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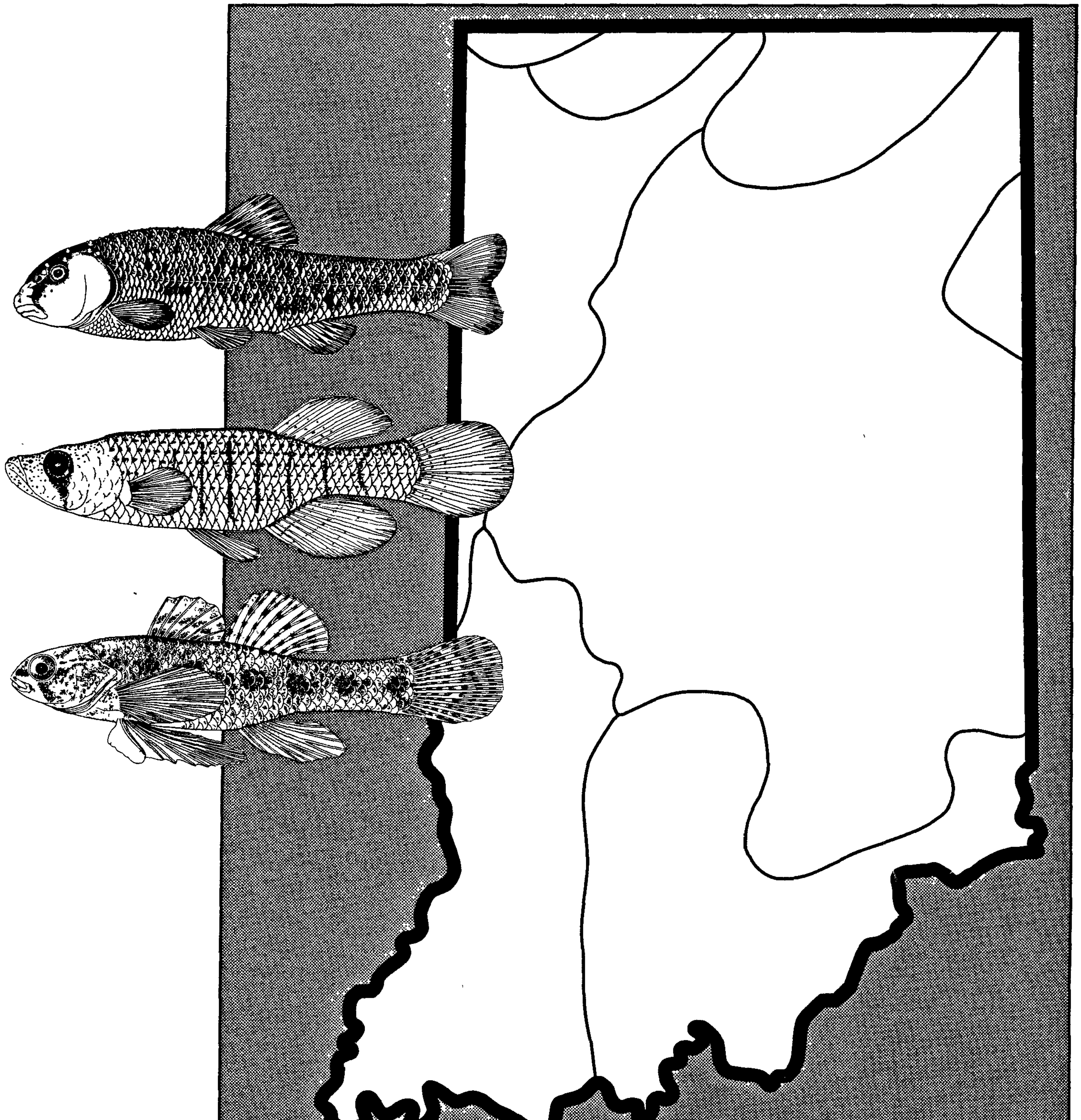
Development of Index of Biotic Integrity Expectations for the Ecoregions of Indiana

I. CENTRAL CORN BELT PLAIN



DEVELOPMENT OF INDEX OF BIOTIC INTEGRITY EXPECTATIONS FOR THE ECOREGIONS OF INDIANA. I. CENTRAL CORN BELT PLAIN

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November 5, 1991

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EXECUTIVE SUMMARY

The Clean Water Act Amendments of 1987 mandate the development of biological criteria for evaluating the nation's surface waters. The requirements of Section 304(a) was implemented in Indiana to determine water resource degradation. A total of 197 headwater and wading stream sites were sampled in the Central Corn Belt Plain ecoregion in order to develop and calibrate an Index of Biotic Integrity for use in Indiana. Based on inherent variance within the ecoregion, sub-basins were established based on the concept of natural areas as recognized by Homoya et al. (1985).

Three sub-basins include the major drainage units of northwest Indiana; Kankakee River, Iroquois River, and Lake Michigan drainages. Graphical analysis of the data enabled the construction of maximum species richness lines for calibrating the Index of Biotic Integrity for 17 metrics as modified for application to the region of Indiana. Metrics were primarily based on the previous works of Karr (1981), Karr et al. (1986), and Ohio EPA (1987). A few additional metrics are original to this study and were evaluated to quantify water quality degradation characteristics.

Separate metrics were developed for headwater (< 20 miles^2) and wading sites (> 20 miles^2) drainage area following the rationale of Ohio EPA (1987). Separate scoring criteria and batteries of metrics were developed for the Lake Michigan drainage while the Kankakee and Iroquois River drainages were evaluated with similar metric categories. Within the Lake Michigan drainage, two divisions are recognized based primarily on the presence of salmonid species. Trout and salmon, as keystone species, determine the fish community where they are residents. The East Branch of the Little Calumet River division includes salmonid metrics and includes the area from Burns Ditch, the East Branch of the Little Calumet River, and all tributaries (e.g. Salt Creek, Reynold's Creek, and the unnamed tributary in LaPorte County). The Lake Michigan Division includes the West Branch of the Little Calumet River, and tributaries (e.g. Deep River, Hart Ditch, Turkey Creek), and the Grand Calumet River basin. This division does not include a salmonid metric for headwater sites.

The water resources of the three drainages were evaluated based on criteria calibrated for the Central Corn Belt Plain ecoregion using the Indiana Index. A water resource distribution approximating a normal curve was observed for the Kankakee and Iroquois River drainages, with respect to site water classification. A trend towards improved water quality with increasing drainage area was evident. The Lake Michigan drainage showed a highly skewed site distribution towards the lower extremes of water resource quality. The trend was towards a declining water resource with increasing drainage area in both divisions, although the East Branch Little Calumet River division possessed a considerably better resource at the headwaters. Site specific data; locality information; species specific scoring criteria for tolerance classification, trophic guilds, and reproductive guild is included in the appendix.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The reauthorization of the Clean Water Act and requirement to adopt narrative and numerical biological criteria for assessing the nations' surface waters, has prompted an instream assessment of the water quality of the State of Indiana in order to develop numerical biological criteria. Section 304 (a) of the Clean Water Act (CWA) directs EPA to develop and publish water quality criteria and information on methods for measuring toxic pollutants on bases other than pollutant-by-pollutant, including biological monitoring and assessment methods. The Clean Water Act suggests using aquatic community components ("... plankton, fish, shellfish, wildlife, plant life..."; sec. 304(1)(a)) and community attributes ("... biological community diversity, productivity, and stability ..."; sec. 304(1)(c)) in any body of water and; factors necessary "... to restore and maintain the chemical, physical, and biological integrity of all navigable waters ..."(sec. 304(2)(a)) for "... the protection and propagation of shellfish, fish, and wildlife for classes and categories of receiving waters..." (sec. 304 (2)(b)) and "...on the measurement and classification of water quality" (sec. 304(2)(c)).

The term biological integrity originated in the Water Pollution Control Act Amendments of 1972 (PL 92-500) and has likewise appeared in subsequent versions (PL 95-217; PL 100-1). Previous attempts to define this concept were based on a "pristine" or "pre-settlement" concept. The expectations that resulted however were unrealistic, and as a goal could not be accomplished. The modification of expectations by utilizing "pristine" as a conceptual goal with consideration of past and present water and land uses has enabled the present definition. Karr and Dudley (1981) defined biological integrity as, "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region". The use of a biological component to evaluate the ambient lotic aquatic community of our nations surface waters has been well discussed elsewhere (Karr et al. 1986; Ohio EPA 1990a, b, c; USEPA 1987; Simon et al. 1987; Davis 1990; Karr 1991).

Utilizing structural and functional components of the aquatic community has been the major advancement in biological assessment techniques. Structural components include the concepts of diversity, taxa guilds, numbers, and biomass. Functional components include the feeding or trophic strategy, reproductive behavior and guild classification, environmental tolerance to perturbations, and individual stress or condition.

The original Index of Biotic Integrity (IBI; Karr 1981; Fausch et al. 1984) provides a framework for evaluating the concepts of structure and function for stream fish communities in the Midwest. Fish have been a major part of any aquatic study designed to evaluate water quality for a number of reasons (Table 1). Not only are fish a highly visible part of the aquatic resource but they are one component which are relatively easily sampled by professional biologists. We are not advocating the exclusive use of fish over any other taxonomic group; on the contrary, a similar effort in the State of Indiana is also being conducted for the benthic macroinvertebrates. Differing sensitivity and recovery levels have required the development of criteria for both taxonomic groups.

Table 1. Attributes of fishes which make them desirable components of biological assessments and monitoring programs.

Goal/Quality	Attribute
Accurate Assessment of Environmental Health	Fish populations and individuals generally remain in the same area during summer seasons.
	Communities are persistent and recover rapidly from natural disturbances. Comparable results can be expected from an unperturbed site at various times.
	Fish have larger ranges and are less affected by natural microhabitat differences than smaller organisms. This makes fish extremely useful for assessing regional and macrohabitat differences.
	Most fish species have long life spans (3-10+ years) and can reflect both long term and current water resource quality.
	Fish continually inhabit the receiving water and assimilate the chemical, physical, and biological histories of the waters.
	Fish represent a broad spectrum of community tolerances from very sensitive to highly tolerant and respond to chemical, physical, and biological degradation in characteristic response patterns.
Visibility	Fish are highly visible component of the aquatic community to the public.
	Aquatic life uses and regulatory language is generally characterized in terms of fish (i.e. fishable and swimmable goal of the Clean Water Act).
Ease of Use and Interpretation	The sampling frequency for trend assessment is less than for short-lived organisms.
	Taxonomy of fishes is well established, allowing professional biologists the ability to reduce laboratory time by identifying many specimens in the field.
	Distribution, life histories, and tolerances to environmental stresses of most North American species are well documented in the literature.

Additional mechanisms for establishing a fish-based response for evaluating use attainment of aquatic resources has been proposed in the past. The Index of Well-Being (Gammon 1976; Gammon 1980; Gammon et al. 1981) utilizes a structural component in numbers, biomass, and species richness for evaluating the water quality of large Rivers like the Wabash. A second type of structural and functional index similar to the Index of Biotic Integrity was developed for larval fishes. The Ichthyoplankton Index (I^2) requires a sample of fishes based on individuals less than 20 mm TL in size (Simon 1988) for water quality determination. Neither the Index of Well Being or the Ichthyoplankton Index will be discussed further for the purposes of this study.

Six criteria have been proposed for evaluation of whether a biological monitoring program meets the objectives of biological integrity. Herricks and Schaefer (1985) divided these into sensitivity, reproducibility, and variability. As demonstrated by Karr et al. (1986) and Ohio EPA (1987), the objectives are met by the IBI and the goals of assessing biological integrity can be achieved (Fausch et al. 1990).

The objective of this study is to evaluate the biological integrity in Indiana water resources based on "least impacted" reference sites for establishing baseline conditions (Hughes 1986). Least impacted reference sites are optimal stream reaches, representative of the ecoregion under study, and represent the least disturbance by anthropogenic change. The following project goals will be addressed during the completion of the entire Indiana ecoregion project:

- o Develop biological criteria for Indiana ecoregions using the Index of Biotic Integrity and habitat classification;
- o Identify areas of least disturbance within the ecoregions for use as reference stations;
- o Verify Indiana ecoregion boundaries;
- o Develop maximum species richness lines from reference stations for each Index of Biotic Integrity metric considering differences in stream order and proximity to Lake Michigan;

This technical report details specific Index of Biotic Integrity criteria, through the development of metrics and maximum species richness lines, to delineate areas of least disturbance in the Central Corn Belt Plain. In order to verify ecoregional boundaries, additional study areas will need to be collected to determine the heterogeneity of the cline areas.

Definition of Reference Conditions

In order to make accurate evaluations of the region in question, various baseline geological, geographic, and climatic differences need to be addressed. The goal is not to provide a definition of pristine conditions, since these types of conditions are either few in number or nonexistent in heavily populated States (Hughes et al. 1982). Our expectations are determined from the structurally and functionally attainable natural conditions of "least impacted" or reference sites. Assessment of these criteria need to be modified nationally since different processes can be attributed to the regional expectations determining distribution of fishes. The concept of the ecoregion is useful for separating large expanses of habitat since these areas are demarcated by the use of four different structural components.

