of this relationship and because of the range of stream sizes examined in this project, box plots of species richness by ecoregion contain variability attributed to that

Table 4. Sites and samples eliminated from analyses of fish data.

The following sites were dropped from the analyses.

SRP CODE	STREAM	RATIONALE
NGTS14B	Bad Creek	channelized/deep trough
WMG116	Mad River	atypical/cold water stream
WMT61A	Honey Creek	no obvious reason, but low species and individual counts
EMT32C	Potter Creek	marsh stream, 0-2 species
EMT29	Pymatuning Creek	swamp stream/black water, deep
SGT107	Still Fork Sandy	dam backwater

The following samples were dropped from the analyses.

SRP CODE	STREAM	SAMPLE #	RATIONALE
NMT66B	Zielke Ditch	3	different site/closer to unsewered community
NMT72B	Gries Ditch	3	dry stream
WGT118	North Fork Paint	1 4	boat sampling late in year
WMG114	Honey Creek	3	high flow
EGT38	Sugar Creek	2 & 3	after fish kill(s)
SMG102	Sunfish Creek	3	late, cold/rainy
SMT1	Pine Creek	1	high flow
SMT4	Federal Creek	1	storm event
SMT5	Wolf Creek	2	leaf fall covered water
SMT5B	W. Br. Wolf Creek	2	data sheet missing
SMT5C	S. Br. Wolf Creek	2	boat sample/deep water
IP109	Stonelick Creek	2 & 3	stream drying/low species counts
BIW77S	E. Fork Little Miami	2 & 3	boat shocker only low species counts

Table 5. Dominant species and percent of samples where species > 10% of sample. Numbers in parentheses identify fish species indicated on Figure 2.

Huron/Erie Lake Plain (38 samples)		Eastern Corn Belt Plains (96 samples)		Erie/Ontario Lake Plain (49 samples)		Western Allegheny Plateau (69 samples)		Interior Plateau (16 samples)	
Bluntnose minnow	(1) 81.6	Bluntnose minnow	(1) 69.8	Bluntnose minnow	(1) 63.3	Bluntnose minnow	(1) 52.2	Longear sunfish	(18) 87.5
Creek Chub	(2) 42.1	Creek chub	(2) 49.0	Central stoneroller	(22) 30.6	Striped shiner	(23) 38.8	Bluntnose minnow	(1) 75.0
Green sunfish	(3) 39.5	Longear sunfish	(18) 26.0	Creek chub	(2) 24.5	Central stoneroller	(22) 37.3	Golden redhorse	(20) 18.8
Blackstripe topminnow	(4) 15.8	Central stoneroller	(22) 25.0	Striped shiner	(23) 16.3	Creek chub	(2) 22.4	Emerald shiner	(21) 18.8
Johnny darter	(7) 13.2	Green sunfish	(3) 13.5	Rockbass	(9) 14.3	Emerald shiner	(21) 17.9	Green sunfish	(3) 18.8
Fathead minnow	(5) 10.5	Striped shiner	(23) 11.5	White sucker	(8) 12.2	Golden redhorse	(20) 13.4	Rosefin shiner	(10) 12.5
Rockbass	(9) 10.5	Spotfin shiner	(17) 10.4	Bluegill	(12) 12.2	Longear sunfish	(18) 10.4		
White sucker	(8) 7.9	Greenside darter	(11) 9.4	Greenside darter	(11) 12.2	Sand shiner	(19) 9.0		
Yellow bullhead	(6) 7.9	Johnny darter	(7) 9.4	Mottled sculpin	(13) 12.2	Spotfin shiner	(17) 9.0		
Striped shiner	(23) 7.9	White sucker	(8) 8.3	Green sunfish	(3) 10.2				
		Golden redhorse	(20) 8.3	Johnny darter	(7) 10.2				
		Rosefin shiner	(10) 8.3	Common shiner	(14) 8.2				
				Rainbow darter	(15) 8.2				
				Fantail darter	(16) 8.2				

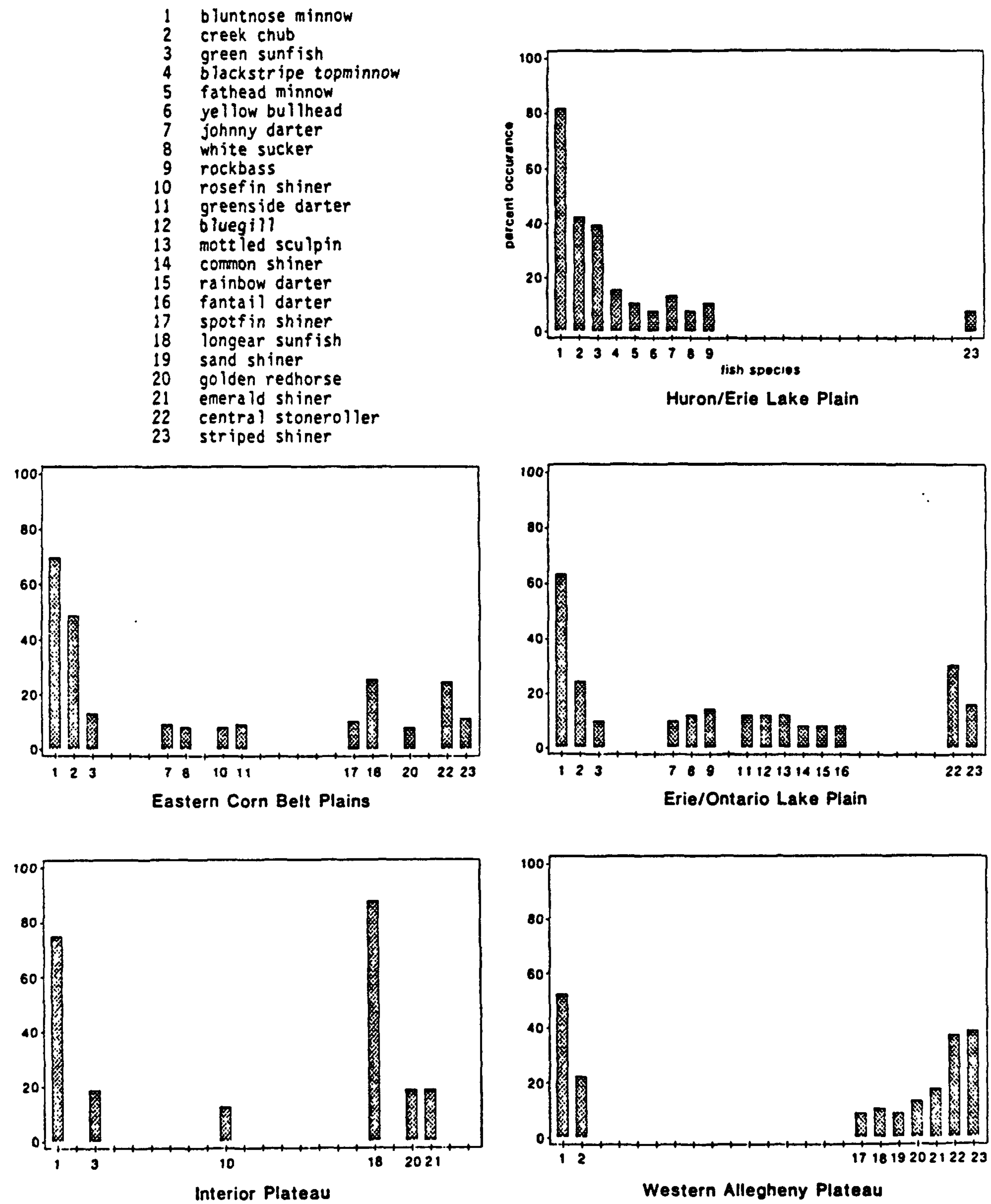

Figure 2. Dominant fish species. Fraction of samples in each region in which these species were dominant (> 10% of sample).

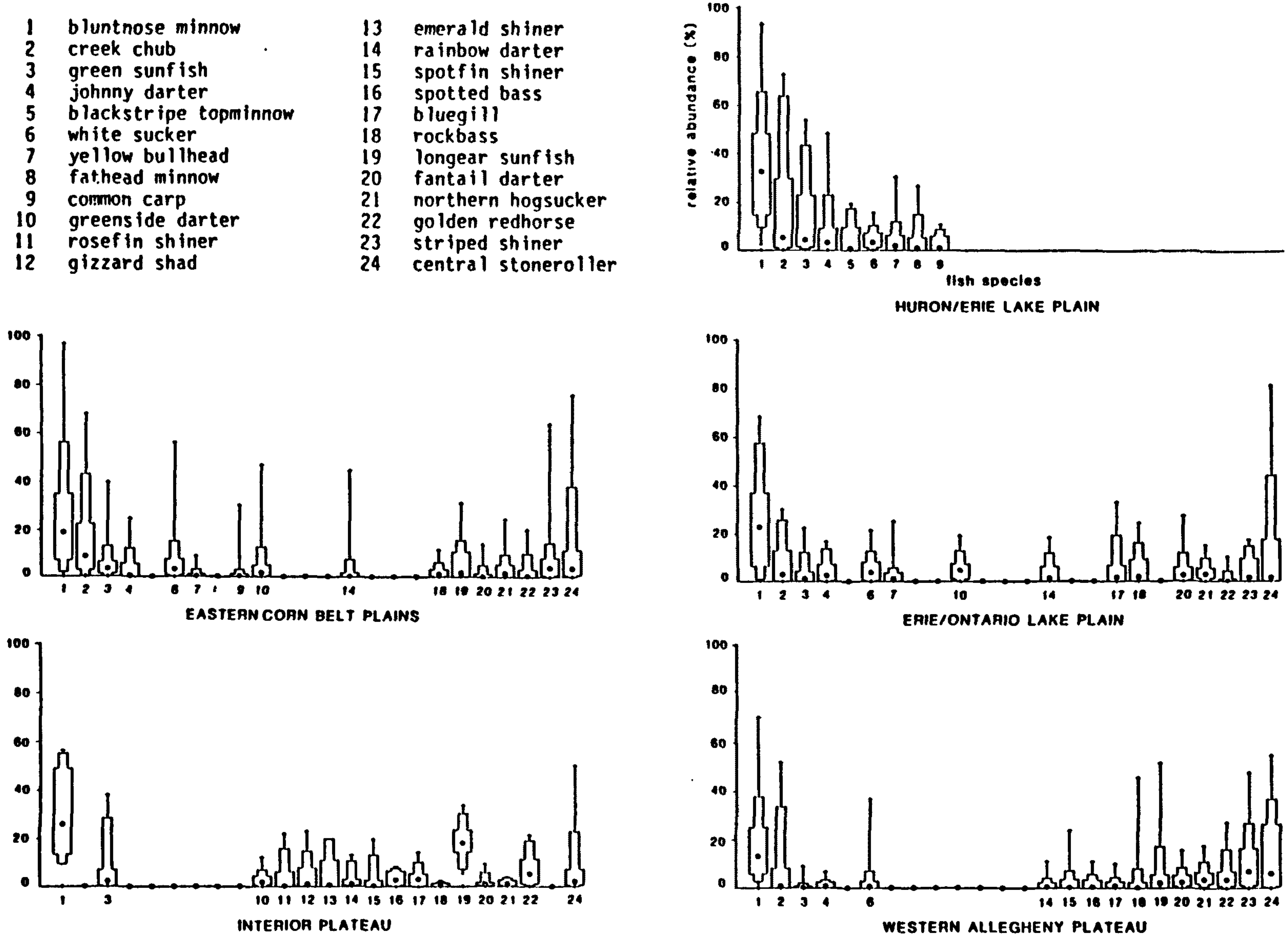

Figure 3. Dominant fish species. Relative abundances of 24 species by region. For each region only those species found in at least 50% of that region's samples are plotted.

source. Therefore, we regressed species richness on watershed area (as a measure of stream size, see Hughes and Omernik 1983), then examined residuals from this relationship for regional patterns.

We regressed the maximum number of species found at each site (from two or three samples) against $\log_{10}$ watershed area (Figure 4a). Box plots by ecoregion of the residuals from this relationship reveal a pattern that will reoccur for all of the other indices (Figure 4b). For watersheds of similar size, species richness tends to be lowest in the Huron/Erie Lake Plain and highest in the Western Allegheny Plateau with intermediate values in the other regions. Greatest variation occurs in the Eastern Corn Belt Plains.

Karr's Index of Biotic Integrity

We introduce the IBI by quoting from Karr (1981):

> Accurate assessment of biotic integrity requires a methodology that integrates responses of biotic communities through an examination of patterns and processes from population to ecosystem levels. One approach is to develop an array of biological metrics like the leading economic indicators used in econometric analyses. The Index of Biotic Integrity (IBI) uses data from collections of entire fish communities and summarizes them as 12 ecological characteristics, or metrics, which can be classified into three categories: species richness and composition, trophic composition, and fish abundance and condition. Values of each metric are compared to values expected at sites of similar stream size and regional location with minimal human influences....
>
> The metrics chosen for this analysis are measurable attributes of the community that are correlated with biotic integrity, which is not directly measurable. Each of the metrics is of interest for the information that it conveys about the overall structure and function of the stream community. In addition, each is of interest because it reflects something about biotic integrity. The values of the metrics are functions of the underlying biotic integrity; biotic integrity is not a function of the metrics.

The IBI scores were calculated as outlined by Fausch et al. (1984). Some of these scores may be slightly reduced by excluding exotic species (common carp and goldfish) from species counts. We used a restricted list of intolerant species. Karr et al. (1986) suggested that intolerant species be limited to 10-15% of the species present in the area, i.e., 12 of 99 species (Appendix A). Only those species most sensitive to habitat

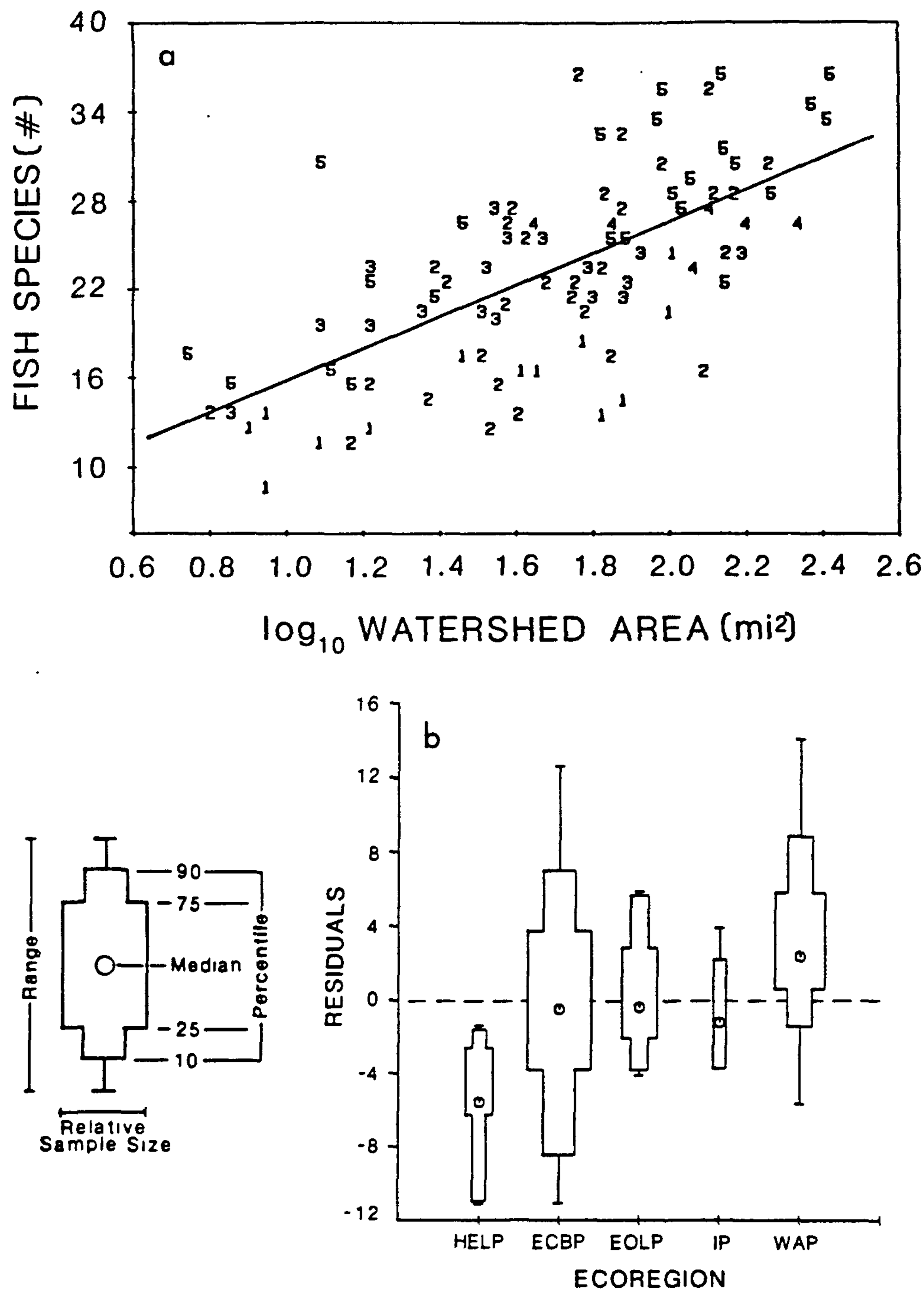

Figure 4. Fish species richness. (a) Regression of maximum fish species at each site vs $\log_{10}$ watershed area: 1 = Huron/Erie Lake Plain, 2 = Eastern Corn Belt Plains, 3 = Erie/Ontario Lake Plain, 4 = Interior Plateau, 5 = Western Allegheny Plateau. (b) Boxplots of the residuals of the species richness regression by region.

degradation, yet are fairly widespread, were used. Anomaly scores are based on the fraction of fishes observed with anomalies, excluding blackspot. To examine possible relationships among blackspot, incidences of other anomalies, and IBI scores, we performed correlations of the fraction of individuals with blackspot *versus* the fraction of all other anomalies, and with the IBI scores both statewide and within ecoregions. No clear pattern was discerned. Blackspot incidence was not correlated with IBI scores or other anomalies. Other anomalies showed a slight negative correlation (r = -.26) with IBI scores (as expected). High incidence of blackspot (> 10%) was used to reduce scores where the fraction of other anomalies was near cutoff points. Refinements of these and other metrics and scoring criteria are being developed by OEPA as part of their ongoing monitoring program.