In order to select stations for sampling it is necessary to know the geographical boundary of the "ecoregions" within the State of Indiana. A valid ecoregion has boundaries where ecosystem variables or patterns emerge (Hughes et al. 1986). Omernik (1987) mapped the ecoregions of the conterminous United States from maps of land-surface form, soil, potential natural vegetation, and land use. Each ecoregion was then delineated from areas of regional homogeneity. Using scaling procedures, ecoregions became a very useful mechanism to determine community complexity and establish boundaries associated with various land forms.

Ecoregions provide a geographical basis for determining the appropriate response from streams of similar proportion and complexity. By selecting reference sites for establishing the areas of "least impact", further calibration of the Index of Biotic Integrity and monitoring will reveal the current conditions of the surface waters of Indiana. Although ecoregional expectations are determined, conditions do not remain static. On the contrary, repeat sampling of stations, both reference and site specific will need to be conducted in order to document improvement over time in a dynamic equilibrium.

Because of the additional microhabitat differences within ecoregion, further demarcation was made examining the role of basin or watershed within the context of natural areas. Fish emigration is determined by the availability of water of appropriate quality to endure existence, sustain growth, and increase fitness through optimal reproduction. Likewise, species-specific differences exist in community structure which may not reveal differences in current water quality but may be determined by historical geomorphic (Leopold et al., 1964) or zoogeographic processes (Hocutt and Wiley, 1986). Trends in Indiana water quality were evaluated using a basin approach, within the framework of the ecoregion concept.

Criteria for Selecting Reference Sites

Several procedures are available for determining reference stations. Larsen et al. (1986) and Whittier et al. (1987) chose sites after careful examination of aerial photographs, sub-basin specific information review, and on-site reconnaissance. This procedure is time extensive and requires that a limited number of high-quality sites are sampled and scaled-up in order to predict regional expectations. The methods chosen were based on evaluation of Regional Water Quality Planning Maps (USGS undated) which identified all known point and non-point sources which may influence site selection. An equal distribution of stations within all parts of the basins were selected based on historic collections sites (Jordan 1877; Meek and Hildebrand 1910; Gerking

1945; Becker 1976; Ledet 1978; Robertson and Ledet 1981; Robertson 1987; IDEM 1990) and were rigorously sampled in order to get representative, distance specific, quantifiable estimates of the species numbers and biomass. In order to avoid bias, these data points were determined for all metrics calibrated in the Index of Biotic Integrity. Maximum species richness lines were then compiled, followed by calculations of Index of Biotic Integrity values to reveal which stations were the "least impacted" stations for the Central Corn Belt Plain. Evaluation of habitat and other physical parameters refined the final list of reference sites. Sites which had habitat or water quality deficiencies but still attained high index ratings would have been removed from the final list. This action was not required since these attributes affected various portions of the community which resulted in a lowered index score. These sites are not pristine or undisturbed (few exist in the northwestern part of Indiana), but they do represent the best conditions given the background activities (i.e. anthropomorphic; cultural eutrophication) necessary for the current evaluation.

Sampling was conducted in all stream sizes of the Central Corn Belt Plain ecoregion from small headwater streams (<20 square miles) to the largest main stem drainage.

2.0 STUDY AREA

Indiana has an area of 36,291 square miles, and drains the Ohio, the upper Mississippi, and Great Lakes Regions (Seaber et al. 1984). These three regions were further subdivided into nine subregions (Fig. 1), five of which drain 86% of the State (USGS 1990). The State of Indiana lies within the limits of latitude 37° 46′ 18" and 41° 45′ 33" north, for an extreme length of 275.5 miles in a north-south direction; and between longitude 84° 47′ 05" and 88° 05′ 50" west with an extreme width in an east-west direction of 142.1 miles.

The State has a maximum topographic relief of about 273 m, with elevations ranging from about 91 m above mean sea level at the mouth of the Wabash River to slightly more than 364 m in Randolph County in east-central Indiana.

The current report considers only the Central Corn Belt Plain ecoregion. The Central Corn Belt Plain ecoregion has an area of 46,400 miles^2. The ecoregion is located in extreme northwestern Indiana and forms the primary ecoregion in the adjacent State of Illinois. In Indiana, the Central Corn Belt Plain drains direct tributaries to Lake Michigan, and the mainstem and tributaries of the Kankakee and Iroquois Rivers.

Physiographic Provinces

Fenneman (1946) divided the State into two physiographic provinces based on the maximum extent of glaciation. The glaciated portion of the State contains the Central Lowland province, which includes the Central Corn Belt Plain, and the unglaciated portion is termed the Interior Low Plateaus province.

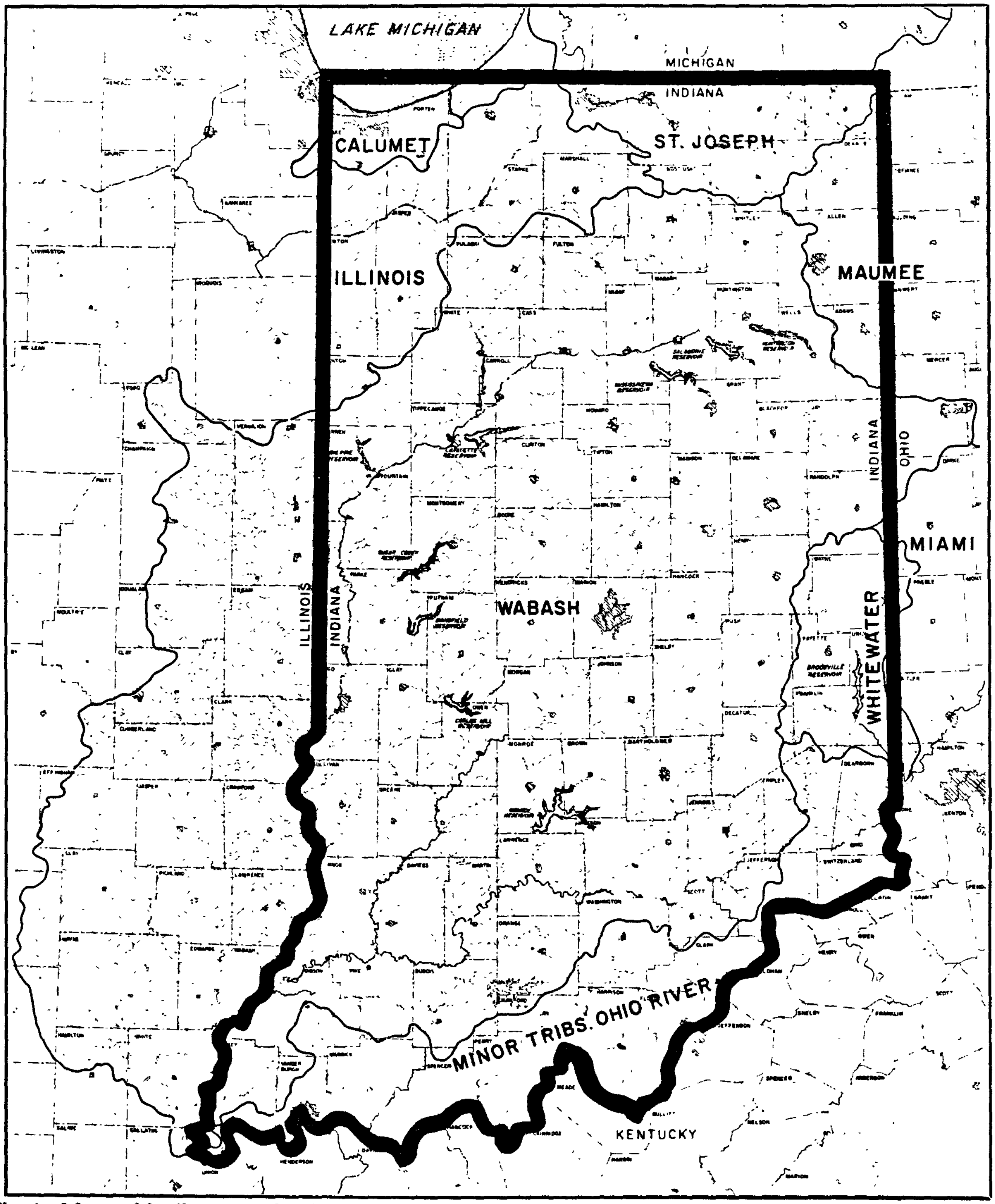

Fig. 1. Map of Indiana and adjacent states showing the major and minor drainage basins (from USGS drainage maps).

Schneider (1966) divided the State into three broad physiographic areas that closely reflect the surface-water characteristics of the State. The Central Corn Belt Plain ecoregion is a part of the Northern Moraine and Lake Region (north of 41° latitude) and is characterized by landforms of glacial origin. The central third of the State is a depositional plain of low relief that has been modified only slightly by postglacial stream erosion. The third area is located south of the Wisconsinan glacial boundary and represents a series of north- and south-trending uplands and lowlands. Landforms in this area are principally due to normal degradation processes.

The last major glaciation event dramatically altered the northwestern portion of Indiana during the Wisconsinan (14,000 to 22,000 years ago). As glaciers advanced and retreated, the topography was dramatically altered as the landform was either scoured by advancing glacial ice or the scoured materials were deposited by retreating glaciers. Two distinct glacial lobes are known to have advanced into Indiana, from the northeast out of the Lake Erie and Saginaw Bay basins and from the north from the Lake Michigan basin.

Ecoregions

Omernik and Gallant (1988) characterized the attributes of ecoregions of the midwest states. Indiana has six recognized ecoregions: Central Corn Belt Plain, Southern Michigan-Northern Indiana Till Plain, Huron-Erie Lake Plain, Eastern Corn Belt Plain, Interior Plateau, and Interior River Lowland (Fig. 2). Subsequent documents will detail the development of biological criteria for each of these ecoregions.

The following is a description of the Central Corn Belt Plain ecoregion, summarized from Omernik and Gallant (1988). Much of the ecoregion consists of dissected glacial till plain mantled with loess. The ecoregion is characterized by low relief; however, some morainal hills occur in the northern portion reaching 60.1 m. Stream valleys are generally shallow throughout the 46,400 $miles^2$ of the ecoregion. Small streams have narrow valley floors; larger streams have broad valley floors. Elevation varies from about 121 m, in the southern portion of the ecoregion, to over 303 m on a few of the hills in the north. Precipitation occurs mainly during the growing season and averages from 80 to 176 cm annually. Except near Lake Michigan, and in the meander corridors along major rivers, few natural lakes occur.

Both perennial and intermittent streams are common in the ecoregion. Constructed drainage ditches and channelized streams further assist in soil drainage in flat, poorly drained areas (e.g. claypans). Stream density is approximately one mile per square mile in the most typical portions of the ecoregion, but ranges from one to two miles per square mile in the "generally typical" portions of the ecoregion (Fig. 2).

Major crops produced in the Central Corn Belt Plain ecoregion are corn, soybeans, feed grains, and some livestock forage. Emphasis on livestock

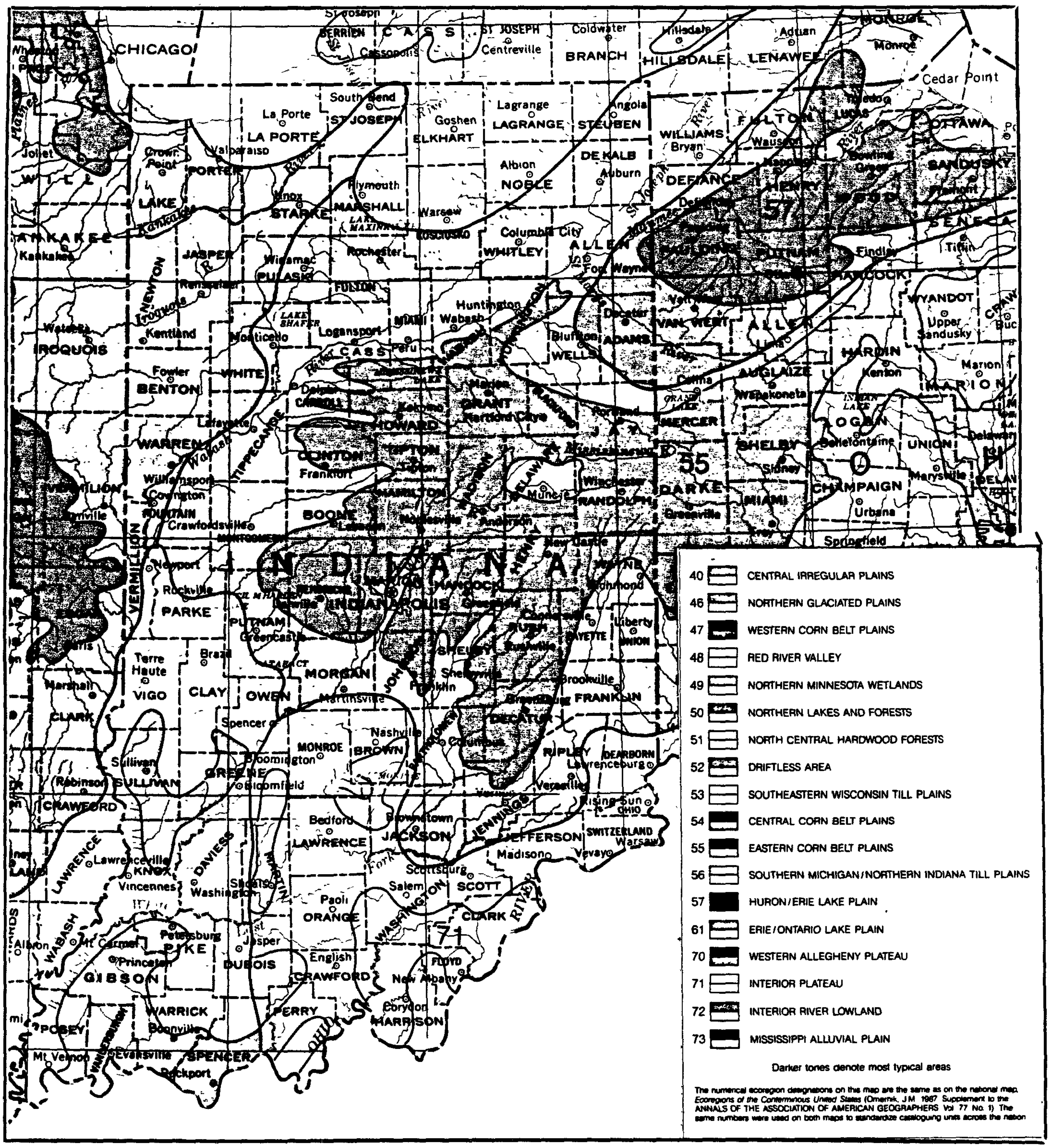

Fig. 2. Map of Indiana and adjacent states showing the ecoregions designation of Omernik and Gallant. (1988).

production is not as great as the adjacent ecoregions. Approximately, five percent of the ecoregion remains as woodland, primarily on wet floodplains, steeply sloping valleys, and morainal ridges.

Most of the soils of the Central Corn Belt Plain ecoregion developed under tall grass prairie. They are dark and fertile soils comprised of Hapludolls and Argiudolls on loess-covered till. Argiaquolls, Haplaquolls, and Ochraqualf's occur on broad, flat uplands, especially in the claypan region of southcentral Illinois. Fragiaqualf's and Hapludalf's are locally common on forested slopes and loessal ridges. Hapludolls, Haplaquolls, Udifluvents, and Fluvaquents are common on the poorly drained silty and clayey alluvium on floodplains. A few Haplaquolls and Medisaprists have formed in poorly drained flats and wet depressions.

The natural vegetation of the area consisted of a mosaic of bluestem prairie and oak/hickory forest. Most of the level uplands and broad floodplains were covered by tall grasses: big and little bluestem, indiangrass, prairie dropseed, and switchgrass. Hardwood forest originally occurred along the irregular topography of streams and moraines. Woodlands were originally a mixture of oak and hickory species: black oak, white oak, bur oak, red oak, shingle oak, shagbark hickory, and bitternut hickory, with occasional black walnut, yellow popular, white ash, sugar maple, basswood, elm, and beech. Riparian areas represent the remaining refugia for pin oak, silver maple, elm, ash, cottonwood, willow, sycamore, and sweetgum in the heavily agricultural area. Cattails, bulrushes, and common reeds grow in the organic soils of the marshes.

Natural Areas

An alternate method of dividing land expanses into smaller workable regional divisions include the recognition of major natural features. A natural region is a major, generalized unit of the landscape where a distinctive assemblage of natural features is present (Homoya et al. 1985). It is similar to the ecoregion concept in that it integrates several natural features, including climate, soils, glacial history, topography, exposed bedrock, presettlement vegetation, and physiography. It differs from the ecoregion concept in the utilization of species composition of the fauna and flora to delineate areas of relative homogeneity.

The Central Corn Belt Plain ecoregion incorporates the Grand Prairie Natural Region and a portion of the Northwestern Morainal Natural Region. The Grand Prairie is identified by an area of tall grass prairie and occupies an area of glacial plain which contains unconsolidated deposits from Wisconsinan glaciation, including sand dunes, lacustrine sediments, outwash plain sediments, and till (Fig. 3). The extent of the area is defined by three subsections: the Grand Prairie Section, Kankakee Sand Section, and the Kankakee Marsh Section (Homoya et al. 1985). The Northwestern Morainal Natural Region is the glaciated area formed by the latest advances of the Lake Michigan lobe of the Wisconsinan ice sheet. This area consists of three

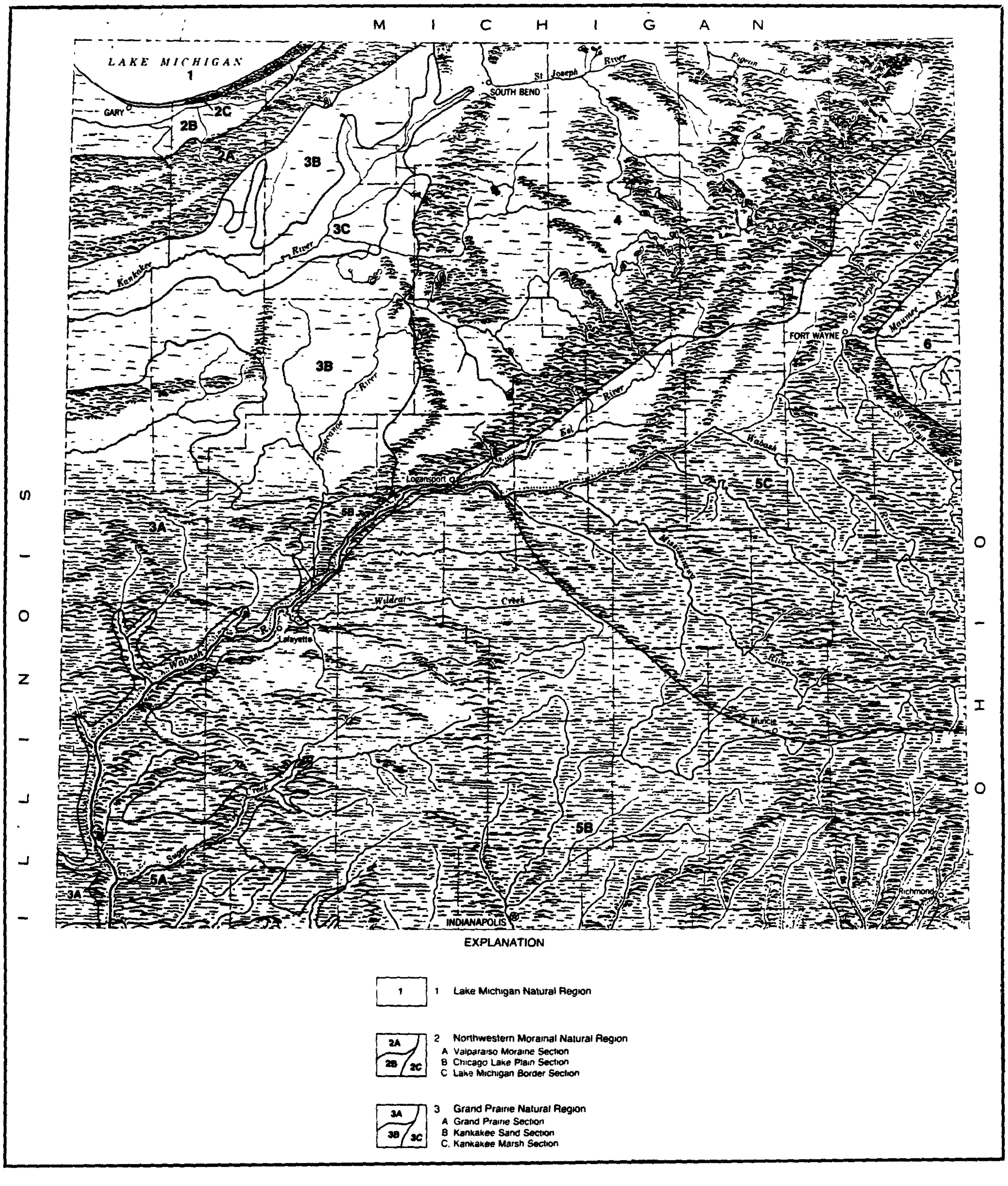

Fig. 3. Map of northern Indiana indicating the natural areas designation of Homoya et al. (1985).

subsections, the Valparaiso Moraine Section, Chicago Lake Plain Section, and Lake Michigan Border Section. Only the Chicago Lake Plain Section is of concern in this ecoregional comparison.

Three major drainage units occur in the Indiana portion of the Central Corn Belt Plain ecoregion: the Calumet River basins, Kankakee River basin, and the Iroquois River Basin. The Calumet River basins include the Grand Calumet River and the Little Calumet River and its tributaries. The Grand Calumet and Little Calumet River are small and drain less than 2% of the State. Flow reversals and streams which cross basin divides makes this basin an extremely difficult area to study. The East Branch of the Little Calumet River flows directly into Lake Michigan after the construction of Burns Ditch (a dredged modification of the original stream channel). A portion of the West Branch of the Little Calumet River likewise drains into Burns Ditch, while a portion flows west into Illinois. Of the Little Calumet tributary segments, Deep River and Salt Creek are the largest components, additional segments includes Hart Ditch, Kemper Ditch, Coffee Creek, Sand Creek, and a number of smaller tributary elements in the East Branch. The East Branch of the Calumet River includes much of the Indiana Dunes National Lakeshore and the Heron Rookery. A number of natural areas occur there as well, including the important Cowles Bog, Clark and Pine Lakes, and many of the dunal ponds studied by Shelford. Much of this area occupies the Northwestern Morainal Natural Region, Chicago Lake Plain Section (Homoya et al. 1985). It was formed by the ridge-and-swale and lacustrine plain topography along Lake Michigan from the water-level fluctuations of Lake Chicago. The flow regime of the Grand Calumet River does not vary much, determined primarily by Lake Michigan levels.

The Kankakee River watershed is the primary basin in the ecoregion, containing the Kankakee River and its major tributary the Iroquois River. The Kankakee Basin encompasses 3,006 square miles, approximately 7% of the State. The Kankakee has been dramatically altered since the 1850's when it was changed from a meandering stream in a marshy wetland to a large channelized stream. Much of the baseflow derives from groundwater. Levees have been constructed along the length of the main stem and tributaries to reduce the chances of flooding. The Kankakee extends from South Bend to the Illinois border flowing southwest, and includes a number of tributary elements, including the Yellow River, Kingsbury Creek, and Cedar Creek. Some of the best water resource streams of this ecoregion occur among the Yellow River. A number of drainage ditches have modified the remainder of the streams and creeks to a relatively straight, homogeneous habitat. Surprisingly, a large amount of recovery has occurred, enabling the Central Corn Belt Plain to possess a diverse ichthyofauna. The majority of this area occurs in the Kankakee Sand Section and Kankakee Marsh Section (Homoya et al. 1985). The Kankakee Sand Section is characterized by the predominance of prairie and savanna communities associated with sandy soils. This area consists primarily of sand dune and outwash plain sediments. The Kankakee Marsh Section is delineated by the high proportion of marsh, lake, and wet prairie communities which existed along the Kankakee River in presettlement times. The marsh was several miles wide on each side of the River for almost its entire course in Indiana. Extensive ditching began in the 1800's to enable agriculture and has all but eliminated the natural wetlands. Average discharge for the Kankakee River, near the Illinois border at Shelby, Indiana, is 1,619 cubic feet per second with ranges of 417 cubic feet per second during 7 day, 10 year low flow and 6,950 cubic feet per second during 100 year flood periods.

The Iroquois River basin is a major tributary segment of the Kankakee River (comprising 780 square miles in Indiana) connecting with the main stem Kankakee River in Illinois near Watseka. The Iroquois River has been channelized, but unlike the Kankakee River it does not receive a substantial amount of its streamflow from groundwater. This is reflected in more extreme high and low flows, and in this regard the Iroquois resembles the Wabash River more than the Kankakee River. The Iroquois River is much shallower, and is not dredged as often as the Kankakee so the resident fish fauna has had a greater opportunity for colonization and stabilization. The major tributary segments of the Iroquois River includes: Ryan ditch, Oliver ditch, Howe ditch, and Carpenter Creek. The Iroquois River occurs in two natural area sections, the Grand Prairie Section and the Kankakee Sand Section. The Grand Prairie section is characterized by the predominance of loamy soil and previously considered the epitome of the vast tall grass prairie of presettlement periods. The Kankakee Sand Section portion is in extreme northern portions of the natural area and was discussed previously. The average discharge of the Iroquois River near Foresman (near the Illinois-Indiana political boundary) is 383 cubic feet per second with ranges of 11 cubic feet per second during 7 day, 10 year low flow and 5,660 cubic feet per second during 100 year flood periods.