Generally, highest IBI values occurred at sites in the Western Allegheny Plateau, while lowest values occurred at sites in the Huron/Erie Lake Plain. In fact, the lowest values in the former exceeded the highest values in the latter. Values in the transitional ecoregions were intermediate and, especially in the Eastern Corn Belt Plains and Erie/Ontario Lake Plain, displayed wide ranges (Figure 5).

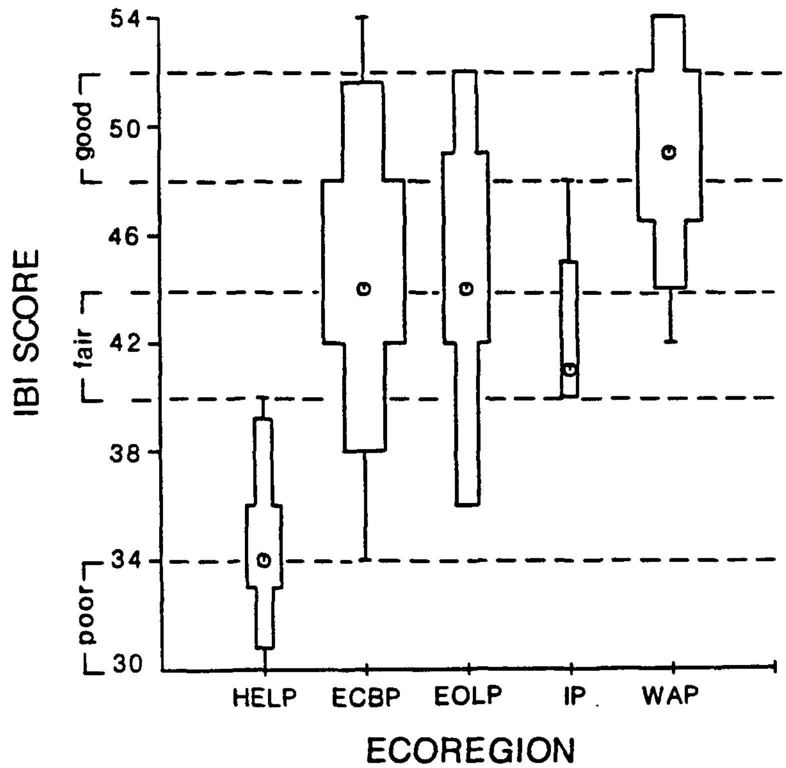

Figure 5. Boxplots of the maximum site Index of Biotic Integrity scores by region. Qualitative evaluations from Karr (1981).

Gammon's Index of Well-Being

Gammon's Index of Well Being (IWB) incorporates two widely used indices: diversity and abundance. Gammon (1976, 1980) reported that it appears to reflect environmental quality more satisfactorily than previously developed community indices. Whereas the IBI was developed for small streams, the IWB was designed for, and usually applied to, large streams and rivers. It is calculated (by OEPA) as:

$$IWB = 0.5 \ln N + 0.5 \ln W + H'(no.) + H'(wt.)$$

where N = number of fish captured per kilometer for boat samples, or per 0.3 kilometer for towed generator and backpack electrofisher

W = weight in kg per distance as above;

H'(no.) = Shannon diversity based on numbers;

H'(wt.) = Shannon diversity based on weight.

The different weightings used above result from differences in sampling efficiency of the equipment.

We found a slight ($r^2 = 0.19$) but statistically significant ($P < 0.0001$) linear relationship between IWB and $\log_{10}$ watershed area (Figure 6a). Residuals display the expected regional pattern, although variability is quite high (Figure 6b). Negative values occur in the Huron/Erie Lake Plain, and positive values in the Western Allegheny Plateau. Because of the very low correlation between IWB and watershed area, it seems appropriate to refer directly to the regional patterns in IWB (Figure 6c).

Species Diversity

Species diversity is a commonly used community index that combines species richness and equitability, the relative abundance of species. Several calculating methods are available. OEPA formerly included Shannon diversity among its analyses, so the same index is used here.

Species diversity is linearly related to $\log_{10}$ watershed area ($r^2 = 0.36$, $p < 0.0001$); a stronger relationship probably exists if the four circled values are excluded as apparent outliers (Figure 7a). Residuals display the previously noted ecoregional patterns, negative values in the Huron/Erie Lake Plain and positive values in the Western Allegheny Plateau (Figure 7b). Relatively low values also occur in the Interior Plateau.

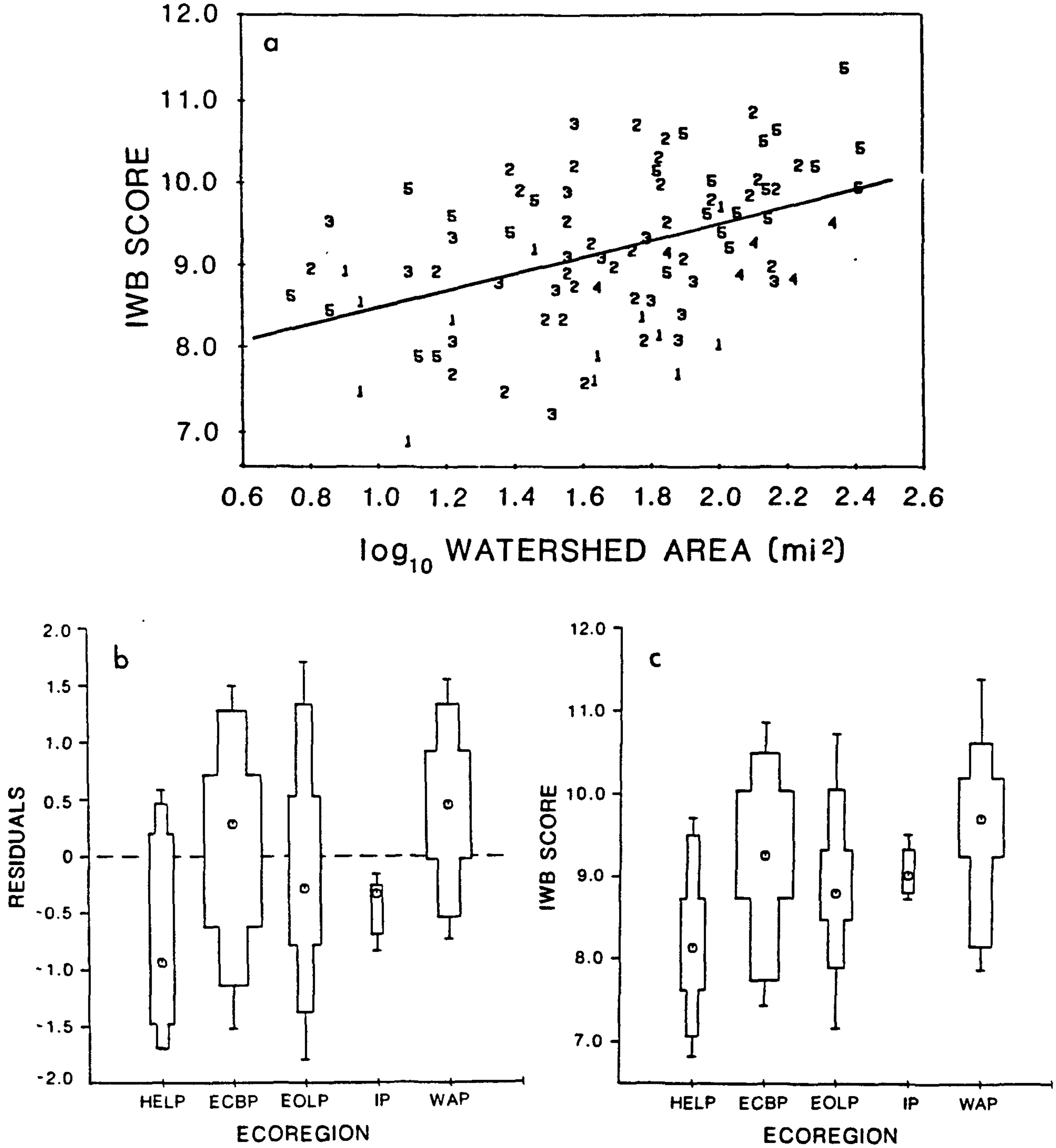

Figure 6. Index of Well-Being (IWB). (a) Regression of maximum IWB score at each site vs $\log_{10}$ watershed area: 1 = Huron/Erie Lake Plain, 2 = Eastern Corn Belt Plains, 3 = Erie/Ontario Lake Plain, 4 = Interior Plateau, 5 = Western Allegheny Plateau. (b) Boxplots of residuals of IWB regression by region. (c) Boxplots of actual IWB scores by region.

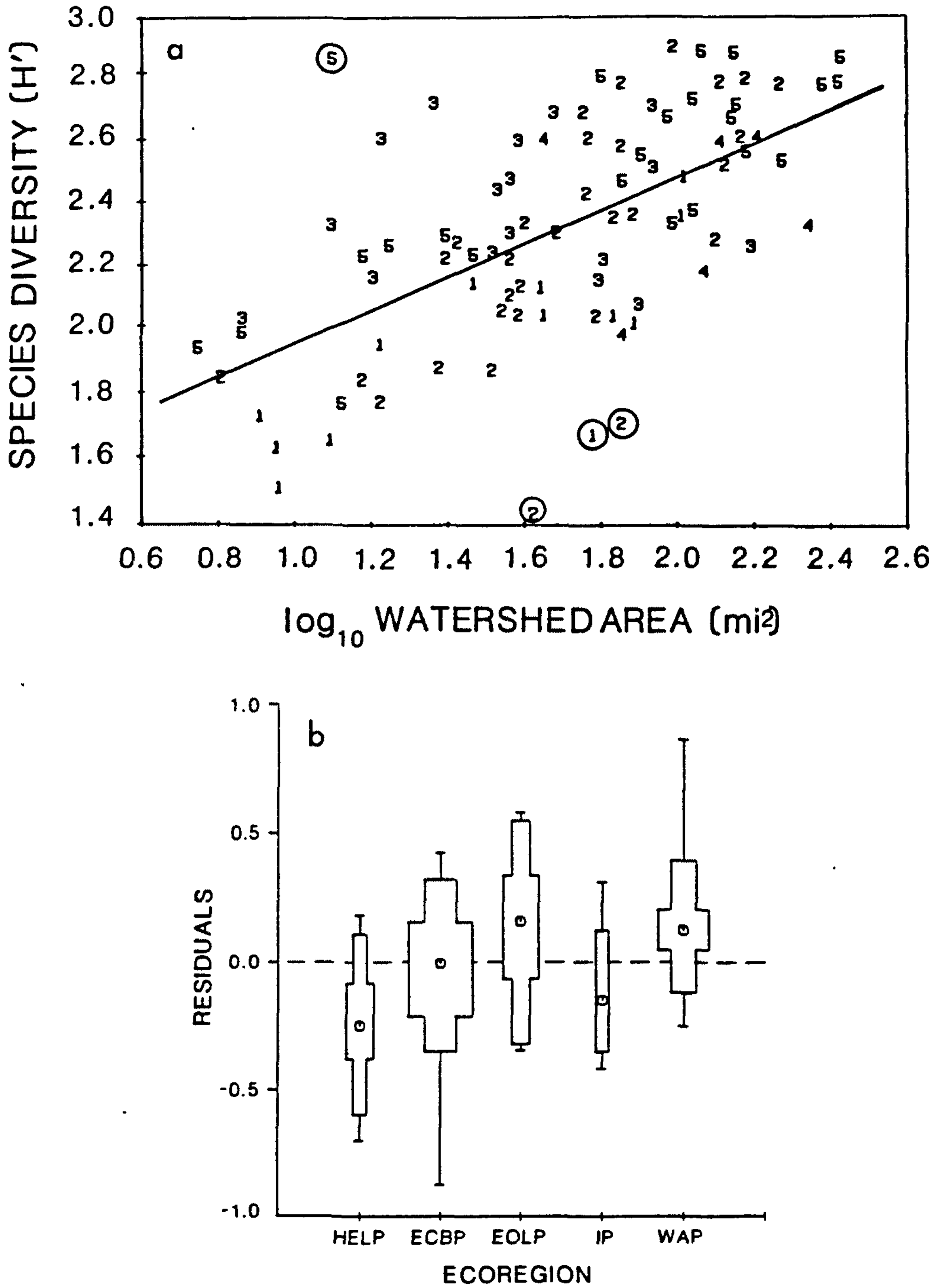

Figure 7. Fish species diversity. (a) Regression of maximum fish species diversity (H') at each site vs log$_{10}$ watershed area: 1 = Huron/Erie Lake Plain, 2 = Eastern Corn Belt Plains, 3 = Erie/Ontario Lake Plain, 4 = Interior Plateau, 5 = Western Allegheny Plateau. Apparent outlier values circled. (b) Boxplots of residuals of fish species diversity regression by region.

Intolerant Species and Individuals

Other measures of the health or integrity of a stream include the number of species and fraction of individuals in a fish community that are generally intolerant of environmental degradation. We consider intolerant species those that tend to require high dissolved oxygen levels and low levels of turbidity and siltation. Information regarding tolerance is generally available from books that summarize fish distributions and habitat by state. We used Becker (1983), Carlander (1969, 1977), Lee et al. (1980), Pflieger (1975), Smith (1979), and Trautman (1981) to establish the list of species tolerances summarized in Appendix A.

As seen with the other measures, there is a significant linear relationship between the number of intolerant species and watershed area ($r^2 = 0.34$, $p < 0.0001$) (Figure 8a). Note that the number of intolerant species in the Huron/Erie Lake Plain appears to increase little or not at all with stream size. Residuals display the typical pattern seen for the other variables, negative in the Huron/Erie Lake Plain, generally positive in the Western Allegheny Plateau, with a fairly wide range of values for some ecoregions (Figure 8b). There is no relationship between the fraction of intolerant individuals and stream size so these are displayed directly (Figure 8c).

MACROINVERTEBRATES

We present only data collected by the kick net method for macroinvertebrates. Preliminary analyses of data collected using Hester-Dendy multiple-plate samplers did not produce a clearer regional pattern than the kick net data. Not all organisms collected could be identified to species. Preliminary plots of the percent of individuals and of taxa keyed to each level indicated no regional differences in the level of taxonomic resolution. For this report, "taxa" refers to the lowest level of taxonomic identification achieved for each specimen and in this sense is analogous to "species".