3.0 MATERIALS AND METHODS

Sampling

Site Specific

A total of 197 sample locations (Fig. 4) were surveyed during July and August of 1990 in order to compile the data needed to evaluate the maximum species richness lines for calibration of the Index of Biotic Integrity. In order to answer the basin specific questions, and determine if ecoregion boundaries were adequately defined, a sufficient number of samples were required to calibrate the Index for various drainages. Site location identifier information for each site evaluated is contained in Appendix E of this report. Since the primary purpose of this study was to evaluate the water quality of Indiana using biological methodology, no further evaluation of site specific data (e.g. site specific taxonomic species lists) will be included other than an overall taxa list for each basin.

To ensure repeat sampling at the exact same site, all locations are based on latitude and longitude and narrative description mileage is reported from the center point rather than the edge of the nearest town since the boundaries of many Indiana towns will change over the next century. All sites were evaluated based on drainage area since this provides the most reliable quantification (Hughes et al. 1986) of stream size. As drainage area

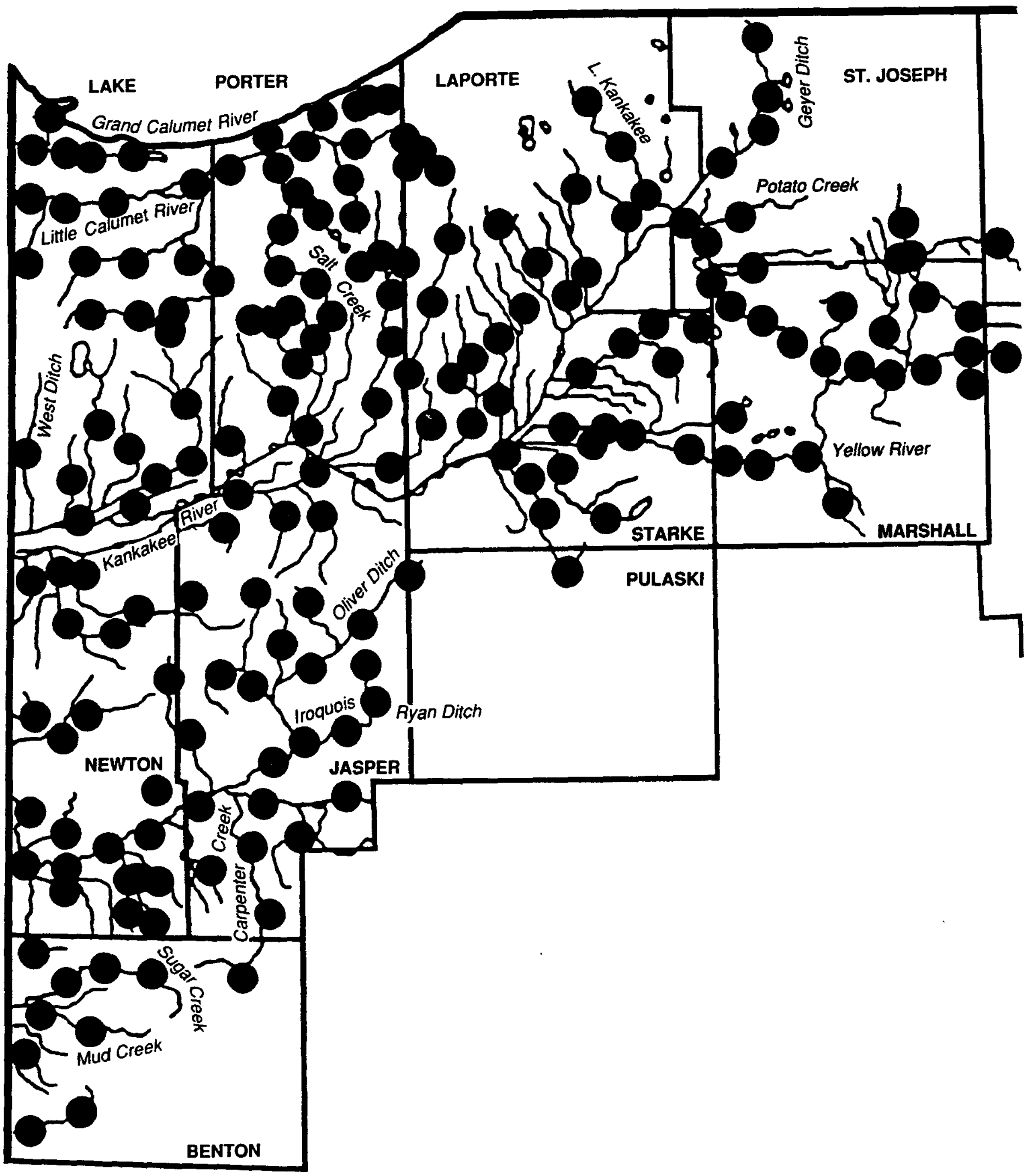

Fig. 4. Central Corn Belt Plain ecoregion indicating the location of 197 headwater and wading sites sampled during 1990.

increases, and with it stream order, fewer locations are available for comparative analysis.

Habitat

The range of habitats sampled has a major effect on data collection. A representative sample always requires that the entire range of riffle, run, pool, and extra-channel habitat be sampled, especially when large rivers are surveyed. Atypical samples result when unrepresentative habitats are sampled adjacent to the sampling site. Species richness near bridges or near the mouths of tributaries entering large rivers, lakes, or reservoirs are more likely to be characteristic of large-order habitats than the one under consideration (Fausch et al. 1984).

A general site description of each established sampling location was conducted using the field observation procedure of Ohio EPA (1987). The Quality Habitat Evaluation Index takes into account important attributes of the habitat which increases heterogeneity. Scoring incorporates information on substrate composition, instream cover, channel morphology, riparian zone and bank erosion, and pool and riffle quality. The following physical parameters were recorded for each sample site to help evaluate the biological data further: dissolved oxygen, pH, temperature, specific conductivity, and current velocity. Equipment utilized for physical water quality analysis was a Hydrolab SVR2-SU, while current velocity was measured using a Teledyne Gurley pygmy meter following the specifications of the manufacturer.

Community Analysis

Sample Considerations

Although great attention has been given to sampling design and procedures, biologists must exercise judgement to ensure that a sample is representative of the system being assessed. Gear must be capable of sampling all species in proportion to their relative abundance. As streams increase in size and structural complexity, sophisticated equipment such as long-lines, sport-yaks, and boat- mounted electrofishing equipment is required (USEPA 1988). However, only one electrofishing gear type need be used at each location (Jung and Libosvarsky 1965; Ohio EPA 1987). Long-line and sport-yak equipment was built following specifications of Ohio EPA (1987) and utilized the same generator, a T&J pulsed-DC generator capable of 300 volt output. Boat electrofishing equipment included the Coffelt 18 ft Jon boat rig with a bow-mounted stainless steel electrosphere. The boat power source was a 5000 watt Honda generator which was fished at 300 volt capacity through a VVP-15 transformer.

The young of fish less than 20 mm in length are excluded from Index of Biotic Integrity analysis. Early life stages exhibit high initial mortality (Simon 1990), and are difficult to identify and to collect with gear designed for larger fish (Angermeier and Karr 1986). Collection of fish from this category will be retained for possible future use in State water monitoring programs (e.g. ichthyoplankton index (I^2)). Specimens were not included in IBI calibration or composite totals, but they received notation on the data sheet. Adult specimens from each stream reach were identified to species utilizing the taxonomic keys of Gerking (1955), Trautman (1981), and Becker (1983). Cyprinid taxonomy follows Mayden (1989), changes in all species nomenclature are listed in Appendix E for comparability with previous investigations.

The length of stream reach sampled is an important consideration. Karr et al. (1986) recommended sample reaches of 100 m sufficient in structurally simple headwater streams. In larger streams, selecting several contiguous riffle-pool sequences rather than relying on a standard length may be more appropriate. When electrofishing equipment was employed in larger rivers, samples were taken in units of 0.5 to 1.0 km (Gammon et al. 1981). The length of the sample reach was long enough to include all major habitat types. Distances of 11 to 15 stream widths were generally adequate to sample two cycles of habitat (Leopold et al. 1964). In addition, the location of the site was precisely recorded so sampling could be repeated in the future. Photographs; township, range, and section numbers; latitude and longitude; and county locations were recorded on the data sheet.

Selecting the appropriate time of year for sampling is critical. Karr et al. (1986) found no single best period could be defined. Periods of low-to moderate stream flow are preferred and the relatively variable flow conditions of early spring and late autumn/winter should be avoided. Species richness tends to be higher later in summer due to the presence of young-of-the-year of rare species, but this can be avoided if sampling does not incorporate young-of-the-year species. Samples of limited area may be less variable in early summer than comparable samples taken later in the year.

The aquatic community of each of the six Indiana ecoregions was sampled at approximately 200 sites to evaluate the water resource using the Standard Operating Procedures of the USEPA Central Regional Laboratory (1988). Sampling was conducted during low to moderate flow periods (June to September). A quantitative fish survey was conducted using the Index of Biotic Integrity (IBI) and all comments in the proceeding sections will deal only with fish field procedures. A total of 5% of the total sites were resampled for precision and accuracy estimates. The station numbering system used for the project followed the methods of the Central Regional Laboratory (1978).

Sample Site Selection

Fish sample sites were selected based upon several factors:

1). Avoiding stream reaches affected by point source dischargers;

2). Stream use designation issues (i.e. Grand Calumet basin);

3). Location of physical habitat features (e.g. dams, changes in geology, changes in stream order, presence of stream confluence, etc.);

4). Location of non-point sources of pollution (e.g. cities/urban areas, and obvious farm runoff);

5). Variations in habitat suitability for fish;

6). Atypical habitat not representative of River reach or basin.

When possible sites were located upstream from pollution sources and adjacent tributaries (Gammon 1973). Should the upstream portion of the stream be impacted, an alternate reference station was selected from another reach or adjacent stream with similar geological and hydrological conditions. Stations were selected from natural areas, parks (Federal, State, County, and Local), exceptional designated streams, and from historical sampling locations whenever available.

When non-impacted areas were not present, "least impacted" areas were selected based on the above criteria. Inferior impacts, sites which exhibit obvious attributable disturbances, may include channelization of rivers, and proximity to non-point sources. Sites were chosen which indicate recovery from channelization or potential non-point source areas, and which have a suitable riparian buffer on the shoreline. When a series of point source dischargers were located on a river, every effort was made to sample upstream of the discharger present on the highest upstream segment, or to search for areas of recovery between the dischargers (Krumholz 1946).

When impoundments or other physical habitat alterations had been installed on the river, sampling was conducted in the tailwaters of a dam (area immediately downstream). Tailwaters posses the greatest semblance of the unregulated lotic habitat. In areas where sampling cannot be accomplished downstream of the physical structure due to lack of access, stream tributary segments were located upstream of the dam away from the immediate influence of the pooled portion. Likewise, bridges were always sampled on the upstream side, away from the immediate vicinity of the structure and bridge construction effects.

Fish from each location was identified to species and enumerated. A voucher specimen of each taxa was retained. Likewise, all smaller and more difficult to identify taxa were preserved for later examination and identification in the laboratory. All fish collected were examined for the presence of gross external anomalies. Incidence of these anomalies was defined as the presence of externally visible morphological disorders, and is expressed as percent of afflicted fish among all fish collected. Incidence of occurrence was computed for each species at each station. Specific anomalies include: anchor worms; leeches; pugheadedness; fin rot; Aeromonas (causes ulcers, lesions, and skin growth, and formation of pus-producing surface lesions accompanied by scale erosion); dropsy (puffy body); swollen eyes; fungus; ich; curved spine; and swollen-bleeding mandible or opercle.

Hybrid species encountered in the field (e.g. centrarchids, cyprinids) were recorded on the data sheet, and if possible, potential parental combinations recorded.

Index of Biotic Integrity

The ambient environmental condition was evaluated using the Index of Biotic Integrity (Karr 1981; Karr et al. 1986). This index relies on multiple parameters (termed "metrics") based on community concepts, to evaluate a complex system. It incorporates professional judgement in a systematic and sound manner, but sets quantitative criteria that enables determination of what is poor and excellent based on species richness and composition, trophic and reproductive constituents, and fish abundance and condition. The twelve original Index of Biotic Integrity metrics reflect insights from several perspectives and cumulatively are responsive to changes of relatively small magnitude, as well as broad ranges of environmental degradation.

Since the metrics are differentially sensitive to various perturbations (e.g. siltation or toxic chemicals), as well as, various degrees or levels of change within the range of integrity, conditions at a site can be determined with considerable accuracy. The interpretation of the index scoring is provided in six narrative categories that have been tested in Region V (Karr 1981; Table 2).

Several of the metrics are drainage size dependent and require selection of numerical scores (Tables 3-7). The ecoregion approach developed by USEPA-Corvallis, OR, was utilized to compare "least impacted" zones within the region (Omernik 1986). Ohio EPA (1987), modified several of the metrics in order to make them more sensitive to environmental effects from their experiences in Ohio. The current study utilizes the experiences of Ohio and Karr et al. (1986) in adapting an index for Indiana.

Metrics

In general, the metrics utilized for the current study are those developed by the State of Ohio (Ohio EPA 1987) for analysis of surface water use-attainment. This includes a slight modification of several of the original Index of Biotic Integrity metrics as proposed by Karr (1981).