Richness and Diversity

The total numbers of different macroinvertebrate taxa collected at each site (taxa richness) do not show distinct differences among ecoregions (Figure 9a). The regional medians range from 27 in the Huron/Erie Lake Plain to 31 in the Erie/Ontario Lake Plain. The total range is from a low of 13 in the Western Allegheny Plateau to a high of 51 in the Erie/Ontario Lake Plain. Shannon diversity values (H') for the taxa collected at each site also do not differ among the ecoregions (Figure 9b). The medians range from 3.06 in the Interior Plateau to 3.39 in

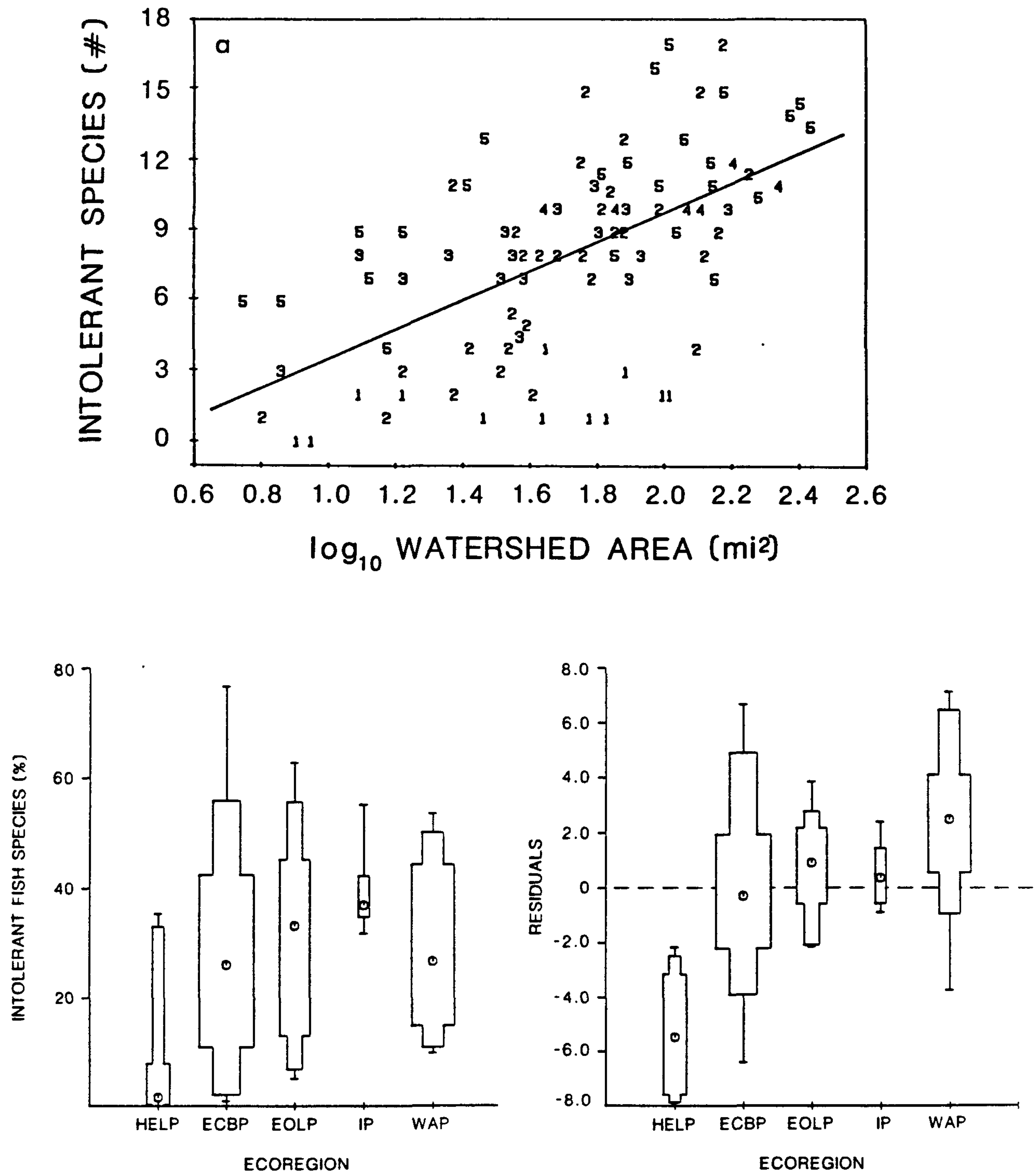

Figure 8. Intolerant fish species. (a) Regression of maximum number of intolerant fish species at each site vs $\log_{10}$ watershed area: 1 = Huron/Erie Lake Plain, 2 = Eastern Corn Belt Plains, 3 = Erie/Ontario Lake Plain, 4 = Interior Plateau, 5 = Western Allegheny Plateau. (b) Boxplots of residuals of intolerant fish species regression by region. (c) Boxplots of maximum percent of intolerant fish species each site by region.

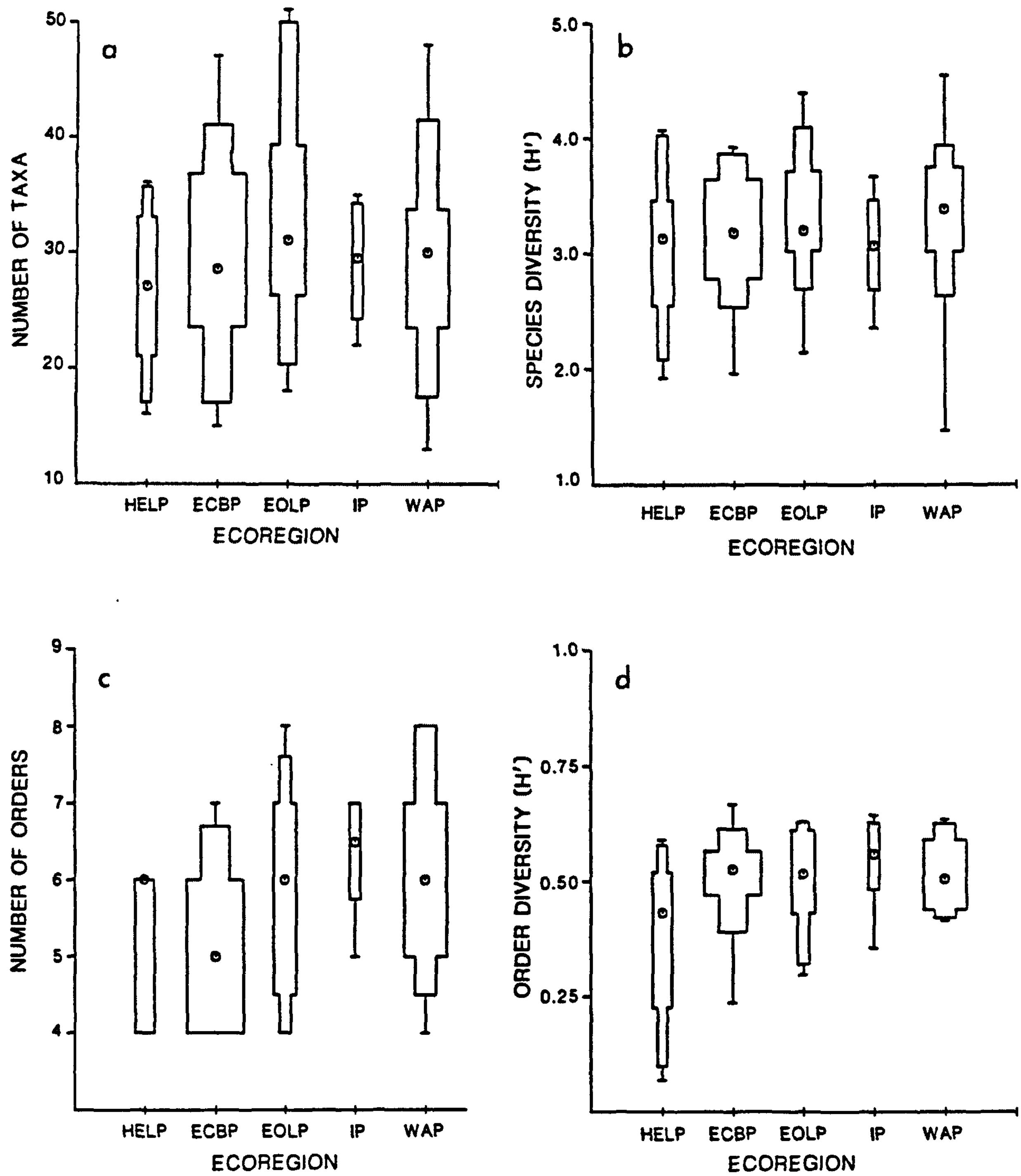

Figure 9. Macroinvertebrate richness and diversity. (a) Taxa richness of macroinvertebrates by region. (b) Taxa diversity (H') by region. (c) Macroinvertebrate order richness by region. (d) Macroinvertebrate order diversity by region.

the Western Allegheny Plateau, and both extreme values fall in the Western Allegheny Plateau (1.47 to 4.54).

Slight differences exist among ecoregions when aquatic macroinvertebrate richness and diversity are calculated at the order level. Medians of the total numbers of orders represented span from 5.0 in the Eastern Corn Belt Plains ecoregion to 6.5 in the Interior Plateau (Figure 9c). These differences seem to result primarily from the Megalopteran and Plecopteran taxa which are present at a greater proportion of sites in the Interior Plateau than the other ecoregions and marginally represented or absent in the Eastern Corn Belt Plains and Huron/Erie Lake Plain. The latter two ecoregions also tend to have fewer Odonate taxa. Note that the median richness in the Huron/ Erie Lake Plain is also the maximum value in this ecoregion. Median insect order diversities span from 0.431 in the Huron/ Erie Lake Plain to 0.561 in the Interior Plateau (Figure 9d). The lower range, 25th percentile and the median of the order diversity values are notably lower in the Huron/Erie Lake Plain ecoregion, apparently as a result of both moderately low richness and high dominance of several Ephemeropteran and Dipteran taxa.

Insect Taxa Dominance by Ecoregion

A "taxa signature" or plot of the relative abundances of various insect taxa that could be expected in each ecoregion was constructed as follows: First, for each ecoregion, the 10 most numerically abundant taxa at each site were listed. Then, those taxa among the 10 most abundant at four or more sites in any ecoregion were placed on the master list. Box plots of the relative abundances of these 24 taxa were prepared for each ecoregion.

Some differences appear among the ecoregions in signature taxa presence, abundance, and degree of dominance (Figure 10). Cheumatopsyche sp. appears to be the dominant Trichopteran in all ecoregions. It is practically the only Trichopteran in the Huron/Erie Lake Plain and Interior Plateau with the exception of some Hydropsyche depravada and Hydroptila sp. in the former and Chimarra obscura and Symphitopsyche bifida in the latter. In the remaining three ecoregions all five Trichopteran signature taxa are represented. The proportional abundances of Isonychia sp. and Baetis sp. are also fairly high at many sites in all ecoregions. Heptagenia sp. and Stenacron sp. also appear frequently in moderate concentrations in the Huron/Erie Lake Plain but decline in importance in the other ecoregions, except for Stenacron sp. in the Erie/Ontario Lake Plain. Proportional abundances of Stenonema vicarium and Caenis sp. increase as one passes from the Huron/Erie Lake Plain, through the other ecoregions, to the Western Allegheny Plateau.

Polypedilum convictum is the most consistently abundant Dipteran across ecoregions and appears to be practically the only

1 Chimarra obscura
2 Cheumatopsyche sp
3 Hydropsyche depravata
4 Symphitopsyche bifida
5 Hydroptila sp
6 Isonychia sp
7 Baetis sp
8 Heptagenia sp
9 Stenacron sp
10 Stenonema pulchellum
11 Stenonema vicarium
12 Caenis sp
13 Simulium sp
14 Thienemannimyia sp
15 Cricotopus bicinctus
16 Microtendipes sp
17 Polypedium convictum
18 Polypedium scalaenum
19 Stictochironomus sp
20 Cladotanytarsus sp
21 Rheotanytarsus exiguus
22 Tanytarsus glabrescens
23 Psephenus herriki
24 Stenelmis sp

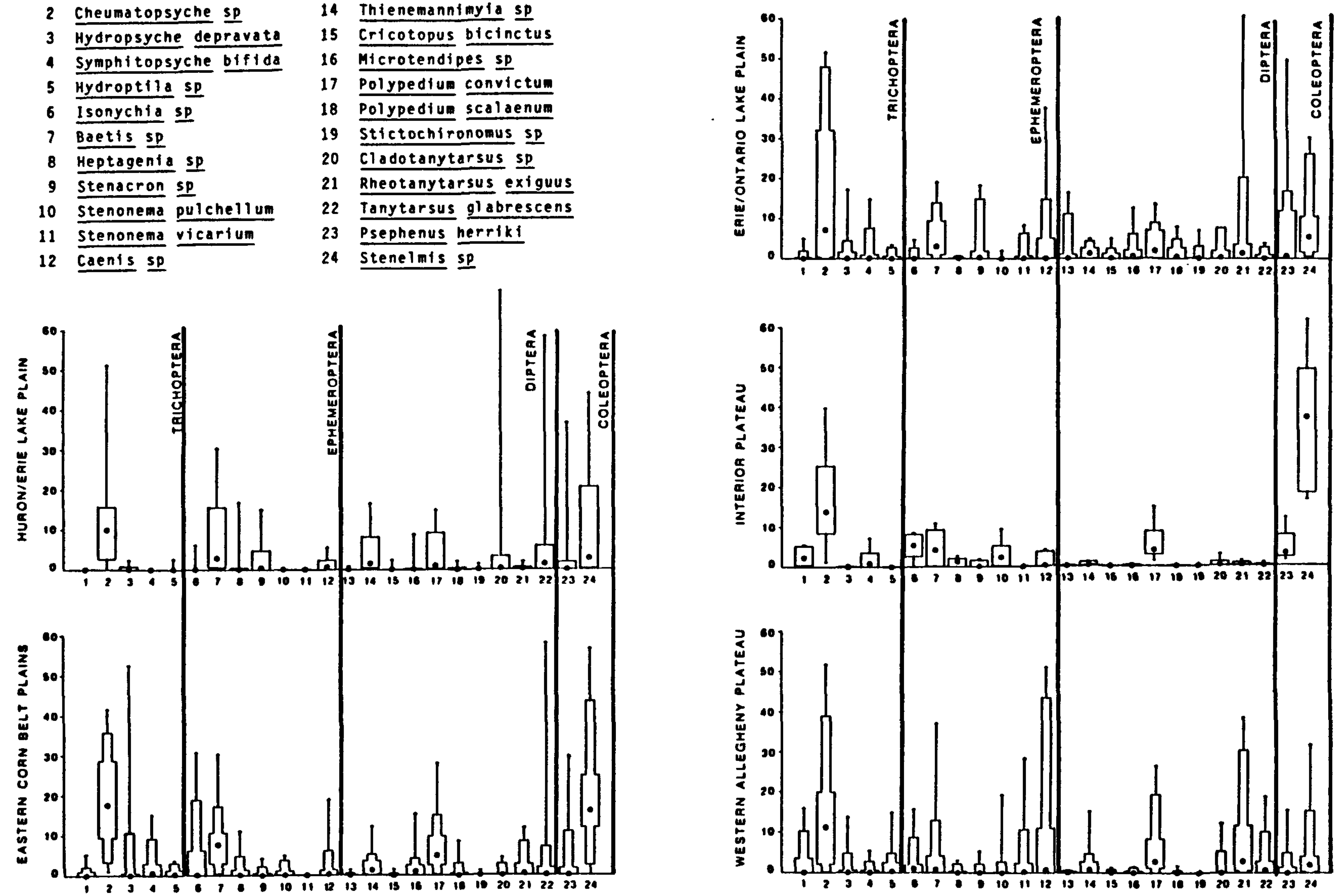

Figure 10. Aquatic insect taxa signature. Relative abundances of 24 dominant taxa.

one present in the Interior Plateau ecoregion. Cladotanytarsus sp. and Tanytarsus glabrescens show greater dominance in the Huron/Erie Lake Plain than in any other ecoregion. Cricotopus bicinctus appears in small numbers in the Huron/Erie Lake Plain and Erie/Ontario Lake Plain, while Stichtochironomus sp. and Simulium sp. appear in moderate numbers only in the latter. Abundances of Rheotanytarsus exiguus appear greatest in the Eastern Corn Belt Plains, Erie/Ontario Lake Plain and Western Allegheny Plateau. Coleopterans appear abundant with fairly high degrees of dominance in all ecoregions, particularly the Eastern Corn Belt Plains and Interior Plateau.