Although the methodology and application of the ecoregional expectations are similar in approach to Ohio and much of the information below is taken directly from the Ohio documents (Ohio EPA 1988), a significant difference exists between the Indiana and Ohio data bases. This difference exists in how the metric expectations are developed. In Ohio, the ecoregional reference stations were combined into a single data set for the entire State, and later modifications were developed for the Huron-Erie Lake Plain. In Indiana, "least impacted" conditions will be developed on a regional basis, with recognition of basin differences within ecoregion, based on the natural areas classification of Homoya et al. (1985). Further evaluation at the completion of the study will determine if differential metric treatment is warranted for

Table 2. Attributes of Index of Biotic Integrity (IBI) classification, total IBI scores, and integrity classes from Karr et al. (1986).

Total IBI score	Integrity Class	Attributes
58-60	Excellent	Comparable to the best situation without human disturbance; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with a full array of age (size) classes; balance trophic structure.
48-52	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species are present with less than optimal abundances or size distributions; trophic structure shows some signs of stress.
40-44	Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, highly skewed trophic structure (e.g. increasing frequency of omnivores and other tolerant species); older age classes of top predators may be rare.
28-34	Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
12-22	Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.
	No fish	Repeated sampling finds no fish.

Table 3. Index of Biotic Integrity metrics used to evaluate headwater sites in the Kankakee and Iroquois River Basins.

Metric Category	Metric	Scoring Classification 5	3	1
Species Composition	Total Number of Species	Varies with drainage area (Fig. 6-7)		
	Number Darter/Sculpin/ Madtom Species	Varies with drainage area (Fig. 9-10)		
	% Headwater Species	>26.6%	13.3%-26.6%	<13.3%
	Number of Minnow Species	Varies with drainage area (Fig. 16-17)		
	Number Sensitive Species	Varies with drainage area (Fig. 21-23)		
	% Tolerant Species	< 25%	25.1-49.9%	>50.0%
Trophic Composition	% Omnivores[1] ≤ 20 square miles	Varies with drainage area (Fig. 26)		
	% Insectivores[1] ≤ 20 square miles	Varies with drainage area (Fig. 27)		
	% Pioneer Species[1]	<24.7%	24.7-49.4%	>49.4%
Fish Condition	Catch per Unit Effort	Varies with drainage area (Fig. 31)		
	% Simple Lithophils	>34%	16.5-33.9%	<16.5%
	% DELT anomalies[1]	<0.1%	0.1-1.3%	>1.3%

1 Special scoring procedures are required when less than 25 individual fish are collected.

Table 4. Index of Biotic Integrity metrics used to evaluate wadable sites in the Kankakee and Iroquois River basins.

Metric Category	Metric	Scoring Classification 5	3	1
Species Composition	Total Number of Species	Varies with drainage area (Fig. 6-7)		
	Number of Darter Species	Varies with drainage area (Fig. 9-10)		
	Number of Sunfish Species	> 3	2-3	< 2
	Number of Sucker Species	Varies with drainage area (Fig. 19)		
	Number Sensitive Species	Varies with drainage area (Fig. 21-22)		
	% Tolerant Species	< 25%	25.1-49.9%	>50.0%
Trophic Composition	% Omnivores[1] > 20 square miles	<19.3%	19.3-38.7%	>38.7%
	% Insectivores[1] > 20 square miles	>50%	25.1-49.9%	<25%
	% Carnivores[1]	>5.0%	2.1-5.0%	<2.0%
Fish Condition	Catch per Unit Effort	Varies with drainage area (Fig. 31)		
	% Simple Lithophils	>34%	16.5-33.9%	<16.5%
	% DELT anomalies[1]	<0.1%	0.1-1.3%	>1.3%

1 Special scoring procedures are required when less than 50 individual fish are collected.

Table 5. Index of Biotic Integrity metrics used to evaluate headwater sites in the Lake Michigan basin (East Branch Little Calumet River Division).

Metric Category	Metric	Scoring Classification 5	3	1
Species Composition	Total Number of Species	Varies with drainage area (Fig. 8)		
	Number Darter/Sculpin/ Madtom Species	Varies with drainage area (Fig. 11)		
	Number of Sunfish Species	Varies with drainage area (Fig. 15)		
	Number of Salmonid Species	Varies with drainage area (Fig. 20)		
	Number Sensitive Species	Varies with drainage area (Fig. 23)		
	% Tolerant Species	< 25%	25.1-49.9%	>50.0%
Trophic Composition	% Omnivores[1] ≤ 20 square miles	Varies with drainage area (Fig. 26)		
	% Insectivores[1] ≤ 20 square miles	Varies with drainage area (Fig. 27)		
	% Carnivores[1]	Varies with drainage area (Fig. 30)		
Fish Condition	Catch per Unit Effort	Varies with drainage area (Fig. 31)		
	% Simple Lithophils	>34%	16.5-33.9%	<16.5%
	% DELT anomalies[1]	<0.1%	0.1-1.3%	>1.3%

1 Special scoring procedures are required when less than 25 individual fish are collected.

Table 6. Index of Biotic Integrity metrics used to evaluate headwater sites in the Lake Michigan basin (Lake Michigan Division).

Metric Category	Metric	Scoring Classification 5	3	1
Species Composition	Total Number of Species	Varies with drainage area (Fig. 8)		
	Number Darter/Sculpin/ Madtom Species	Varies with drainage area (Fig. 11)		
	Number of Sunfish Species	Varies with drainage area (Fig. 15)		
	Number of Minnow Species	Varies with drainage area (Fig. 18)		
	Number Sensitive Species	Varies with drainage area (Fig. 23)		
	% Tolerant Species	< 25%	25.1-49.9%	>50.0%
Trophic Composition	% Omnivores[1] ≤ 20 square miles	Varies with drainage area (Fig. 26)		
	% Insectivores[1] ≤ 20 square miles	Varies with drainage area (Fig. 27)		
	% Pioneer Species[1]	<24.7%	24.7-49.4%	>49.4%
Fish Condition	Catch per Unit Effort	Varies with drainage area (Fig. 31)		
	% Simple Lithophils	>34%	16.5-33.9%	<16.5%
	% DELT anomalies[1]	<0.1%	0.1-1.3%	>1.3%

1 Special scoring procedures are required when less than 25 individual fish are collected.

Table 7. Index of Biotic Integrity metrics used to evaluate wadable sites in the Lake Michigan basins (East Branch Little Calumet River and Lake Michigan Divisions).

Metric Category	Metric	Scoring Classification 5	3	1
Species Composition	Total Number of Species	Varies with drainage area (Fig. 8)		
	Number of Darter Species	Varies with drainage area (Fig. 11)		
	Number of Sunfish Species	> 3	2-3	< 2
	Number of Salmonid Species	Varies with drainage area (Fig. 20)		
	Number Sensitive Species	Varies with drainage area (Fig. 23)		
	% Tolerant Species	< 25%	25.1-49.9%	>50.0%
Trophic Composition	% Omnivores[1] > 20 square miles	<19.3%	19.3-38.7%	>38.7%
	% Insectivores[1] > 20 square miles	>50%	25.1-49.9%	<25.0%
	% Carnivores[1]	>5.0%	2.1-5.0%	<2.0%
Fish Condition	Catch per Unit Effort	Varies with drainage area (Fig. 31)		
	% Simple Lithophils	>34%	16.5-33.9%	<16.5%
	% DELT anomalies[1]	<0.1%	0.1-1.3%	>1.3%

1 Special scoring procedures are required when less than 50 individual fish are collected.

basin specific or larger scale criteria.

The Index of Biotic Integrity is very sensitive to differences in collection effort and gear type. In order to account for these inherent biases, separate expectations are developed for each of the three stream classification types utilized in the current study. Headwater sites were primarily sampled using a long-line unit or common sense minnow seine, wadable sites were sampled using a sport-yak or long-line unit, while larger unwadable rivers were sampled using various boat-mounted equipment.

Below is a metric by metric definition of each of the twelve metrics utilized for the calibration of the Indiana Index of Biotic Integrity. Due to inherent differences between the Lake Michigan and Mississippi River drainages, different metrics were necessary to evaluate both sections of the ecoregion. Salmonid species in the Lake Michigan tributaries have a dramatic effect on the fish community such that conventional (Karr et al. 1986; Ohio EPA 1987) index metrics were not able to evaluate certain structural and functional aspects of the community. Several modifications were necessary for headwater streams and wadable streams where salmonid species occurred. Thus, two different sets of metrics are included for Lake Michigan headwater tributaries (Tables 5 and 6). The provisional break is set at the mouth of Burns Ditch and includes the East Branch of the Little Calumet River and all tributary segments of the East Branch to its origination in LaPorte County (Table 5). Likewise, the West Branch of the Little Calumet River, Grand Calumet River, and all tributaries to these Rivers are more similar to the Mississippi River drainage and were evaluated using metrics in Table 6. Omernik (1987) recognized a division of the Calumet Region and included a portion in the adjacent ecoregion (Southern Michigan-Northern Indiana Till Plain). Further analysis of this situation is required in order to determine the exact delineation of the two ecoregional boundaries.

Maximum species richness lines were drawn following the procedure of Fausch et al. (1984) and Ohio EPA (1989). Scatter plot data diagrams of individual metrics were first evaluated for basin specific patterns. The maximum species richness line method primarily used was the trisection method. This requires the uppermost line to be drawn so that 95% of the data area lies beneath. The other two lines were then drawn so the remainder of the area beneath the 95th percentile line was divided into three equivalent areas. In situations where no significant deviation in relationship was observed within the three basin segments, the segments were pooled to reflect an ecoregional consensus. Likewise, if no relationship with increasing drainage area was observed, the maximum species richness lines either leveled off at the point where no additional increases were exhibited or horizontal plots were delineated indicating no increase with drainage area.

The drainage area, where differentiation between headwater and wading sites was conceived, was indicated on the graphs by a vertical dashed line on the maximum species richness lines. This relationship was determined by searching for bimodal patterns in the basin specific data set plots of species richness. A sixth order polynomial defined where a significant bimodal effect was evident for each of the drainage basins (Fig. 5). The tails of the data are not significant, rather the point where the data differentiates into two distinct peaks suggest that at approximately 20 $miles^2$ the transition between headwater and wading methods should be made.

Metric 1. Total Number of Fish Species (All methods)

Impetus

This metric is utilized for all of the stream classification types used for calibrating the Indiana Index of Biotic Integrity. Unlike the Ohio metric, exotic species are included in the total number of taxa. The premise behind this metric is based on the observation that the number of fish species increases directly with environmental complexity and quality of the aquatic resource (Karr 1981; Karr et al. 1986). Although the number of exotic or introduced species may be indicative of a loss of integrity (Karr et al. 1986; Ohio EPA 1987), the differences between lower levels of resolution may be due to colonization of habitats by pioneer or tolerant taxa which mostly incorporate exotic species.

This single metric is considered to be one of the most powerful metrics in resolving water resource issues since a direct correlation exists between high quality resources and high numbers of species for warmwater assemblages (Ohio EPA 1987; Davis and Lubin 1989; Plafkin et al. 1989). As total number of species increases, species become more specialized and have narrower niche breadths, numerous higher levels interactions occur and presumably enable greater efficiency in resource utilization.

The determination of headwater and wadable classifications for Indiana was made primarily on the data from this metric. A sixth order polynomial curve fit line revealed two peaks at drainage areas of approximately 20 square miles (Fig 5).

Headwater and Wading Sites

The number of species is strongly correlated with drainage area at headwater and wading sites up to ca. 100 square miles. Determining the Index of Biotic Integrity scoring criteria for this metric requires the comparison of maximum species richness lines for the appropriate basin and drainage area (Fig 6, 7, 8; headwater and wading sites).