Indicator Taxa

The Cornell Ecology Program TWINSPAN (Gauch 1982) was used to hierarchically divide the samples (sites) into clusters based on similarities in taxa composition. This program also identifies characteristic taxa of each cluster. Rather than identifying the numerically dominant taxa, it chooses the (indicator) taxa that distinguish each cluster from the others. Because the geographic pattern of sites grouped by TWINSPAN resembles the ecoregion classification, these taxa are of interest. We prepared box plots of the relative abundances of the indicator taxa, by insect order, for each ecoregion (Figure 11).

The number of indicator taxa present with any degree of dominance increases from 10 in the Huron/Erie Lake Plain to 17 in the Western Allegheny Plateau. Hemiptera are not important in distinguishing clusters except in the latter ecoregion where Rhagovelia sp. and Microvelia sp. are present at some sites. The Trichopteran component ranges from none in the Huron/Erie Lake Plain to moderate numbers of Symphitopsyche bifida in the other ecoregions; Hydropsyche dicantha becomes equally important in the southern two ecoregions. The Megalopteran Corydalus cornutus also helps to distinguish these two ecoregions from the others. Isonychia sp., Baetis sp., and Stenacron sp. are fairly abundant, and differ proportionally in each ecoregion; they are the only Ephemeropteran indicators in the Huron/Erie Lake Plain. Stenonema vicarium is an Ephemeropteran indicator in the eastern two ecoregions, while S. pulchellum replaces it in the Eastern Corn Belt Plains and Interior Plateau; both species are observed in the Western Allegheny Plateau ecoregion.

For the Dipterans, Polypedilum convictum occurs in moderate abundances in all ecoregions. It is combined with Tanytarsus glabrescens in the Huron/Erie Lake Plain, and with Rheotanytarsus exiguus in the Erie/Ontario Lake Plain. P. convictum is combined with both other Dipterans in the Eastern Corn Belt Plains and Western Allegheny Plateau, and neither in the Interior Plateau. The Coleopteran Stenelmis sp. is the most dominant indicator at sites in the Erie/Ontario Lake Plain, Eastern Corn Belt Plains, and Interior Plateau.

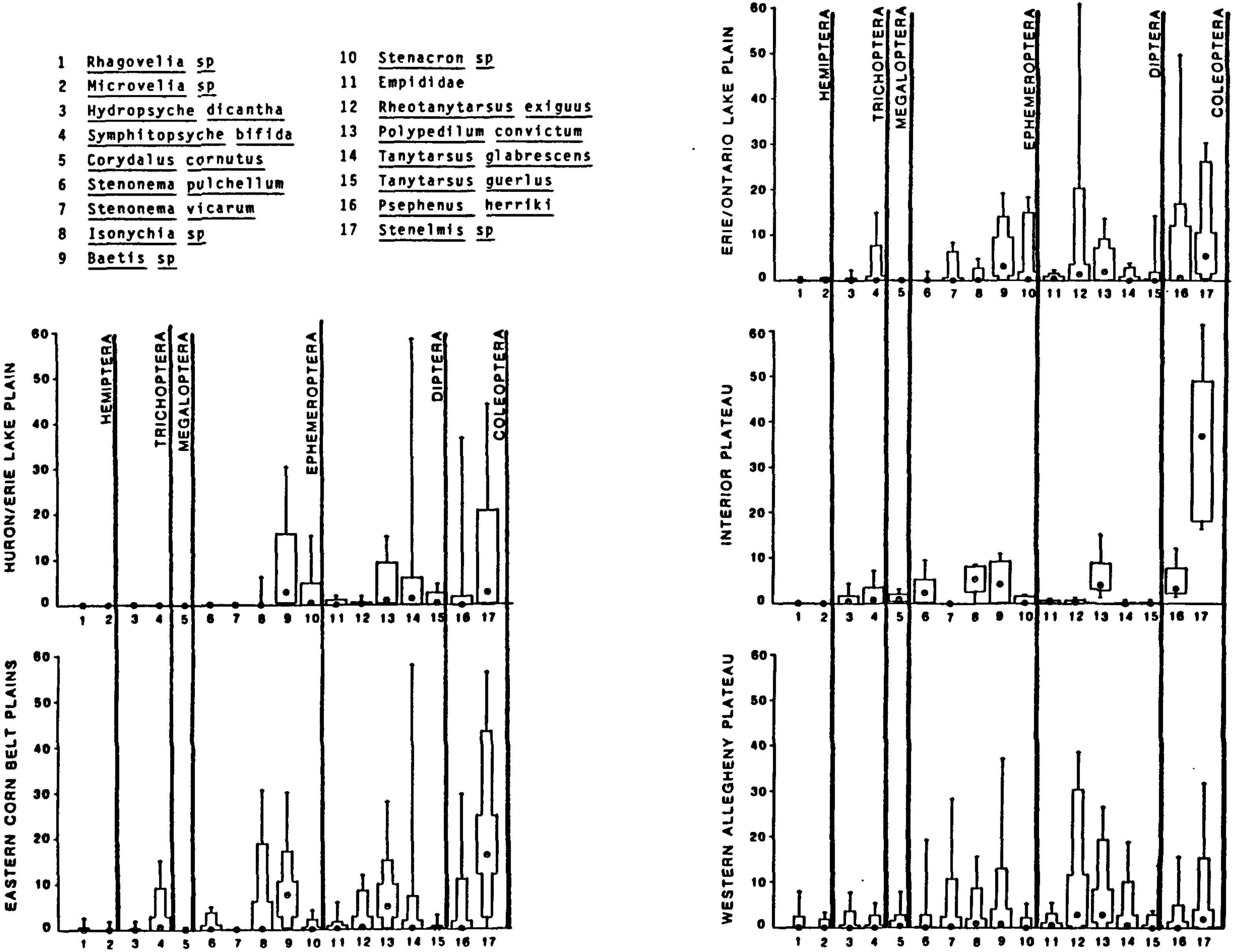

Figure 11. Aquatic insect indicator taxa. Relative abundances of 17 insect taxa selected by the TWINSPAN program.

WATER CHEMISTRY

The results in this water chemistry section are grouped into three categories: ionic strength (conductivity, alkalinity, total hardness, calcium, and magnesium); nutrients (nitrate, nitrite, ammonia, Kjeldahl nitrogen, total phosphorus, and total organic carbon); and selected metals (copper, iron, and lead).

Patterns in water chemistry are displayed in four ways. First, we selected the median value over the 16-month sampling interval to represent a site and used those site medians to develop regional box plots. The median value on each box plot is, therefore, a median of medians.

A second way presents selected nutrients at selected sites in the Eastern Corn Belt Plains by graphs of changes through the 16-month sampling interval. These time series graphs illustrate the range in values found in one region. Sites exhibiting patterns of low nutrient concentration occur in watersheds that may differ naturally or anthropogenically from those watersheds where high levels occur. We will develop this theme further in the interpretation section. We chose nutrients for these displays because of national efforts to minimize nutrients in water bodies.

A third method displays data by mapping the spatial distribution of water chemistry values. This provides a synoptic picture of the spatial similarity of site chemistry; it indicates how well ecoregional patterns correspond with water chemistry patterns. If other spatial patterns stand out, they may suggest causal mechanisms controlling the pattern.

Finally, we used principal components analysis (PCA) to identify components that would express patterns in nutrient richness and ionic strength. PCA is a technique that extracts from correlated data one or a few variables (principal components) that can account for most of the variability in a set of multivariate correlated data (SAS 1985). We examined the correspondence between spatial patterns in these variables and the ecoregions.

Box Plots of Water Chemistry

Ionic Strength

Streams in the Huron/Erie Lake Plain and Eastern Corn Belt Plains tend to exhibit higher concentrations of chemical constituents in this category than do streams in the other three regions (Figure 12). Although there is a considerable overlap in values among adjoining regions, the same general pattern occurs among all the variables.

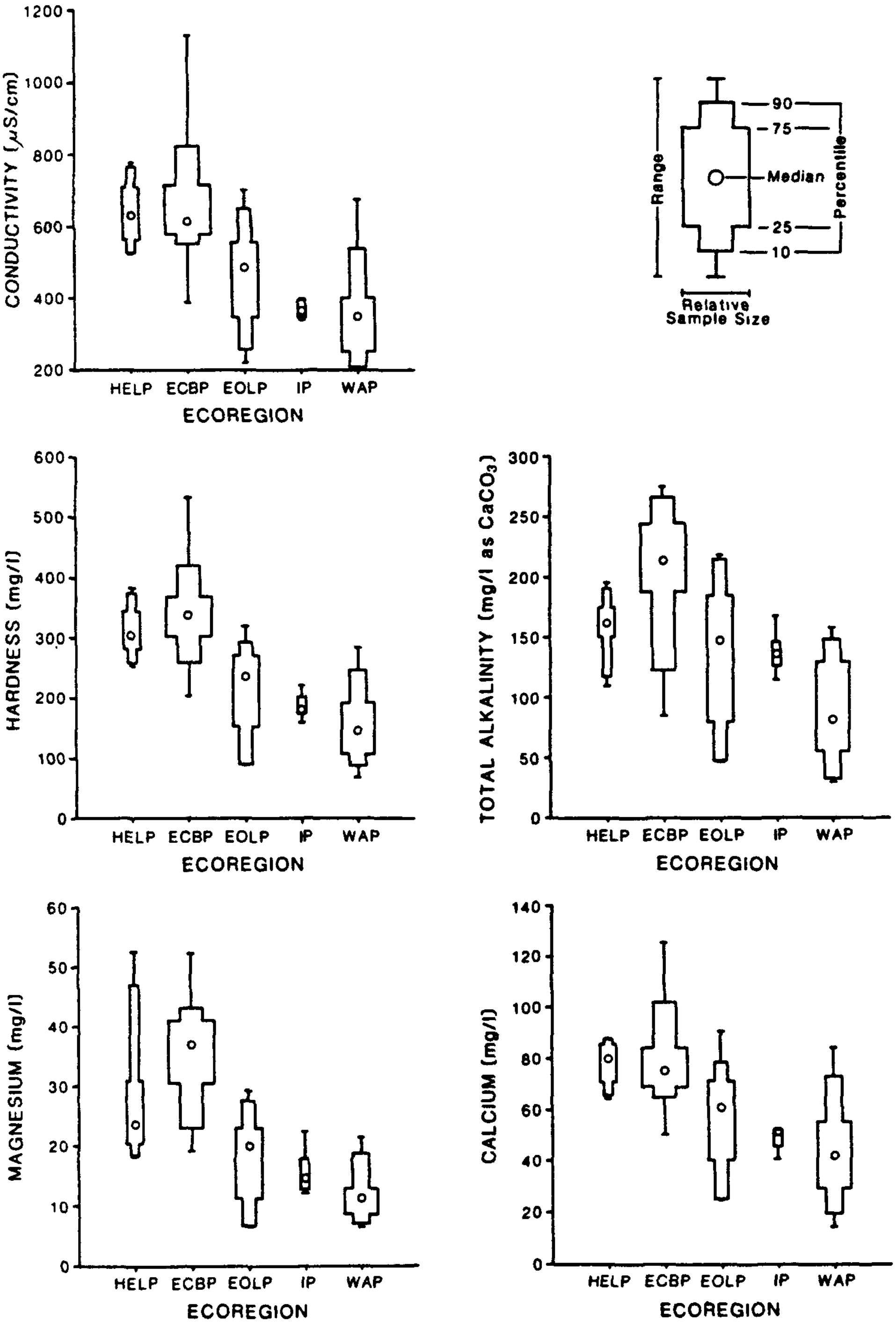

Figure 12. Selected ionic strength measures of water quality by region. Boxplots of site medians of 16 monthly samples.

Nutrients

Concentrations and variability of nitrogenous compounds tend to be highest in the Huron/Erie Lake Plain and lowest in the Western Allegheny Plateau (Figure 13). In some cases, extremely high values occur, e.g. nitrate values at some sites in the Huron/Erie Lake Plain approach the 10 mg/l public water supply standard. In the same region, some values are quite low, suggesting substantially different kinds of management practices or natural differences in the respective watersheds.

Total phosphorus exhibits a similar pattern to that of the nitrogen compounds. Total phosphorus values at most sites in the Western Allegheny Plateau were at or below analytically detectable limits of the method used. The pattern for total organic carbon differed from that seen for the other nutrient variables such that values in the Erie/Ontario Lake Plain were similar to those of the Huron/Erie Lake Plain; lowest values occurred in the Western Allegheny Plateau.

Iron, Copper, and Lead

A similar pattern to that seen for nutrients is also seen for these metals (Figure 14). Highest values and greatest variability occur in the Huron/Erie Lake Plain and the Eastern Corn Belt Plains; lowest values are in the Western Allegheny Plateau. A few sites are characterized by a consistent pattern of high values throughout the sampling season; medians are shown in Table 6. There might be unusual watershed activity or local perturbations associated with these sites relative to other sites.

Temporal Patterns in Water Chemistry Variables

We selected several sites in the Eastern Corn Belt Plains to illustrate the seasonal patterns in the nutrient concentration in these streams and to indicate the extremes that can occur within ecoregions, even at minimally impacted sites. It is likely that there are identifiable management activities that differ among these watersheds. An understanding of these activities might be a useful guide for improving chemical water quality, but not necessarily biotic integrity (Karr et al. 1985).

Large differences between total phosphorus and Kjeldahl nitrogen occur among these watersheds (Figure 15a, 15b), but no consistent seasonal pattern is evident in all. Also, within sites, large differences in concentration occur over relatively short periods of time; however, these are not so large as to mask the clear differences among high and low sites. The variability within sites is not unexpected as nutrient levels often fluctuate with changes in stream flow associated with storm events.

In contrast to these measures, nitrate seems to display a definite seasonal pattern, with the exception of site WGT 61A; while relatively low values occur in the late summer-early fall,

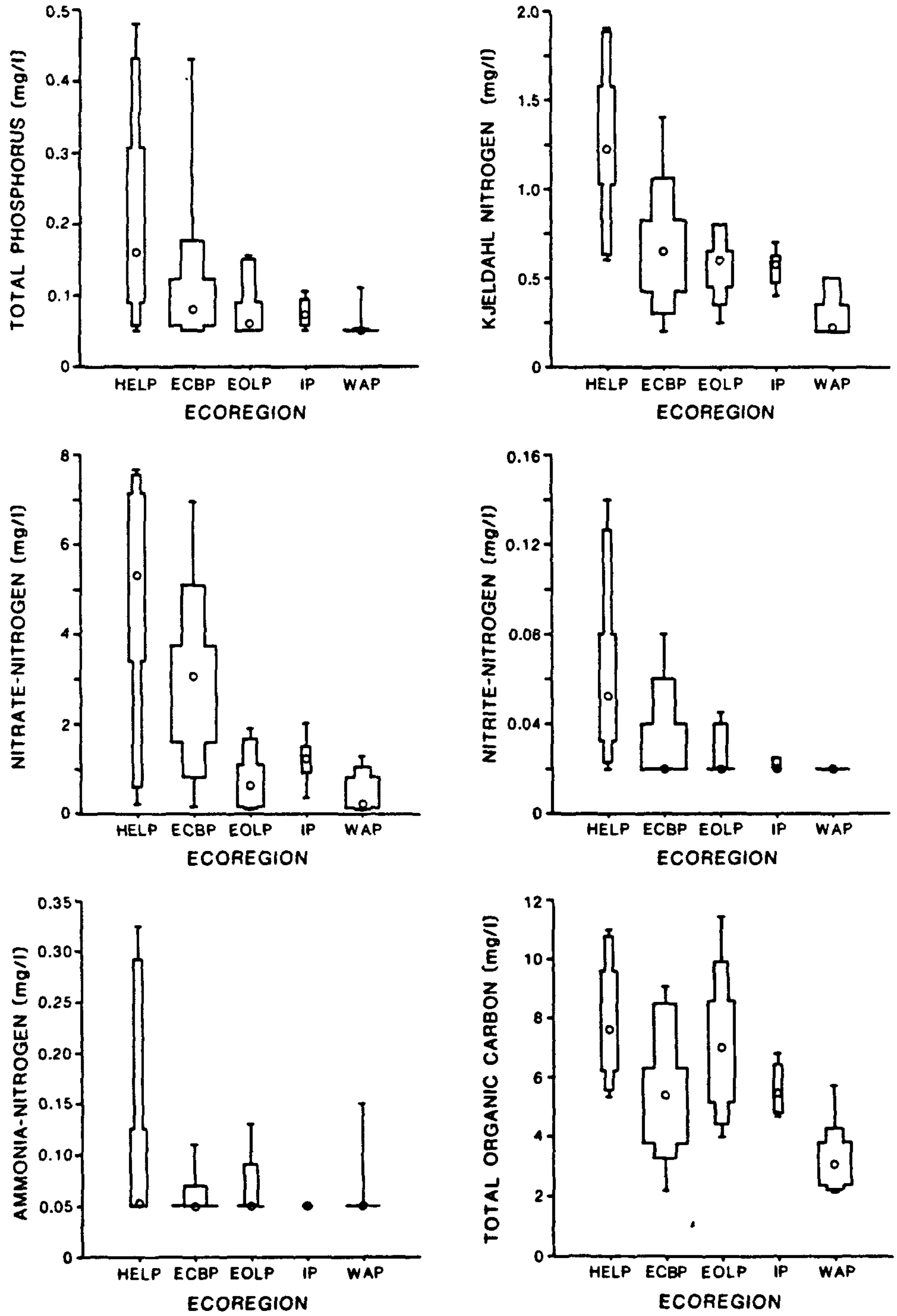

Figure 13. Selected nutrient measures of water quality by region. Boxplots of site medians of 16 monthly samples.

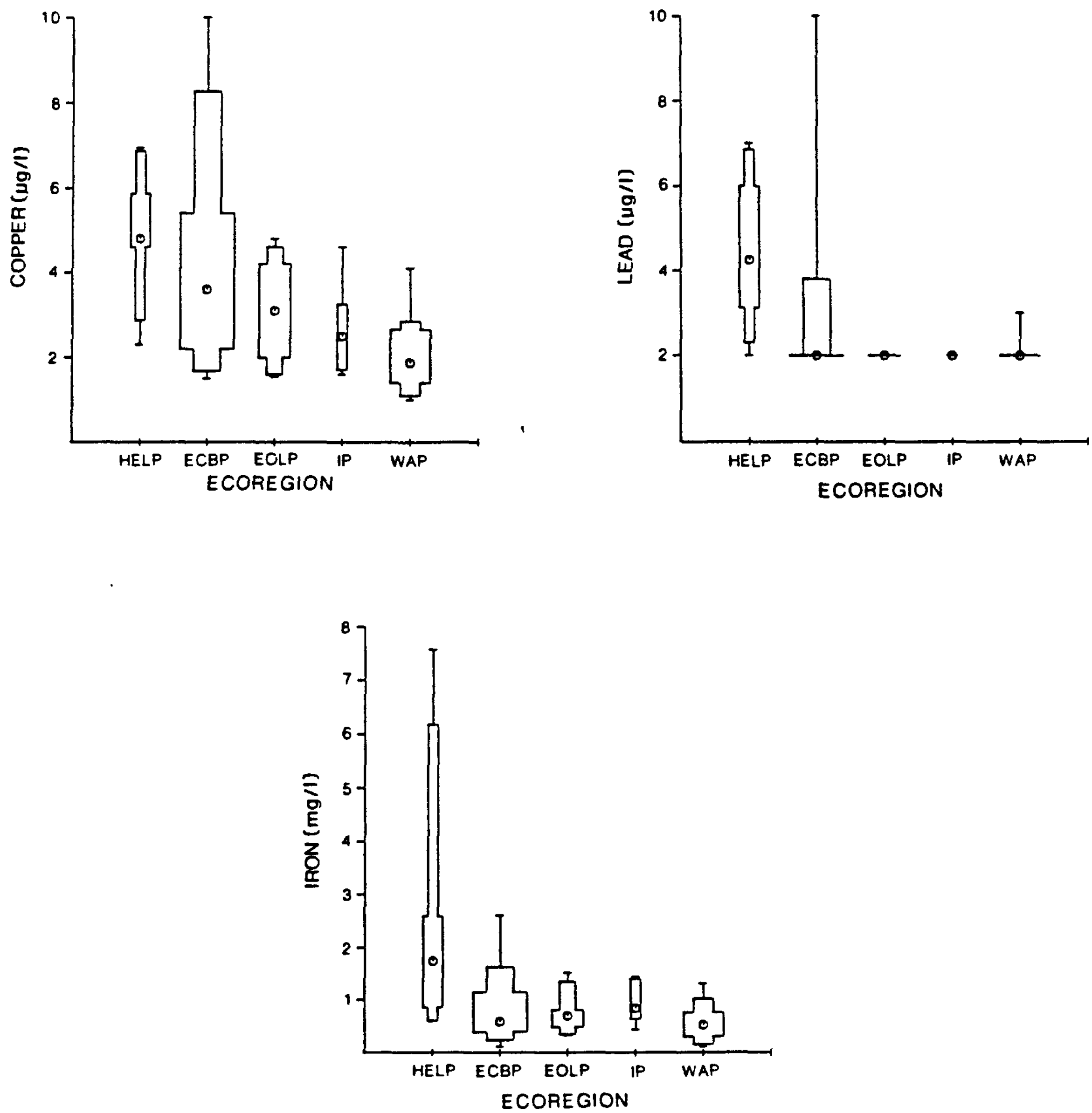

Figure 14. Selected metal concentrations by region. Boxplots of site medians of 16 monthly samples (12 for copper).

relatively high values characterize the remainder of the year (Figure 15c). For ammonia the pattern shows that sites with low concentrations are characterized by values consistently at the detection limits of the analytical procedures used, while other sites display large increases from this background level with apparently no consistent seasonal pattern (Figure 15d).

Although the sites chosen to display temporal patterns represent the extremes for one region, the general patterns hold true for sites in other regions. In the Huron/Erie Lake Plain patterns and extremes are similar to those just described, while for the other three regions differences among extremes are not so great. This is also reflected in the box plots of median values over the entire 16-month interval (Figure 13).

Table 6. Sites characterized by unusually high metal concentrations (median values).

Site (SRP Code)	Iron mg/l	Copper ug/l	Lead ug/l
Huron/Erie Lake Plain			
Little Auglaize (NGT7BB)	2.7		6.5
Brush Creek (NGT75)	2.9		
Black Creek (NGT93)			7.0
Powell Creek (NMT67)			6.5
Lost Creek (NMT68B)	7.6		
Eastern Corn Belt Plains			
Mill Creek (WGT117)		9.1	
Slate Creek (WGT62B)	2.6	9.4	10.0
Eagle Creek (WMG49B)		7.0	
Mad River (WMG116)		10.0	

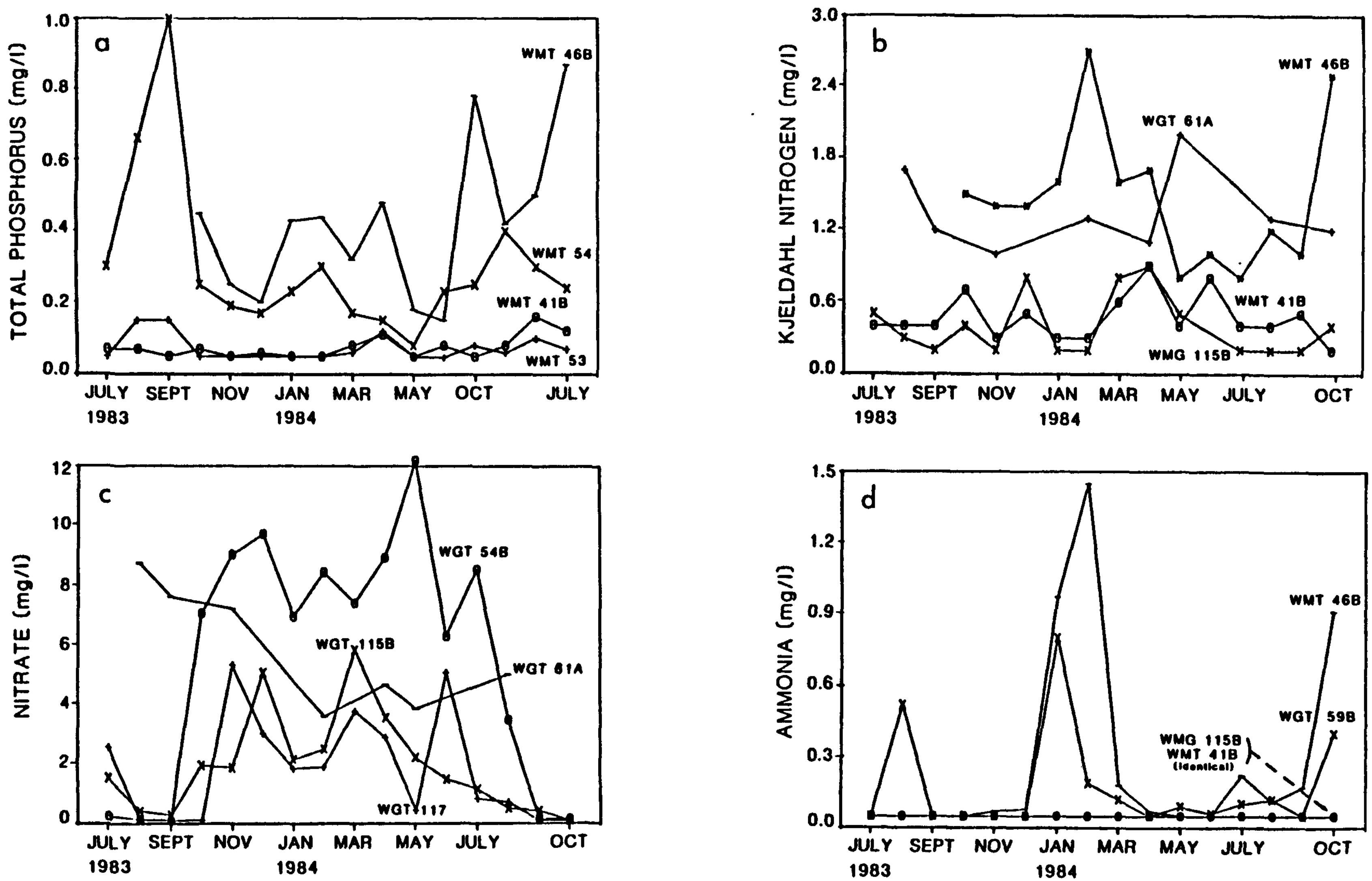

Figure 15. Temporal patterns of nutrient concentrations at selected sites in the Eastern Corn Belt Plains. (a) Total phosphorus levels. (b) Kjeldahl nitrogen levels. (c) Nitrate levels. (d) Ammonia levels.

Spatial Patterns in Selected Water Chemistry Variables

Spatial patterns in water chemistry characteristics can be displayed through color- or shade-coded dot maps. These maps are constructed by dividing the range of site values (medians in this case) into intervals that split the sites into relatively evenly sized groups. The number of intervals depends on the size of the data set and the level of resolution desired. We found four to nine intervals provided good resolution.

Representative of nutrient patterns, the total phosphorus map shows the consistently low values in streams throughout the Western Allegheny Plateau (with one exception) and the generally high values in the Huron/Erie Lake Plain (Figure 16). It also illustrates the high variability among sites in the Eastern Corn Belt Plains and the incidence of sites with low values scattered throughout this ecoregion. Representative of ionic strength patterns, the conductivity map indicates lowest values in the streams of the Western Allegheny Plateau and the Interior Plateau and highest values in the Huron/Erie Lake Plain and the Eastern Corn Belt Plains (Figure 17). The map also shows some spatial segregation of values in regions with higher variability, as is seen in the patterns in the Erie/Ontario Lake Plain. Here, lowest values occur at sites in the northeast and higher values are found in central and southwestern areas of the ecoregion.

Principal Components Analysis (PCA)

The minimum correlation among the ionic strength variables is between conductivity and alkalinity ($r = 0.73$); for all other pairs of variables, r is 0.80 or higher. As a result, PCA axis I (PCA I) accounts for a high proportion (90%) of the total variability in this multivariate data set; each variable is almost equally loaded on ionic strength PCA I.

The correlations among the nutrient richness variables are not as high as those for ionic strength because nutrients fluctuate more independently of each other. This lower correlation is also reflected in the lower fraction of multivariate variability accounted for by the principal axes in the nutrient analysis: PCA I accounts for 64% of the variability; adding PCA II increased that to 78% of the variability. The lower correlations are reflected in the PCA I and PCA II loadings; not all variables are loaded as similarly on PCA I as they are for the ionic strength variables on the ionic strength PCA I. Total phosphorus, Kjeldahl nitrogen, and nitrite are equally and most heavily loaded on PCA I, while nitrate, ammonia, and total organic carbon are also equally but less heavily loaded on PCA I. PCA II reflects a dominance of total organic carbon with a lesser influence of nitrates. PCA I seems to express the overall quality of nutrient richness of the stream water, i.e. the combination of nitrogen, phosphorus, and carbon compounds.

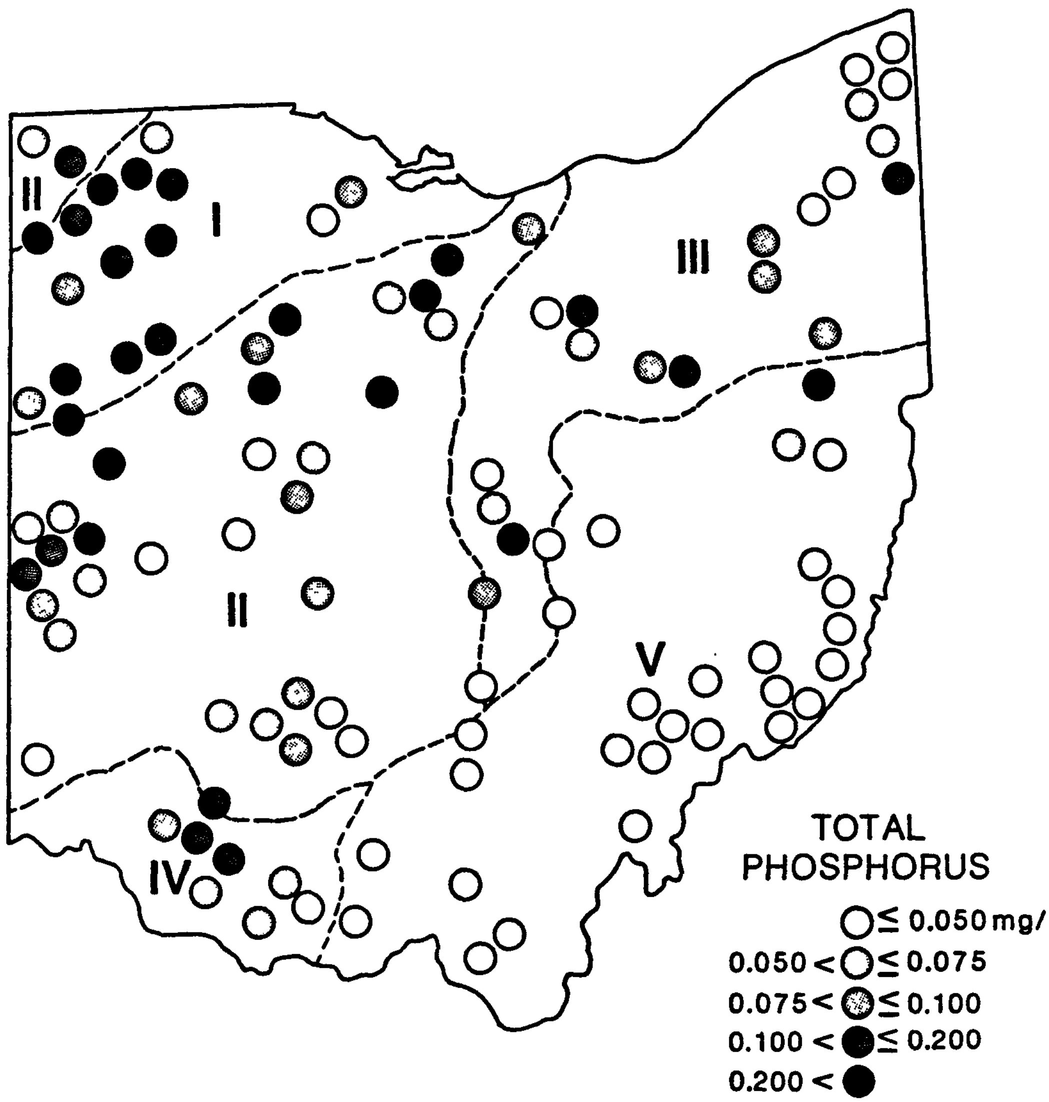

Figure 16. Spatial patterns of total phosphorus in Ohio streams. Values are site medians of 16 monthly samples.