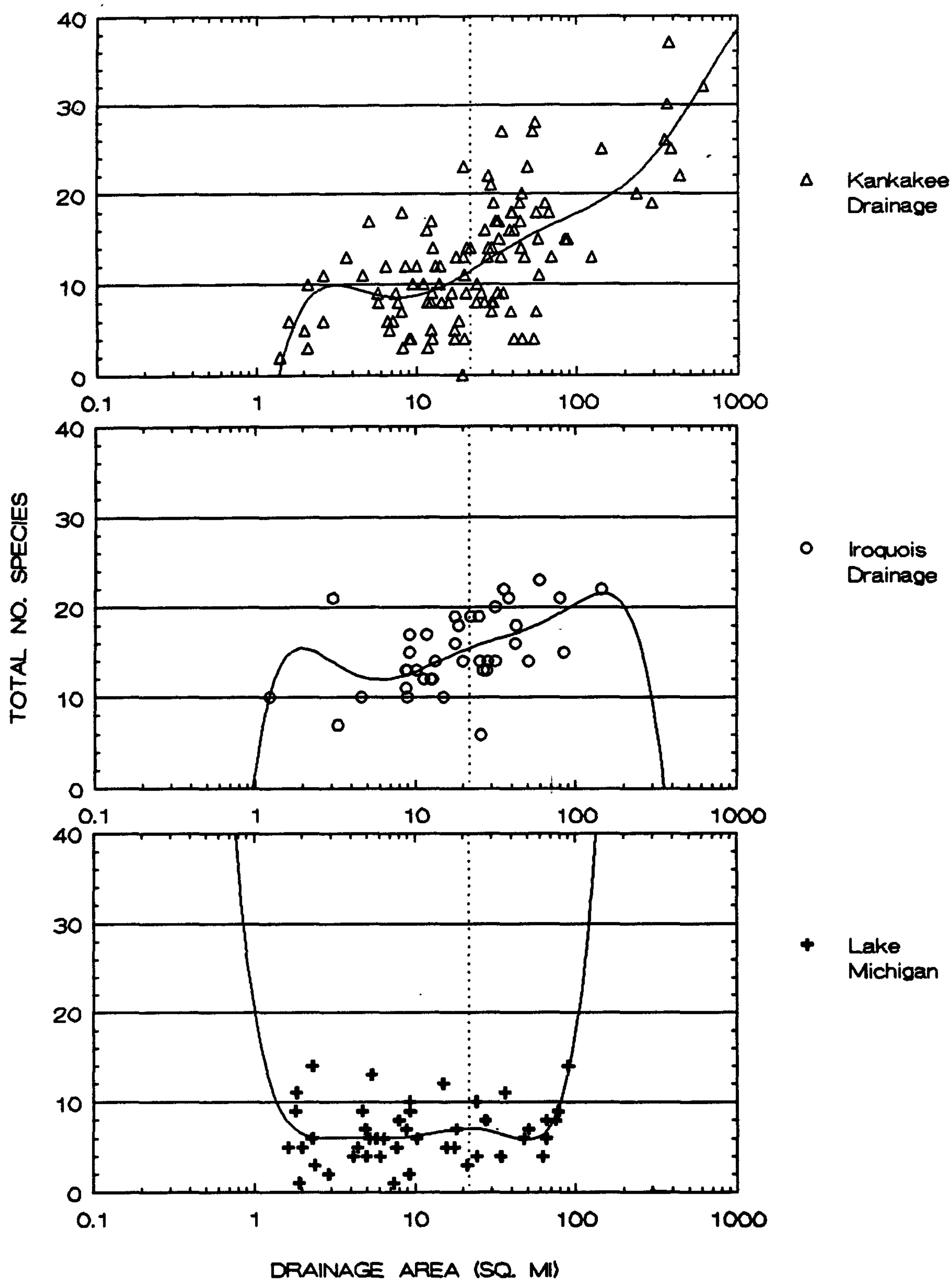

Fig. 5. **Species diversity trends with drainage area for determining the separation of headwater and wading catergories using polynominal curve fit graphing techniques.**

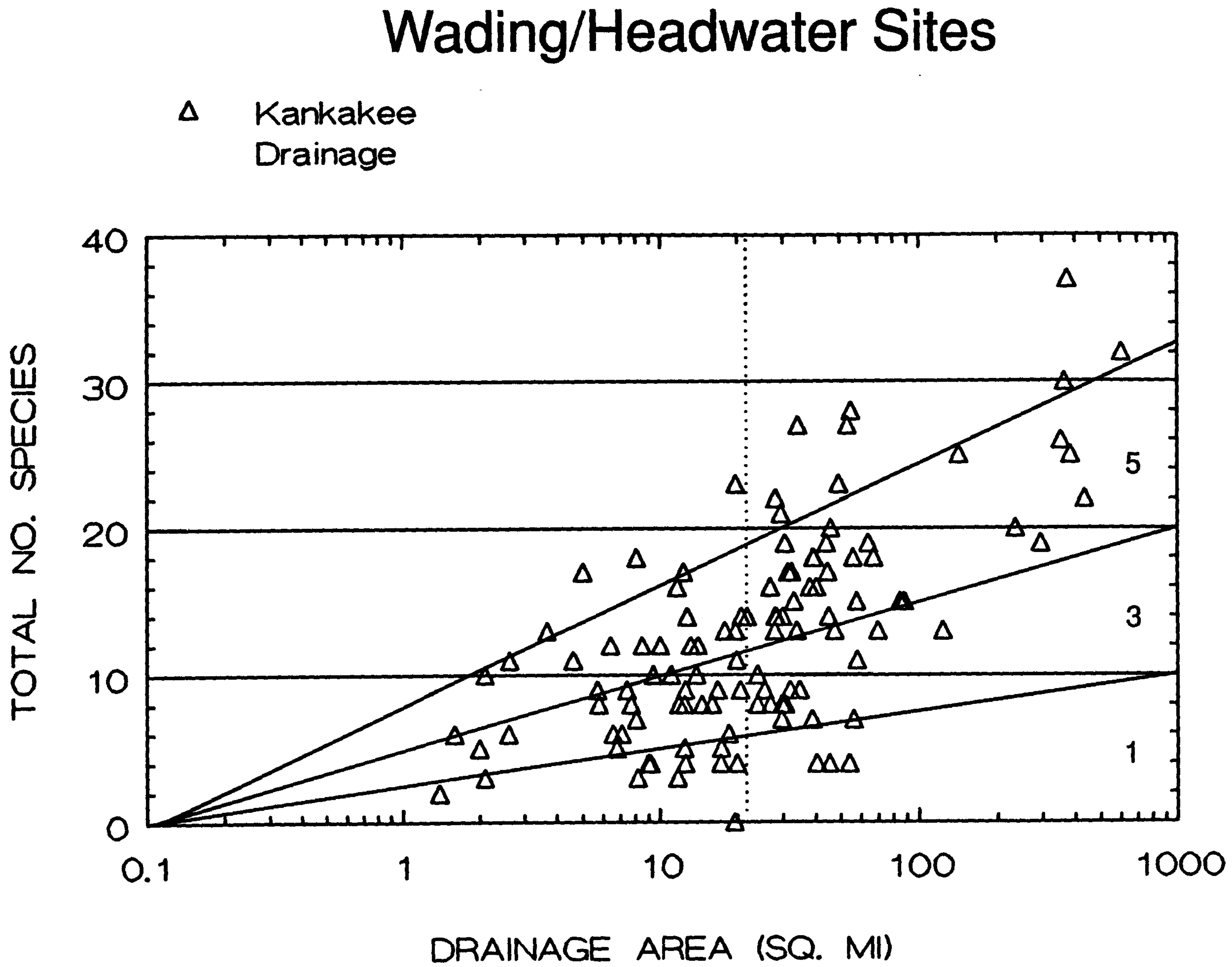

Fig. 6. Maximum species richness lines determining trends in total number of species with increasing drainage area for the Kankakee River drainage.

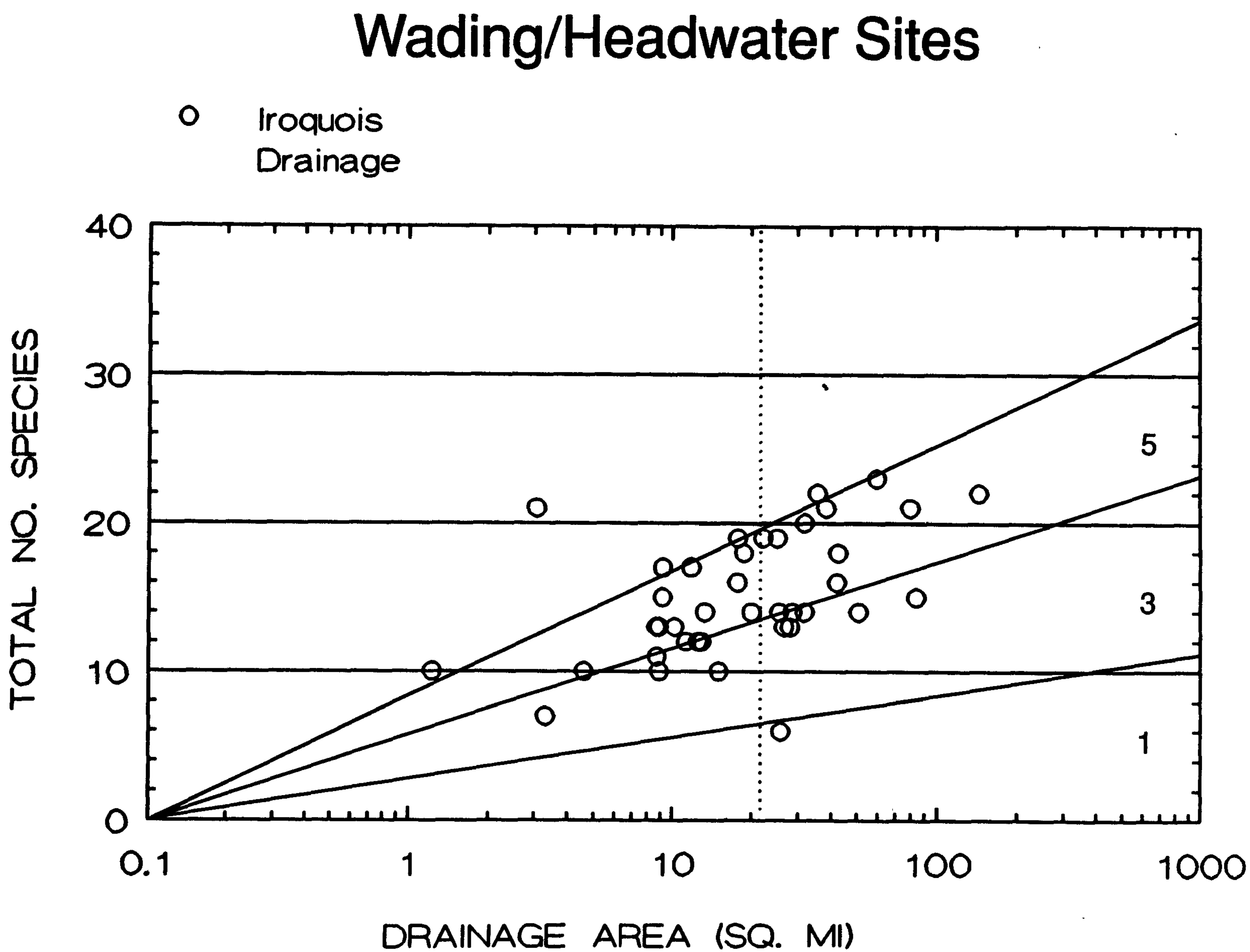

Fig. 7. Maximum species richness lines for determining trends in total number of species with increasing drainage area for the Iroquois River drainage.

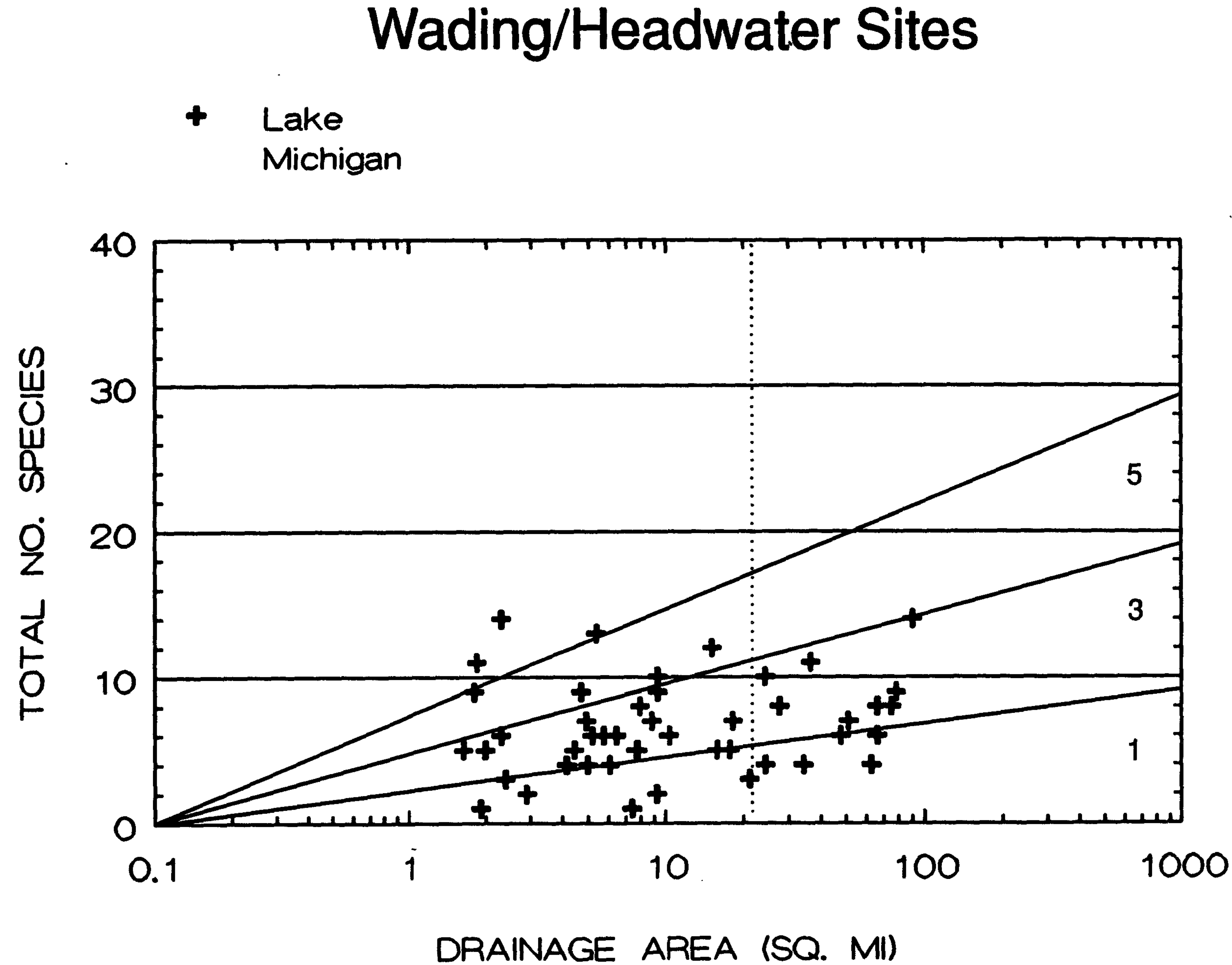

Fig. 8. Maximum species richness lines for determining trends in total number of species with increasing drainage area for the Lake Michigan drainage.