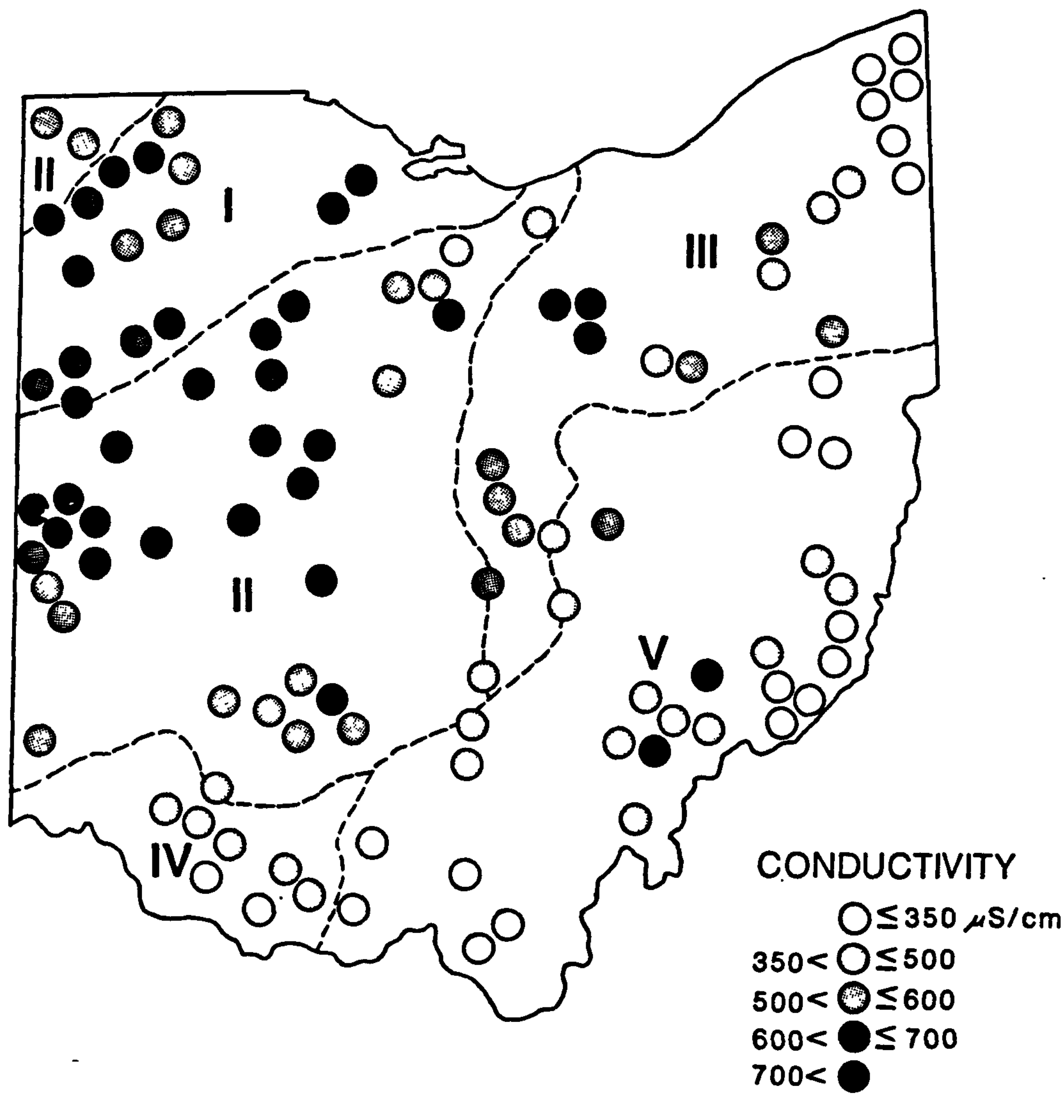

Figure 17. Spatial patterns of conductivity in Ohio streams. Values are site medians of 16 monthly samples.

The results of the two PCAs are summarized as a graph of nutrient richness PCA I vs. ionic strength PCA I (Figure 18). This graph displays a clear relationship between the water quality of the sites and their ecoregions. Sites in the Western Allegheny Plateau are concentrated in the area of low nutrient richness and low to intermediate ionic strength. Sites in the Interior Plateau group closely with intermediate values for ionic strength and nutrient richness while sites for the Erie/Ontario Lake Plain are slightly more scattered and encompass those of the Interior Plateau. Sites in the Huron/Erie Lake Plain and the Eastern Corn Belt Plains are similar along the ionic strength axis but separate somewhat along the nutrient richness axis.

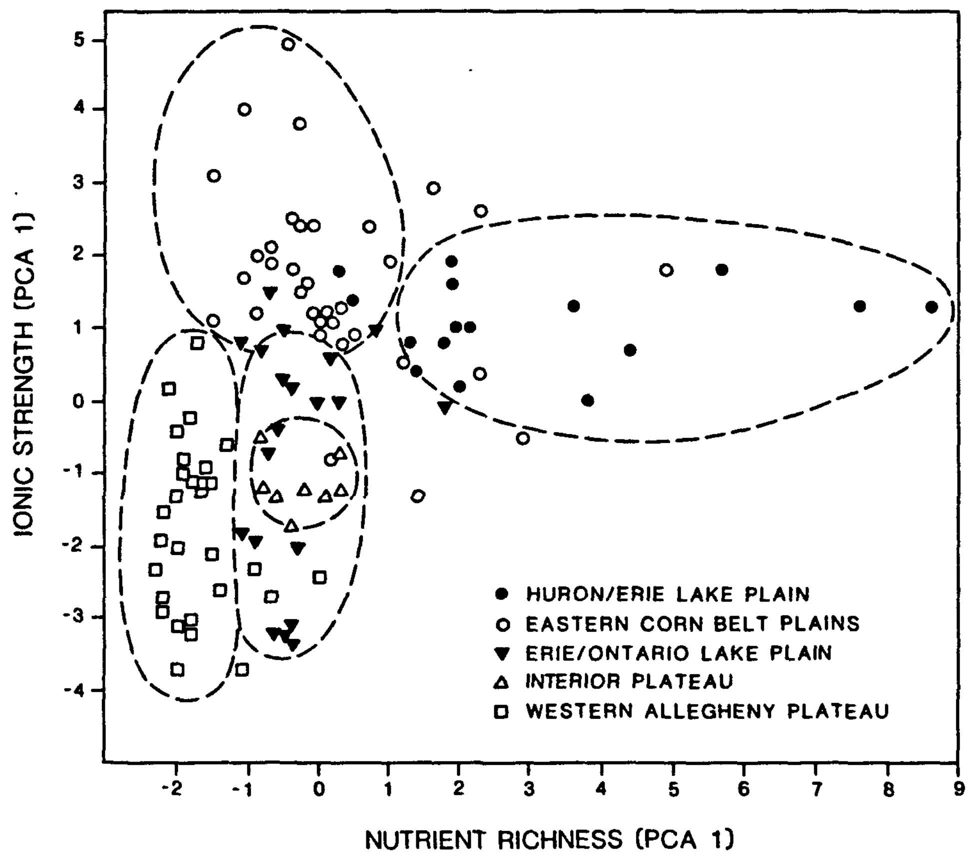

Figure 18. Regional patterns in nutrient richness and ionic strength variables indicated by principal component axis I scores for each. Areas enclosed indicate hypothesized attainable water quality for each region.

Groupings that define water quality typical of each ecoregion are indicated by the enclosed areas on Figure 18. Each region can be distinguished from the others based on the combination of nutrient richness and ionic strength. These areas are delineated subjectively to indicate the general regional distinctiveness of water quality. While not all sites fit this pattern uniformly, especially in the Eastern Corn Belt Plains, the ecoregional patterns are evident. The Huron/Erie Lake Plain and the Western Allegheny Plateau differ considerably from each other with the other three regions having intermediate water quality indicative of their transitional nature.

PHYSICAL HABITAT

The physical habitat measures were not collected consistently enough to allow a thorough analysis. Here, we present a narrative summary of the trends discernible in each region and a brief overview of cover and substrate patterns.

Huron/Erie Lake Plain

About one third of the streams sampled in this ecoregion were intermittent. Currents were never fast, distributed among none, interstitial and moderate. Only one site had clear water; the majority were turbid and some were stained. Most reaches were > 50% pools and development was poor more often than good. Pools had primarily sandy/silty bottoms (70%). About 70% of the riffle substrates were gravel and sand, most of the remainder were silt and clay. Several sites had cobble substrate.

About 75% of the sites had been channelized and were in various states of recovery. Bank slopes were generally moderate to steep; the majority were eroding moderately to severely. There was 10-60% instream cover at most sites, consisting mainly of logs and trees. Canopy openness varied widely (10-100%) but within this ecoregion canopy tended to be less open than in other ecoregions, except the Eastern Corn Belt Plains. Emergent vegetation was observed at half the sites. Where buffer vegetation occurred, it generally consisted of 3-10 m of shrubs and immature beech/oak/maple growth. Land use was agriculture at every site (mostly rowcrops with some pasture). About half the sites also had residential areas, forest and open vegetation.

Eastern Corn Belt Plains

All but one of the streams sampled in this ecoregion had continuous flows, generally with slow to moderate current. About half of the sites were turbid with silt and diatoms the most frequent sources. About 70% of the reaches were in pools; development was good more often than poor. Pools had very diverse substrates, ranging from boulder to silt and clay at each site. About 60% of the riffle substrates were composed of cobble and gravel, the remainder were generally divided among larger and smaller particle sizes.

Bank slopes varied from gentle to steep and generally had little or no evidence of erosion. Only a few sites had been channelized. Instream cover was comprised equally of undercut banks, rocks and boulders, and logs and trees. There was a wide range of canopy cover, but generally it was less open than in other ecoregions, except the Huron/Erie Lake Plain. Emergent vegetation was noted at about half the sites. Buffers of 15 to 30 m were generally present, often consisting of mature trees or shrubs and grasses. Every site had agricultural land use (rowcrops or pasture). Approximately two thirds of the sites also had some forest or open vegetation.

Erie/Ontario Lake Plain

Streams in this ecoregion were generally continuous (several were intermittent). Most had moderate flows, a few had slow- or no-flows. About half the sites were turbid. Generally 10-40% of the reaches were in riffles with development good at half of the sites and poor at the remainder. Pool substrates ranged from silt and clay to boulder at every site. Riffle substrates were about 90% cobble and gravel.

Few sites had evidence of channelization and banks varied from gently sloping to steep and stable. A quarter of the sites had moderate to severe erosion. Sites in this ecoregion tended to have the least instream cover (10-40%). The range of canopy openness was wide but generally more open than in the Huron/Erie Lake Plain and Eastern Corn Belt Plains ecoregions. A fair amount of emergent vegetation, principally grasses, occurred at most sites. The predominant land use was forest with some open vegetation, and agriculture at several sites.

Interior Plateau

The streams sampled in this ecoregion had continuous flows with moderate currents. The water was generally turbid. There were equal numbers of reaches that were all pool and reaches that were 20% riffle; development was good. Pool substrates were fine gravel and sand. Where riffles were present their substrates were mostly cobble mixed with some boulders and coarse gravel.

Stream channels were natural and banks varied from gradual to steep. Generally there was little to moderate erosion. The instream cover was 20-80% and unlike other ecoregions it consisted mostly of rocks and boulders. There was a wide range of canopy openness, but the canopy was generally more open than in the Huron/Erie Lake Plain and Eastern Corn Belt Plains ecoregions. Emergent waterwillow occurred at a few sites.

Buffers strips of mature trees, 10 to 30 m wide, were found at most sites. All sites were agricultural (mixed pasture and rowcrops), and most had some forest.

Western Allegheny Plateau

Continuous flows were characteristic of streams in this ecoregion. Currents were moderate in about two thirds of the streams, the remainder divided equally into fast and slow classes. Clarity was highly variable. Generally 2-40% of the reaches were in riffle and the majority of sites had good development, the rest divided equally between excellent and poor. Pools had diverse substrates with sand and fine gravel most dominant. Riffle substrates were about 75% cobble and gravel; the remaining sites split between larger and smaller particle sizes.

The channels of all sites were natural. Most banks had moderate to steep slopes. About 50% of the sites had moderate to severe erosion. The sites in this ecoregion had the greatest instream cover (40-70%). Canopy openness was variable, but generally more open than in the Huron/Erie Lake Plain and Western Corn Belt Plains ecoregions. There was noticeable algae on rocks at many sites and emergent waterwillow at others. Land use at most sites was half agricultural (50% pasture, 50% rowcrops) and half forest (with some open vegetation).

Instream Cover and Substrate Composition

Total instream cover (Figure 19) was generally greater in the Western Allegheny Plateau (median = 57%) than in the other regions (medians: 22-33%). The portion of cover provided by undercut banks did not vary among regions (medians: 1-7%). Cover provided by rocks and boulders was greatest in the Interior Plateau, median = 20% (2-10% in the others). Cover by logs and trees was greatest in the Huron/Erie Lake Plain (median = 20%) and the Western Allegheny Plateau (median = 15%).

Pool substrate profiles (Figure 20) are quite similar among regions except for the Huron/Erie Lake Plain which generally has smaller particle size substrates. Riffle substrate profiles show the same overall pattern of small particle sizes in the north-western part of the state and larger sizes in the south.

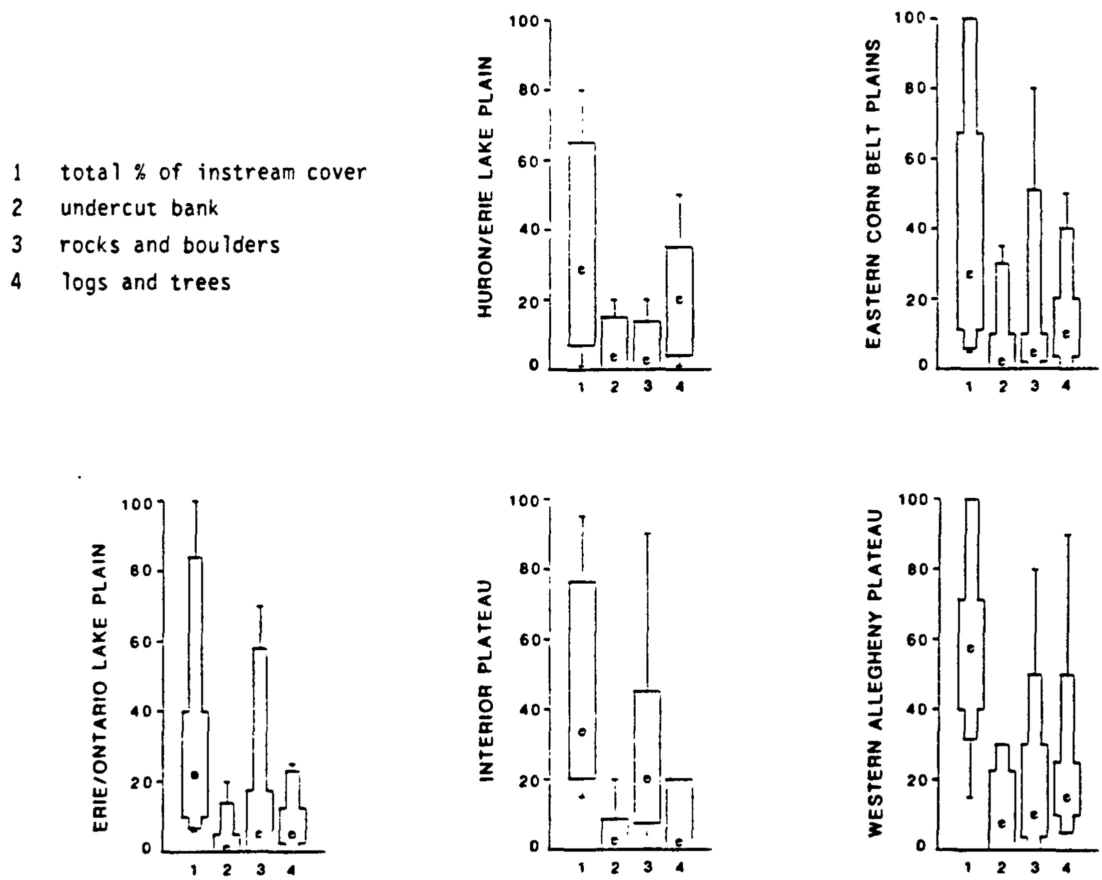

Figure 19. Profiles of instream cover (per cent composition) by region.

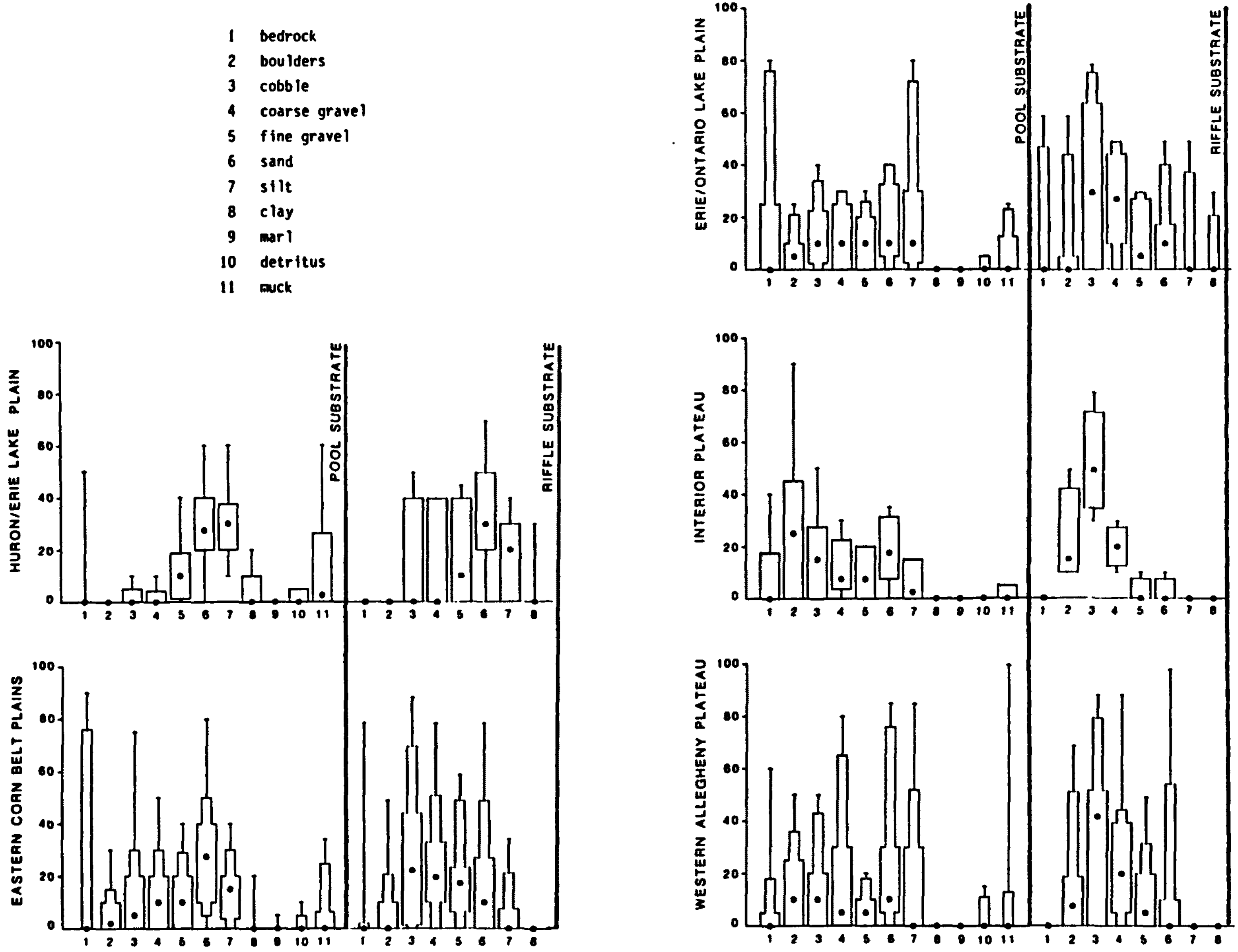

Figure 20. Profiles of stream substrate (per cent composition) for pools and riffles, by region.

SECTION 6

INTERPRETATION

AQUATIC LIFE USE DESIGNATIONS AND ATTAINMENT

The objective of the Clean Water Act (CWA, PL 95-217) is to restore and maintain the physical, chemical, and biological integrity of the Nation's waters. State and Federal water quality standards have been established to help meet that objective (Federal Register 1983). These standards serve a dual function: they establish water quality goals and serve as a regulatory basis for establishing treatment controls. Water quality standards consist of the combination of designated uses for water bodies and water quality criteria that, if met, presumptively protect those uses. States are required to specify appropriate uses to be achieved and protected, as well as to adopt criteria to protect those uses. The criteria are numerical values or may be narrative where numerical criteria cannot be established or need to be supplemented.

States have traditionally designated uses in a qualitative way. This is particularly evident for uses that pertain to aquatic life. In some cases, "aquatic life" is the designated use. In others, the aquatic life use might be identified as warm or cold water fishery, or salmonid passage. What is generally lacking are specific or quantitative measures that characterize the use and provide a test of whether the water body actually supports that use. Therefore, although the Act requires assurance of protection and propagation of a balanced indigenous population of fish, shellfish, and wildlife, states rarely specify quantitative measures to meet this objective. There are a few exceptions. For example, OEPA (1984b) specifies four aquatic life categories, with qualitative and quantitative statements about fish species composition, species richness and diversity, and numerical abundance of fish and macroinvertebrates used as measures that delineate those uses (Table 7). Wisconsin has developed a similar system that establishes five categories of aquatic life use, and establishes quantitative assessments of various ecological characteristics that determine whether a particular use category has been met.

One of the difficulties in determining whether uses are being attained and therefore whether criteria are appropriate is the lack of reference data describing what to expect. Quantitative expression of aquatic life uses is needed to serve as a benchmark for site specific or regional assessments. Partly this has not been done because aquatic ecosystems display such variability and because there has been no conceptual framework

Table 7. Ohio EPA biological criteria (fish) for determining water quality use designations and attainment of Clean Water Act (CWA) goals (November 1980).

Evaluation Class[a] Category	"Exceptional" Class I (EWH)	"Good" Class II (WWH)	"Fair" Class III	"Poor" Class IV
	- - - - - - - -MEETS CWA GOALS- - - - - - -		- - - - - -DOES NOT MEET CWA GOALS- - - - - -	
1. Species assemblage	Exceptional or unusual	Usual association of expected species	Some expected species absent or very low abundance	Most expected species absent
2. Sensitive species	Abundant	Present	Absent or very low abundance	Absent
3. Diversity	Exceptionally high	High	Declining	Low
4. Composite index[b]	> (9.0 - 9.5)	> (7.0 - 7.5) < (9.0 - 9.5)	> (4.5 - 5.0) < (7.0 - 7.5)	< (4.5 - 5.0)
5.	Outstanding recreational fishery		Tolerant species increasing, beginning to dominate	Tolerant species dominate
6.	Rare, endangered, or threatened species present			

[a] Conditions: Categories 1,2,3 and 4 (if data are available) must be met and 5 or 6 must also be met in order to be designated in that particular class.
[b] Based primarily on boat electrofishing samples, ranges may vary for other sampling methods.

within which to partition that variability. A regional classification system, such as the one developed at ERL-Corvallis, can provide the needed framework for States to establish attainable aquatic life uses and to protect those uses.

The design of this project called for selecting stream sites that were in least-disturbed watersheds representative of the different ecoregions of Ohio. Therefore, the data we obtained should provide a good picture of reasonably attainable conditions in streams of similar size throughout Ohio. Box plots of the data by ecoregion indicate the central tendencies and range of conditions found within each region. It might be useful to consider as goals the range of conditions attained by the best 50% of the reference sites. For example, the IBI values in the top 50% of the range for an ecoregion might be those specified as attainable (see Figure 5).

The figures presented throughout the results section are useful guides as a comparative data base. They can be continually expanded as monitoring programs obtain more data from least-disturbed sites. Some of these data can come from comprehensive water quality surveys when data are collected from unimpacted sites upstream of sites suspected to be impacted. This regional framework allows comparison of the quality of any site relative to the least impacted ones. It could show, relative to the reference situations, the effectiveness of treatment actions for improving stream conditions. Reference sites could serve in evaluating the quality of upstream control and downstream recovery sites (Hughes 1985; Hughes et al. 1986).

We assessed fish species richness in Little Yellow and Yellow Creeks as an example of how the regional reference data can be combined with the standard upstream/downstream analyses to display the relative magnitude of impacts. The Yellow Creek Basin is a small watershed in the Huron/Erie Lake Plain. The headwater of Little Yellow Creek is the effluent from the Leipsic Wastewater Treatment Plant (WWTP). Little Yellow Creek runs about 6.4 mi. before joining Yellow Creek, a somewhat larger stream. Land use in the Yellow Creek Basin is primarily row crop agriculture, typical of this ecoregion. Both streams have been extensively channelized, and riparian vegetation is sparse, although some areas have relatively good riparian cover. A comprehensive water quality survey on those streams was conducted in 1981, including fish sampling at six sites in August and September (Ohio EPA, 1982).

The Yellow Creek fish species richness data are plotted with data from the Huron/Erie Lake Plain ecoregion (Figure 21). Note that the watershed size of Little Yellow Creek is smaller than any of the reference sites, while watershed sizes for Yellow Creek are within the range of the reference sites. Extrapolation of the species richness-watershed area regression suggests that

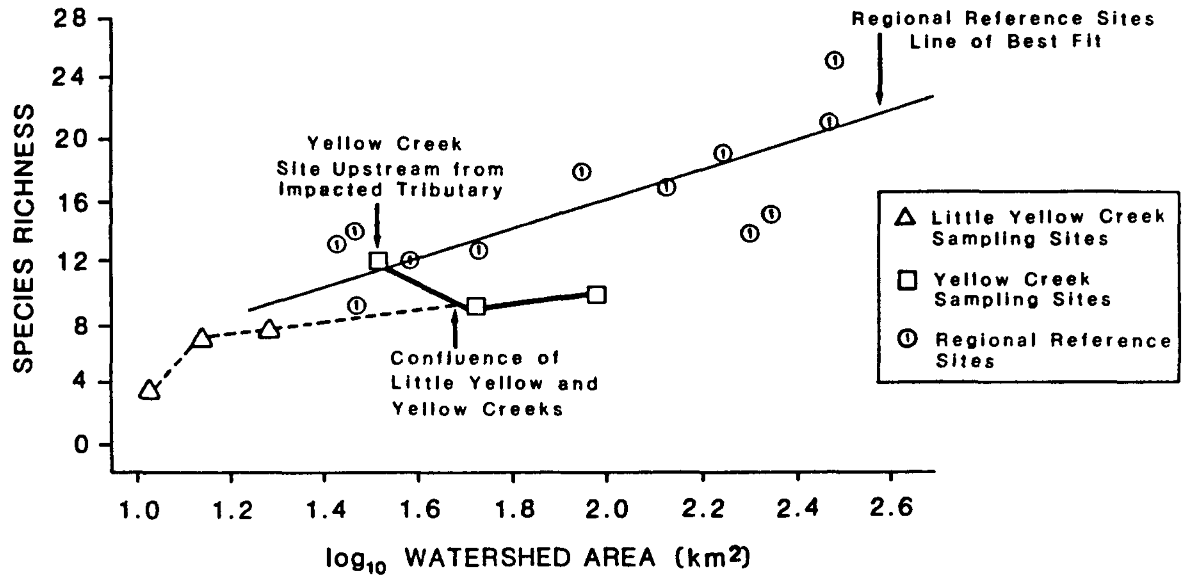

Figure 21. Comparison of fish species richness in an impacted stream with data from the regional reference sites in the Huron/Erie Lake Plain.

species richness of Little Yellow Creek falls within the range of values expected for watersheds of this size in this ecoregion, but might be at the low end. The species richness at the uppermost site on Yellow Creek is also within the expected range for sites in this region. However, the lower two sites display definite impact. The key point here is not only have species richness values decreased (not major decreases of themselves) but that they are noticeably lower than the minimally-impacted streams of the same size in this region.

This effect is probably due to the combined effects of wastewater originating from the Leipsic WWTP and degraded physical habitat (Ohio EPA, 1982). Physical habitat conditions at the downstream Yellow Creek sites are more degraded than at the upstream sites, and the intermediate site is of poorest quality, reflected in the lowest species richness relative to regional expectations. Attainment of expected species richness in this basin probably requires the restoration of more natural physical habitat conditions, as well as continued or increased treatment of Leipsic wastewater.

Although we used species richness in this example, any of several measures of environmental health or a combination could be used to show how particular sites or basins match expectations. Note that it would have been inappropriate to expect species richness in the Yellow Creek Basin to have attained values characteristic of the Western Allegheny Plateau, at least under current land management practices (compare with Figure 4).

Ohio's current aquatic life use designations, although relatively detailed, do not incorporate regional differences in stream potentials, except through the professional judgement of the technical staff of OEPA. Data collected during this project could be used to quantify regional differences. The largest differences in fish communities occur between the Huron/Erie Lake Plain and the Western Allegheny Plateau. These regions also differ most geographically: flat plains vs. rolling hills; row crop agriculture vs. mixed forest and cropland. Smaller differences occur among the other regions. Therefore, it might be reasonable to identify three sets of reference conditions for fish that reflect expectations in the Huron/Erie Lake Plain, the Western Allegheny Plateau, and in the remaining transitional regions. It is worth noting that several of these regions extend into bordering states, so data from least impacted sites in those states would be useful additions to the current reference set.

We present an example in Table 8 of how quantitative criteria might be used within a regional framework to determine whether existing use designations are likely to be met. The form is consistent with Ohio's current practice of identifying

Table 8. Attainable fish assemblage attributes for small streams in Ohio. Values are based on 50^{th} percentiles of this study and subject to further refinement by Ohio EPA.

	Huron/Erie Lake Plain	Eastern Corn Belt Plains	Erie/ Ontario Lake Plain	Interior Plateau	Western Allegheny Plateau
Species Richness[a]	10-20	13-30	13-30	13-30	16-35
Number of Intolerant Species[a]	1-2	2-10	2-10	2-10	4-14
Percent Intolerant Individuals	> 5	> 25	> 30	> 35	> 25
Index of Biotic Integrity	> 32	> 44	> 44	> 42	> 49
Index of Well-Being	> 8.2	> 9.3	> 9.0	> 9.0	> 9.7

[a]Site specific values must be determined from maximum species richness and maximum number of intolerant species lines (Figures 4, 8) for watershed area of site.

objective criteria for uses, but here the expectations are all quantitative and specified regionally. This regional perspective does not preclude Ohio EPA from maintaining its current set of use designations and criteria; they simply provide a set of reasonable expectations (which may be further refined as OEPA gathers more data) for streams in the various regions of the state.

ATTAINABLE WATER QUALITY

Identifying attainable water quality as a function of ecoregions is a straightforward way to specify realistic goals. Recall that we selected sites in minimally impacted watersheds in each ecoregion. For example, in the Huron/Erie Lake Plain, this minimal impact means row crops (corn and soybeans), a fringe riparian forest at best, tile drainage, and heavy fertilizer applications. It is apparent that the water quality in this region is both enriched and of relatively high ionic strength (a function of natural land type and land use) compared with other regions in Ohio. Thus, attainable water quality, as observed at these minimally impacted sites, is one way to express realistic expectations for this region (without major changes in land management). It certainly represents what has been attained under existing conditions.

Knowledge of regionally attainable water quality can be used to the advantage of water quality managers and the public. Assessing streams affected directly by point sources, feedlots, mining, or other harmful activities compared to regional water quality goals provides a way to demonstrate the degree of impact. This regional assessment approach does not force unrealistic requirements in areas where the water quality standards are unlikely to be met. It is a way to place water quality goals into an environmental perspective, eliminating unrealistic expectations.

As described for the biological component, attainable water quality can be summarized as univariate box plots or maps that display values from regional reference sites. Regionally attainable water quality can be defined by selecting a range of values representative of the highest quality achieved in that region. The water quality achieved by 50% of the sites with highest overall quality might be designated as the goal. For example, attainable phosphorus levels in the Western Allegheny Plateau would be < 0.05 mg/l, but in the Huron/Erie Lake Plain a more realistic goal would be < 0.15 mg/l (see Figure 13). Graphs that display these goals could then be compared with data from other sites to show the degree and extent to which goals are met.