Metric 2. Number of Darter Species (Headwater, Wading Methods)

Impetus

Karr et al. (1986) indicated that the presence of members of the tribe Etheostomatini are indicative of a quality resource. Darters require high dissolved oxygen concentrations, are intolerant to toxicants and siltation, and thrive over clean substrates. Life history information for all of the 27 Indiana species indicates darters are insectivorous, habitat specialists, and sensitive to physical and chemical environmental disturbances (Page 1983; Kuehne and Barbour 1983). Darters are excellent indicators of a quality resource, generally in riffle habitats.

The darters include the genera: Ammocrypta, Crystallaria, Etheostoma, and Percina. Of the 28 species recorded from Indiana, six are commonly found throughout the State and are not restricted to a particular stream size (Gerking 1945). Fifteen species are confined to the Ohio River basin; none of the species are restricted to the Mississippi River basin; and a single species occurs only in the Great Lakes drainages (Table 8).

Headwater Sites

For headwater sites, those less than 20 square miles drainage area, this metric also includes members of the family Cottidae (sculpins) and Ictaluridae (madtoms; genus Noturus, tribes Noturus, Schilbeodes, and Rabida). The sculpins and madtoms are benthic insectivores and functionally occupy the same type of niche as darters. Their inclusion enables a greater degree of sensitivity in evaluating streams that naturally have fewer darter species. This metric changes with drainage area, thus maximum species richness lines were prepared using Central Corn Belt Plain data (Fig. 9, 10, 11). An increase in the number of benthic insectivores increases with increasing drainage area for each of the three basins. In the Lake Michigan drainage, few darters actually occurred so this metric was estimated based on the total number of species which could be expected rather than actually observed during the current study.

Wading Sites

The darter metric, as originally proposed by Karr (1981), is used only in wadable habitats. The criteria developed for the maximum species richness lines was determined from the Indiana data set (Fig. 9, 10, 11) and indicates a positive relationship with increasing drainage area. Due to the reduction of quality sites in higher drainage area categories for the Lake Michigan drainage, the number of expected species in quality habitats was estimated. Madtom and sculpin species are not included in cumulative scoring for drainage areas greater than 20.0 square miles.

Table 8. The distributional characteristics of Indiana darter species (tribe: Etheostomatini).

Species	Distribution in Indiana Drainages			
	Statewide	Ohio River	Great Lakes	Mississippi River
Ammocrypta pellucida		X	X	
A. clara		X		X
Crystallaria aprella		X		
Etheostoma asprigene		X		
E. blennioides		X		
E. caeruleum	X			
E. camurum		X		
E. chlorosoma	X			
E. exile			X	
E. flabellare	X			
E. gracile		X		
E. histrio		X		
E. kennicotti		X		
E. maculatum		X		
E. microperca[1]		X	X	X
E. nigrum	X			
E. spectabile		X		X
E. squamiceps		X		
E. tippecanoe		X		
E. variatum		X		
E. zonale		X		X
Percina caprodes	X			
P. copelandi		X		
P. evides		X		
P. maculata	X			
P. phoxocephala		X		X
P. sciera		X		
P. shumardi		X		

1 Restricted to northern portions of these drainages.

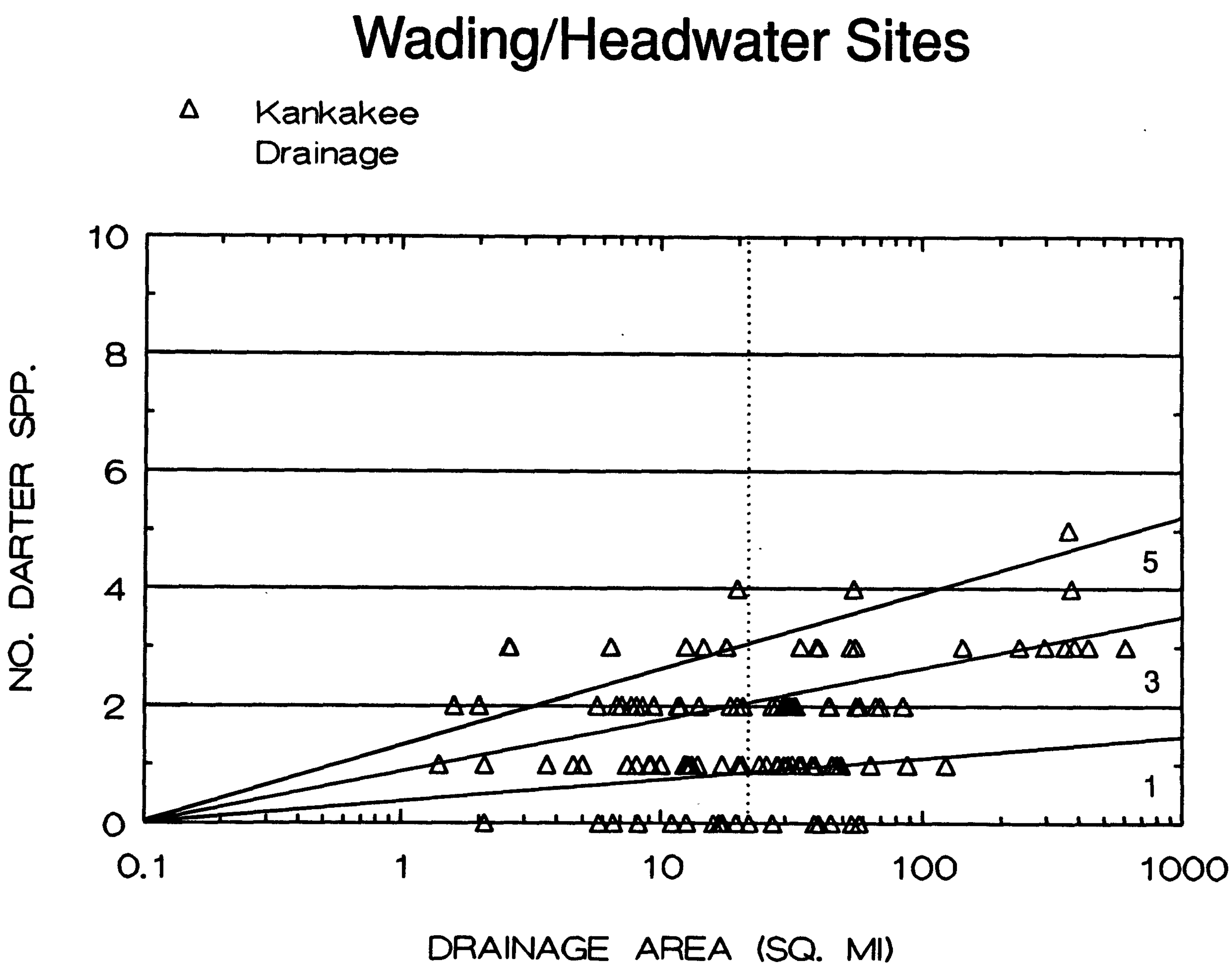

Fig. 9. Maximum species richness lines for determining trends in number of darter species with increasing drainage area for the Kankakee River drainage.

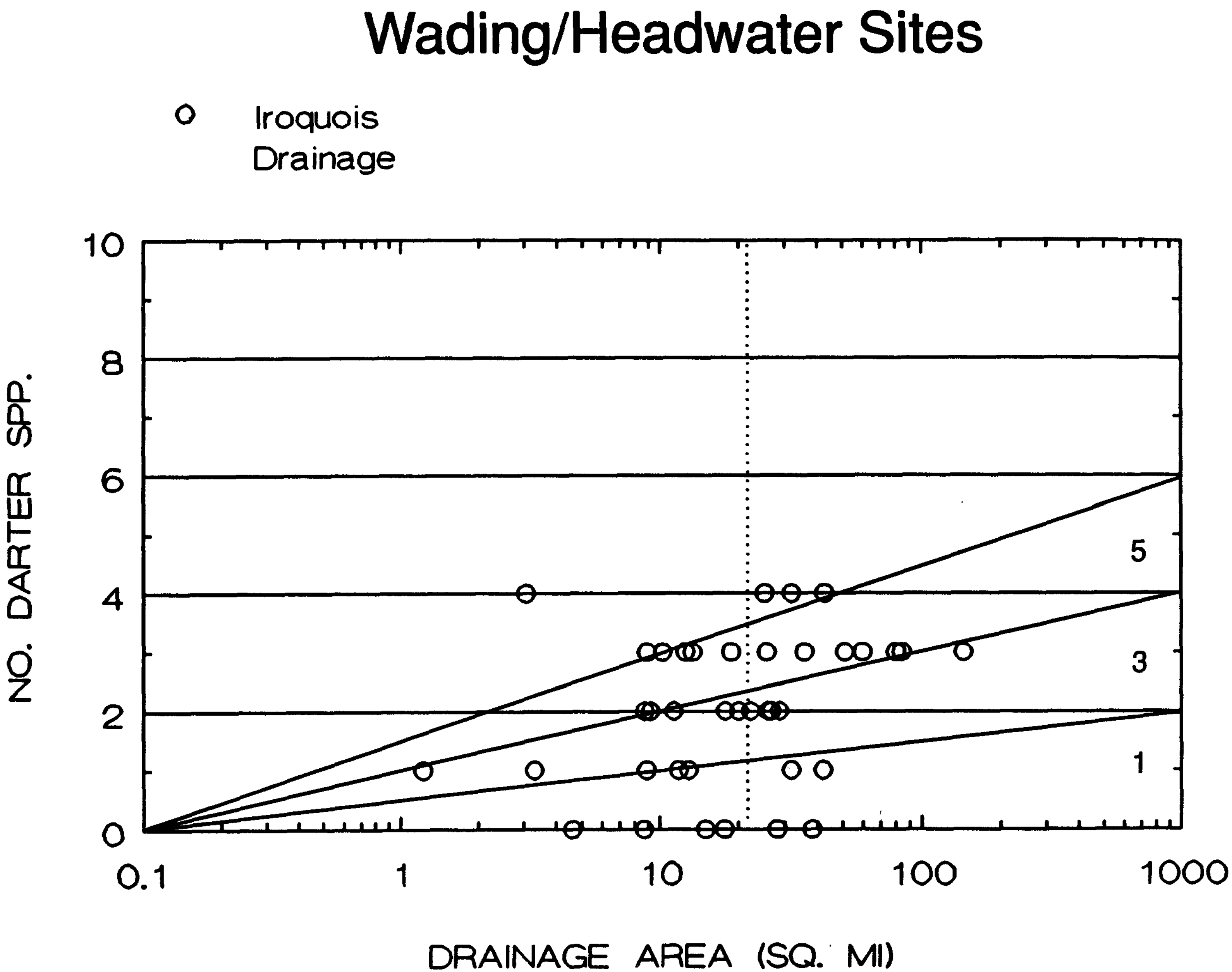

Fig. 10. Maximum species richness lines for determining trends in number of darter species with increasing drainage area for the Iroquois River drainage.