Examination of the variability within a particular region can provide insight into land management practices that would minimize water quality degradation. For example, the considerable variation among sites in the Eastern Corn Belt Plains might be used to advantage. These watersheds occur in areas of the same land type; however, there might be some localized anomalies that explain high or low values. For example, although the soil in the region is generally of one type, sites with particularly high water quality values might be located in watersheds with a soil not mapped on the small-scale maps used to delineate regions. A more likely scenario is that the watersheds characterized by the high values are managed differently from those with the low values. There might be less riparian forest along the streams characterized by the high values, or an abundance of feedlots in the watershed, or tillage and fertilizer application patterns might differ. Where great within-region variation in water quality is observed, explanation of the variation should lead to watershed management procedures that minimize water quality problems originating from diffuse sources. This does not suggest drastic changes in land use patterns, but merely educates the manager about how current use might be modified to result in overall water quality benefits.

Finally, a regional framework and reference data also can be used to help monitor the quality of water statewide by facilitating the design of efficient sampling strategies. Areas known to be similar to each other can be represented by samples drawn from relatively few representative sites, whereas more variable areas will require greater sampling effort. Unique situations should be examined individually. Moreover, knowledge of regionally attainable water quality gives an important perspective for applying what is learned from site-specific monitoring programs. Large negative deviations from regional reference data suggest greater potential for significant improvement. Sites with minor deviations probably have achieved what is reasonably attainable and further expenditure would result in minimal benefits. Large positive deviations suggest streams worthy of special protection.

LITERATURE CITED

Anderson, J. R. 1970. Major land uses. Map (scale 1:7,500,000). Plates 157-159. In: The National Atlas of the United States of American. U.S. Geological Survey. U.S. Government Printing Office. Washington, D.C.

Austin, M. E. 1965, revised 1972. Land Resource Regions and Major Land Resource Areas of the United States. Agriculture Handbook 296. USDA Soil Conservation Service. Washington, D.C.

Bailey, R. G. 1976. Ecoregions of the United States. Map (scale 1:7,500,000). U.S. Department of Agriculture, Forest Service. Intermountain Region. Ogden, Utah.

__________ 1983. Delineation of ecosystem regions. Environ. Manage. 7:365-373.

Becker, G. C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison. 1052 pp.

Carlander, K. D. 1969. Handbook of Freshwater Fishery Biology. Volume I. The Iowa State University Press, Ames. 752 pp.

__________ 1977. Handbook of Freshwater Fishery Biology. Volume II. The Iowa State University Press, Ames. 431 pp.

Fausch, K. D., J. R. Karr, and P. R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Am. Fish. Soc. 113:39-55.

Federal Register. 1983. Water Quality Standards Regulation. 48:51399-51413.

Gammon, J. R. 1976. The Fish Populations of the Middle 340 km of the Wabash River. Tech. Report No. 86. Purdue Univ. Water Resources Research Center. West Lafayette, Indiana. 73 pp.

__________ 1980. The use of community parameters derived from electrofishing catches of river fish as indicators of environmental quality. p. 335-363 In: Seminar on Water Quality Tradeoffs. EPA-905/9-80-009. U.S.Environmental Protection Agency. Washington D.C.

Gauch, H. Jr. 1982. Multivariate Analysis in Community Ecology. Cambridge University Press. New York. 298 pp.

Hammond, E. H. 1970. Classes of land-surface form. Map (scale 1:7,500,000). Plates 61-63. In: The National Atlas of the United States of America. U.S. Geological Survey. U.S. Government Printing Office. Washington, D.C.

Hughes, R. M. 1985. Use of watershed characteristics to select control streams for estimating effects of metal mining wastes on extensively disturbed streams. Environ. Manage. 9:253-262.

Hughes, R. M., and J. M. Omernik. 1981. A proposed approach to determine regional patterns in aquatic ecosystems. p. 92-102. In: N. B. Armantrout (ed.). Acquisition and Utilization of Aquatic Habitat Inventory Information. Am Fish. Soc. Bethesda, MD.

__________ 1983. An alternative for characterizing stream size. p. 87-101. In: T. D. Fontaine III and S. M. Bartell (eds.), Dynamics of Lotic Ecosystems. Ann Arbor Science, Ann Arbor, Michigan.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: A method for assessing stream potentials. Environ. Manage. 10:629-635.

Hughes, R. M., E. Rexstad, and C. E. Bond. 1987. The relationship of aquatic ecoregions, river basins, and physiographic provinces to the ichthyogeographic regions of Oregon. Copeia 1987:423-432.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Karr, J. R., R. C. Heidinger, and E. H. Helmer. 1985. Effects of chlorine and ammonia from wastewater treatment facilities on biotic integrity. J. Wat. Poll. Con. Fed. 57:912-915.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, I. J. Schlosser. 1986. Assessing biological integrity in running waters: A method and its rationale. Ill. Nat. Hist. Surv. Spec. Pub. No. 5. Champaign, IL. 28 pp.

Kuchler, A. W. 1970. Potential natural vegetation. Map (scale 1:7,500,000). Plates 89-91. In: The National Atlas of the United States of America. U. S. Geological Survey. U. S. Government Printing Office. Washington, D.C.

Larsen, D. P. and D. R. Dudley. 1987. A regional approach for assessing attainable water quality: Ohio as a case study. J. Soil Water Cons. (In Press).

Larsen, D. P., J. M. Omernik, R. M. Hughes, C. M. Rohm, T. R. Whittier, A. J. Kinney, A. L. Gallant, and D. R. Dudley. 1986. Correspondence between spatial patterns in fish assemblages in Ohio streams and aquatic ecoregions. Environ. Manage. 10:815-828.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina State Museum of Natural History, Raleigh. 854 pp.

Ohio Environmental Protection Agency. 1982. Comprehensive Water Quality Report for Yellow Creek and Brush Creek, Maumee River Basin, Putnam County, Ohio. Ohio Environmental Protection Agency, Division of Wastewater Pollution Control, Columbus, OH.

Ohio Environmental Protection Agency. 1984a. Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices. 3rd Revision. Columbus, Ohio.

Ohio Environmental Protection Agency. 1984b. Biological Field Evaluations Group Methods Study and Water Quality Criteria Justication. (Draft). Columbus Ohio.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77:118-125.

Omernik, J. M., and A. L. Gallant. 1986. Ecoregions of the Pacific Northwest (with map). EPA/600/3-86/033. U.S.Environmental Protection Agency, Corvallis, OR. 39 pp.

Omernik, J. M., M. A. Shirazi, and R. M. Hughes. 1982. A synoptic approach for regionalizing aquatic ecosystems. p. 199-218. In: T. B. Brann, L. O. House IV, and H. G. Lund (ed.). In-place Resource Inventories: Principles and Practices. Soc. Am. Forest. Bethesda, MD.

Pflieger, W. L. 1975. The Fishes of Missouri. Missouri Dept. of Conservation, Jefferson City. 343 pp.

Pollard, J. E., and W. L. Kinney. 1979. Assessment of Macroinvertebrate Monitoring Techniques in an Energy Development Area. EPA-600/7-79-163. U. S. Environmental Protection Agency. Las Vegas, NV. 26 pp.

Reckhow, K. H. 1980. Techniques for exploring and presenting data applied to lake phosphorus concentration. Can. J. Fish. Aquat. Sci. 37:290-294.

Rohm, C. M., J. W. Giese and C. C. Bennett. 1987. Evaluation of an aquatic ecoregion classification of streams in Arkansas. J. Fresh. Ecol. 4:127-140.

Rowe, J. S., and J. W. Sheard. 1981. Ecological land classification: A survey approach. Environ. Manage. 5:451-464.

SAS Institute Inc. 1985. SAS Users Guide: Statistics. 1985 ed. SAS Institute, Cary, NC. 956 pp.

Smith, P. W. 1979. The Fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Trautman, M. B. 1981. The Fishes of Ohio. Ohio State University Press, Columbus, Ohio. 782 pp.

U. S. Department of Agriculture Soil Conservation Service. 1981. Land Resource Regions and Major Land Resource Areas of the United States. U. S. Department of Agriculture Handbook 296. Washington, D.C. 156 pp. and map.

U. S. Department of Agriculture Soils Surveys of the States of the North Central Region of the United States. North Central Regional Publication No. 76, Bulletin 544. Agricultural experimental station, University of Wisconsin, Madison. 192 pp. and map.

U. S. Environmental Protection Agency. 1979. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020. U. S. Environmental Protection Agency, Cincinnati, OH.

U. S. Geological Survey. 1970. Distribution of principal kinds of soils: Orders, suborders, and great groups. Map (scale 1:7,500,000). Plates 85-86. In: The National Atlas of the United States of America. U. S. Geological Survey. U. S. Printing Office. Washington, D.C.

Warren, C. E. 1979. Toward Classification and Rationale for Watershed Management and Stream Protection. EPA 600/3-79-059. U. S. Environmental Protection Agency, Corvallis, OR. 143 pp.

Appendix A: **TOLERANCE AND TROPHIC LEVELS OF 99 OHIO FISH SPECIES.** These are the trophic levels and tolerances used for this study by ERL-C and are not necessarily Ohio EPA's final designations. The * indicates the most intolerant species as used to calculate IBI scores.

SPECIES	TROPHIC LEVEL	TOLERANCE
NORTHERN BROOK LAMPREY	OMNIVORE	INTOLERANT
OHIO LAMPREY	PISCIVORE	INTOLERANT
LEAST BROOK LAMPREY	OMNIVORE	*INTOLERANT
AMERICAN BROOK LAMPREY	OMNIVORE	INTOLERANT
LONGNOSE GAR	PISCIVORE	MODERATELY TOLERANT
GIZZARD SHAD	OMNIVORE	TOLERANT
BROWN TROUT	PISCIVORE	*INTOLERANT
RAINBOW TROUT	INSECTIVORE	*INTOLERANT
CENTRAL MUDMINNOW	INSECTIVORE	MODERATELY TOLERANT
GRASS PICKEREL	PISCIVORE	INTOLERANT
NORTHERN PIKE	PISCIVORE	INTOLERANT
MUSKELLUNGE	PISCIVORE	INTOLERANT
BIGMOUTH BUFFALO	OMNIVORE	MODERATELY TOLERANT
BLACK BUFFALO	OMNIVORE	MODERATELY TOLERANT
QUILLBACK	OMNIVORE	MODERATELY TOLERANT
RIVER CARPSUCKER	OMNIVORE	MODERATELY TOLERANT
HIGHFIN CARPSUCKER	OMNIVORE	MODERATELY TOLERANT
SILVER REDHORSE	INSECTIVORE	MODERATELY TOLERANT
BLACK REDHORSE	INSECTIVORE	INTOLERANT
GOLDEN REDHORSE	INSECTIVORE	MODERATELY TOLERANT
SHORTHEAD REDHORSE	INSECTIVORE	MODERATELY TOLERANT
RIVER REDHORSE	INSECTIVORE	INTOLERANT
NORTHERN HOGSUCKER	INSECTIVORE	*INTOLERANT

SPECIES	TROPHIC LEVEL	TOLERANCE
WHITE SUCKER	INSECTIVORE	TOLERANT
SPOTTED SUCKER	INSECTIVORE	MODERATELY TOLERANT
CREEK CHUBSUCKER	INSECTIVORE	*INTOLERANT
COMMON CARP	OMNIVORE	TOLERANT
GOLDFISH	OMNIVORE	TOLERANT
GOLDEN SHINER	INSECTIVORE	TOLERANT
HORNYHEAD CHUB	INSECTIVORE	*INTOLERANT
RIVER CHUB	INSECTIVORE	*INTOLERANT
BIGEYE CHUB	INSECTIVORE	*INTOLERANT
GRAVEL CHUB	HERBIVORE	INTOLERANT
BLACKNOSE DACE	INSECTIVORE	MODERATELY TOLERANT
CREEK CHUB	PISCIVORE	TOLERANT
TONGUETIED MINNOW	INSECTIVORE	INTOLERANT
SUCKERMOUTH MINNOW	INSECTIVORE	MODERATELY TOLERANT
SOUTHERN REDBELLY DACE	HERBIVORE	*INTOLERANT
REDSIDE DACE	INSECTIVORE	*INTOLERANT
EMERALD SHINER	INSECTIVORE	MODERATELY TOLERANT
SILVER SHINER	INSECTIVORE	INTOLERANT
ROSYFACE SHINER	INSECTIVORE	*INTOLERANT
REDFIN SHINER	INSECTIVORE	TOLERANT
ROSEFIN SHINER	INSECTIVORE	INTOLERANT
STRIPED SHINER	INSECTIVORE	MODERATELY TOLERANT
COMMON SHINER	INSECTIVORE	MODERATELY TOLERANT
BIGEYE SHINER	INSECTIVORE	INTOLERANT
STEELCOLOR SHINER	INSECTIVORE	MODERATELY TOLERANT
SPOTFIN SHINER	INSECTIVORE	TOLERANT

SPECIES	TROPHIC LEVEL	TOLERANCE
SAND SHINER	INSECTIVORE	MODERATELY TOLERANT
MIMIC SHINER	INSECTIVORE	INTOLERANT
GHOST SHINER	INSECTIVORE	MODERATELY TOLERANT
SILVERJAW MINNOW	INSECTIVORE	MODERATELY TOLERANT
MISSISSIPPI SILVERY MINNOW	HERBIVORE	INTOLERANT
FATHEAD MINNOW	OMNIVORE	TOLERANT
BLUNTNOSE MINNOW	OMNIVORE	TOLERANT
CENTRAL STONEROLLER	HERBIVORE	MODERATELY TOLERANT
CHANNEL CATFISH	INSECTIVORE	MODERATELY TOLERANT
YELLOW BULLHEAD	INSECTIVORE	MODERATELY TOLERANT
BROWN BULLHEAD	INSECTIVORE	MODERATELY TOLERANT
BLACK BULLHEAD	INSECTIVORE	TOLERANT
FLATHEAD CATFISH	PISCIVORE	MODERATELY TOLERANT
STONECAT	INSECTIVORE	*INTOLERANT
BRINDLED MADTOM	INSECTIVORE	INTOLERANT
TADPOLE MADTOM	INSECTIVORE	MODERATELY TOLERANT
BLACKSTRIPE TOPMINNOW	INSECTIVORE	MODERATELY TOLERANT
TROUTPERCH	INSECTIVORE	MODERATELY TOLERANT
BROOK SILVERSIDE	INSECTIVORE	INTOLERANT
WHITE BASS	PISCIVORE	MODERATELY TOLERANT
WHITE CRAPPIE	PISCIVORE	TOLERANT
BLACK CRAPPIE	PISCIVORE	MODERATELY TOLERANT
ROCKBASS	PISCIVORE	INTOLERANT
SMALLMOUTH BASS	PISCIVORE	INTOLERANT
SPOTTED BASS	PISCIVORE	MODERATELY TOLERANT
LARGEMOUTH BASS	PISCIVORE	MODERATELY TOLERANT

SPECIES	TROPHIC LEVEL	TOLERANCE
WARMOUTH	PISCIVORE	MODERATELY TOLERANT
GREEN SUNFISH	PISCIVORE	TOLERANT
BLUEGILL	INSECTIVORE	TOLERANT
ORANGESPOTTED SUNFISH	INSECTIVORE	TOLERANT
LONGEAR SUNFISH	INSECTIVORE	*INTOLERANT
PUMPKINSEED	INSECTIVORE	INTOLERANT
SAUGER	PISCIVORE	MODERATELY TOLERANT
WALLEYE	PISCIVORE	MODERATELY TOLERANT
YELLOW PERCH	PISCIVORE	MODERATELY TOLERANT
DUSKY DARTER	INSECTIVORE	INTOLERANT
BLACKSIDE DARTER	INSECTIVORE	MODERATELY TOLERANT
SLENDERHEAD DARTER	INSECTIVORE	INTOLERANT
LOGPERCH	INSECTIVORE	INTOLERANT
EASTERN SAND DARTER	INSECTIVORE	*INTOLERANT
JOHNNY DARTER	INSECTIVORE	MODERATELY TOLERANT
GREENSIDE DARTER	INSECTIVORE	INTOLERANT
BANDED DARTER	INSECTIVORE	INTOLERANT
VARIEGATE DARTER	INSECTIVORE	INTOLERANT
RAINBOW DARTER	INSECTIVORE	INTOLERANT
ORANGETHROAT DARTER	INSECTIVORE	MODERATELY TOLERANT
FANTAIL DARTER	INSECTIVORE	MODERATELY TOLERANT
FRESHWATER DRUM	INSECTIVORE	MODERATELY TOLERANT
MOTTLED SCULPIN	INSECTIVORE	*INTOLERANT
BROOK STICKLEBACK	INSECTIVORE	INTOLERANT