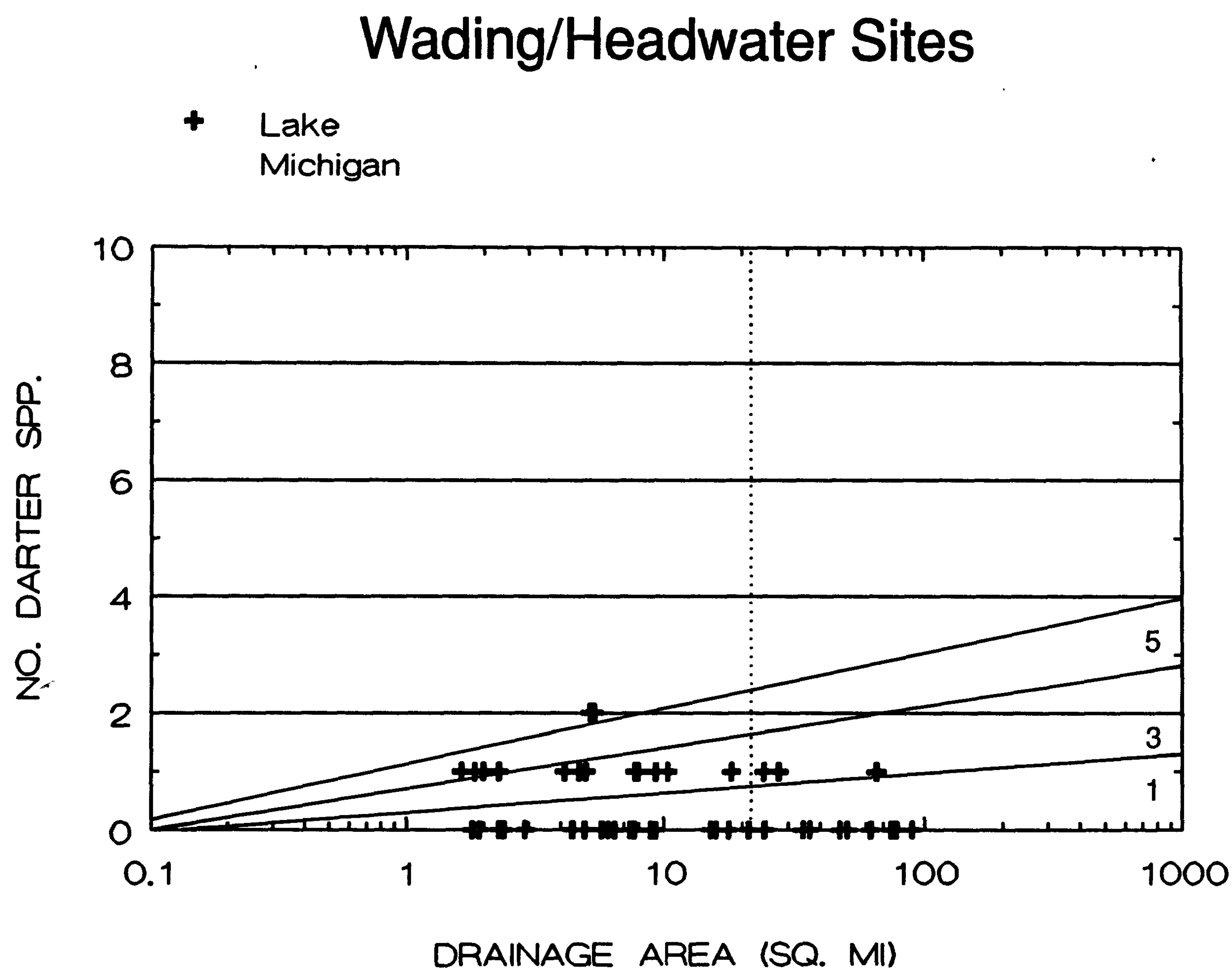

Fig. 11. Maximum species richness lines for determining trends in number of darter species with increasing drainage area for the Lake Michigan drainage.

Metric 3. Proportion of Headwater Species (Headwater Methods)
Number of Sunfish Species (Lake Michigan Headwater, Wading Methods)

Impetus

This metric follows Karr (1981) and Karr et al. (1986) by including the number of sunfish species (family Centrarchidae), and excluding the black basses (Micropterus spp). Unlike the Ohio metric, the redear sunfish Lepomis microlophus is included because it is native to Indiana. Hybrid sunfish are not included in this metric following Ohio EPA (1987).

This metric is an important measure of pool habitat quality. It includes all members of the sunfish genera Ambloplites (rock bass), Centrarchus (round sunfish), Lepomis (sunfish), and Pomoxis (crappies), as well as, the ecological equivalent Elassomatidae. Sunfish normally occupy slower moving water which may act as sinks for the accumulation of toxins and siltation. This metric measures degradation of rock substrates (i.e. gravel and boulder) and instream cover (Pflieger 1975; Trautman 1981), and the associated aquatic macroinvertebrate community which are an important food resource for sunfish (Forbes and Richardson 1920; Becker 1983). Sunfish are important components of the aquatic community since they are wide ranging, and distributed in most streams and rivers of Indiana. They are also very susceptible to electrofishing gear. Karr et al. (1986) found sunfish to occupy the intermediate to upper ends of sensitivity of the index of biotic integrity.

Headwater Sites

The amount of pool habitat is a limiting factor in many headwater streams which prohibits colonization by sunfish due to their deep-bodied shape. This metric is replaced with the proportion of headwater species at sites with drainage areas less than 20 square miles (OEPA 1987). Nine headwater species were defined by Ohio EPA (1987) and their presence indicates permanent habitat with low environmental stress (Table 9). The presence of headwater species does not show a trend with increased drainage area (Fig. 12). Due to the natural absence of most of the headwater taxa in the Lake Michigan drainage, the number of sunfish species metric was retained (Fig. 15) since a direct relationship was observed between number of species and increasing drainage area.

Wading Sites

The number of sunfish species is not affected by increasing drainage area using wading methods for any of the basins (Fig. 13, 14, 15).

Table 9. List of Indiana fish species considered to be headwater species for evaluating permanent habitat in headwater streams (Smith 1971).

Headwater Species

Common Name	Scientific Name
Least brook lamprey	*Lampetra aepyptera*
American brook lamprey	*Lampetra appendix*
Redside dace	*Clinostomus elongatus*
Blacknose dace	*Rhinichthys atratulus*
Southern redbelly dace	*Phoxinus erythrogaster*
Brook stickleback	*Culaea inconstans*
Fantail darter	*Etheostoma flabellare*
Mottled sculpin	*Cottus bairdi*
Banded sculpin	*Cottus carolinae*

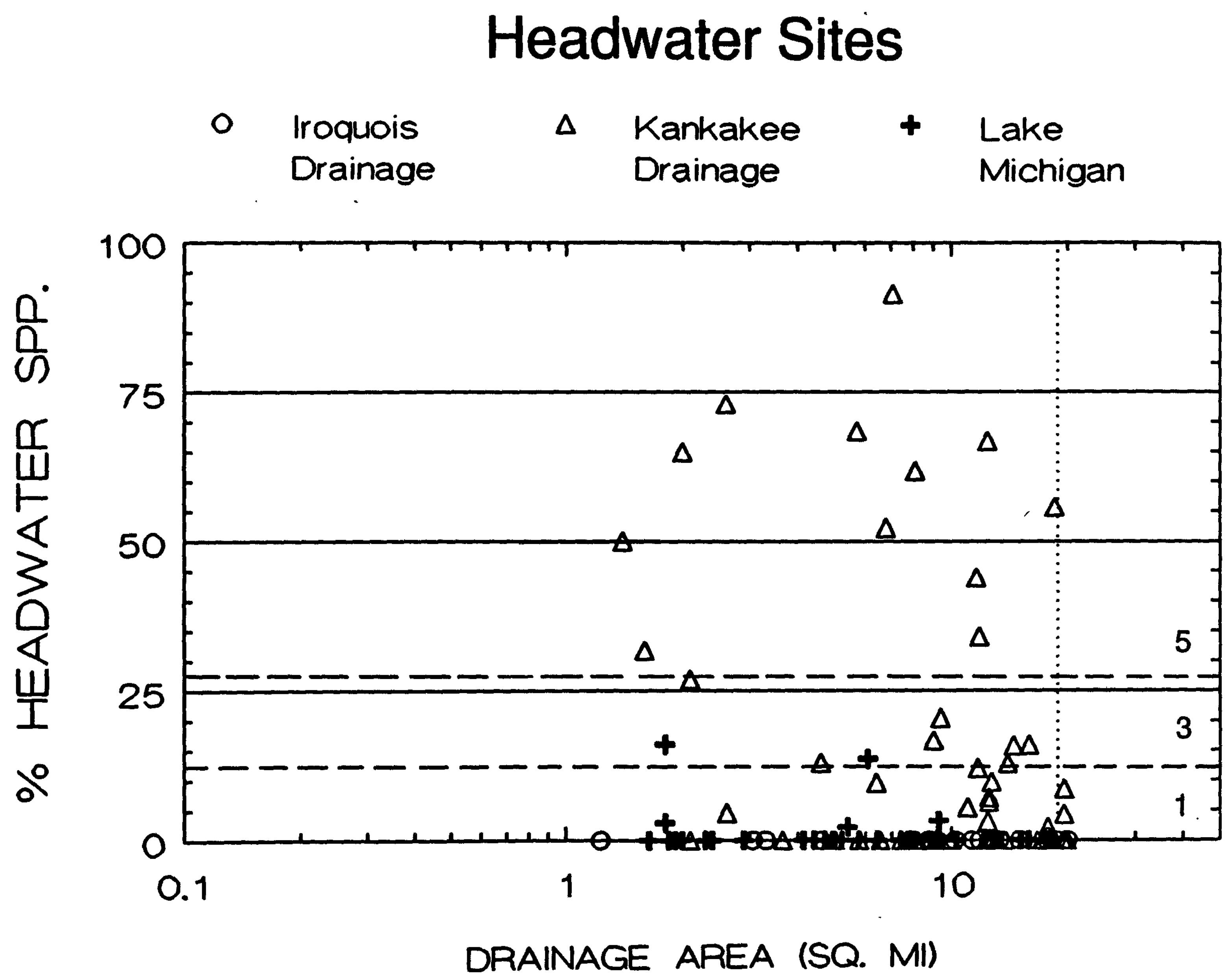

Fig. 12. Maximum species richness lines for determining trends in the proportion of headwater species with increasing drainage area for the Central Corn Belt Plain ecoregion.

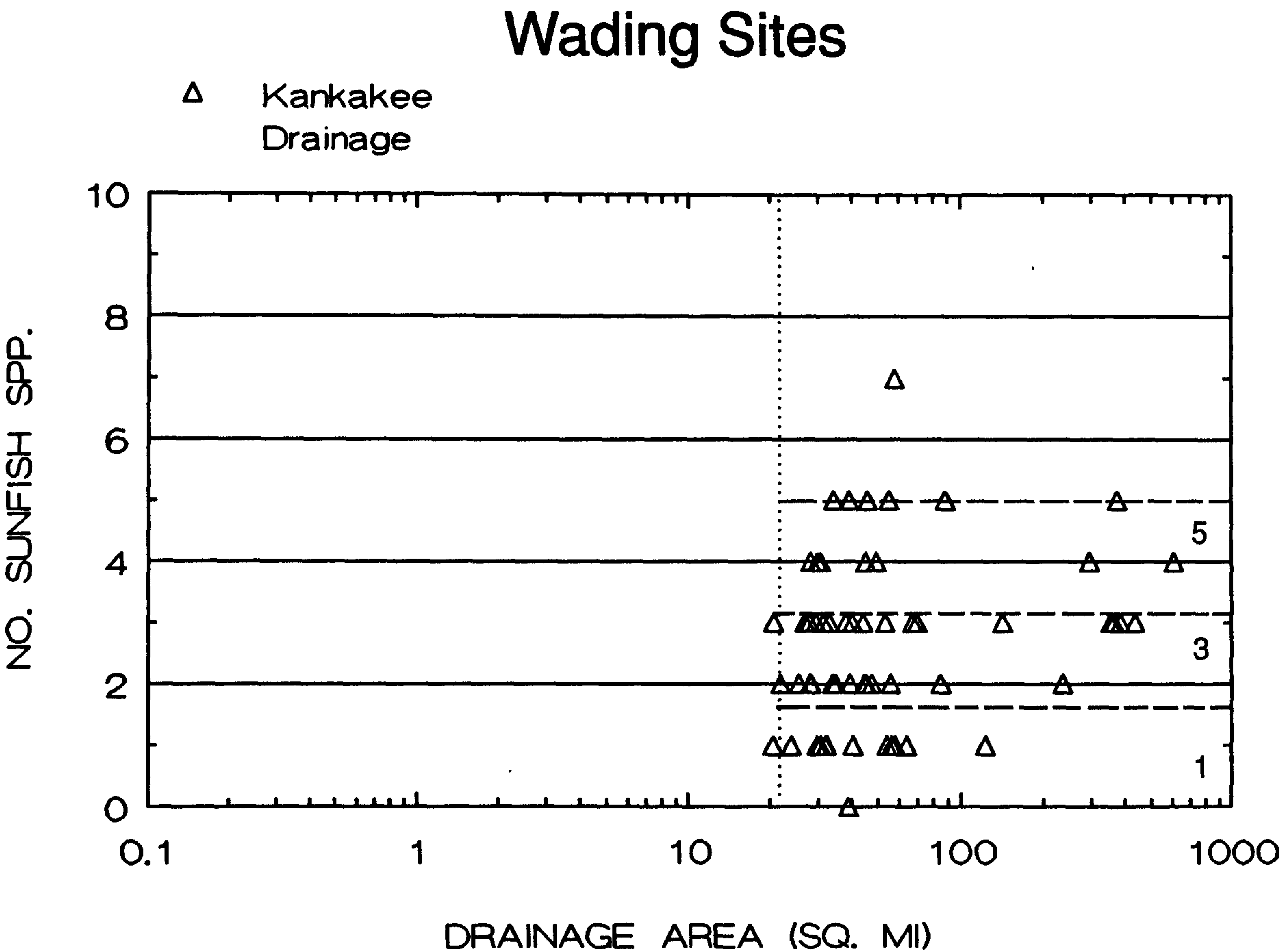

Fig. 13. Maximum species richness lines for determining trends in number of sunfish species with increasing drainage area for the Kankakee River drainage.

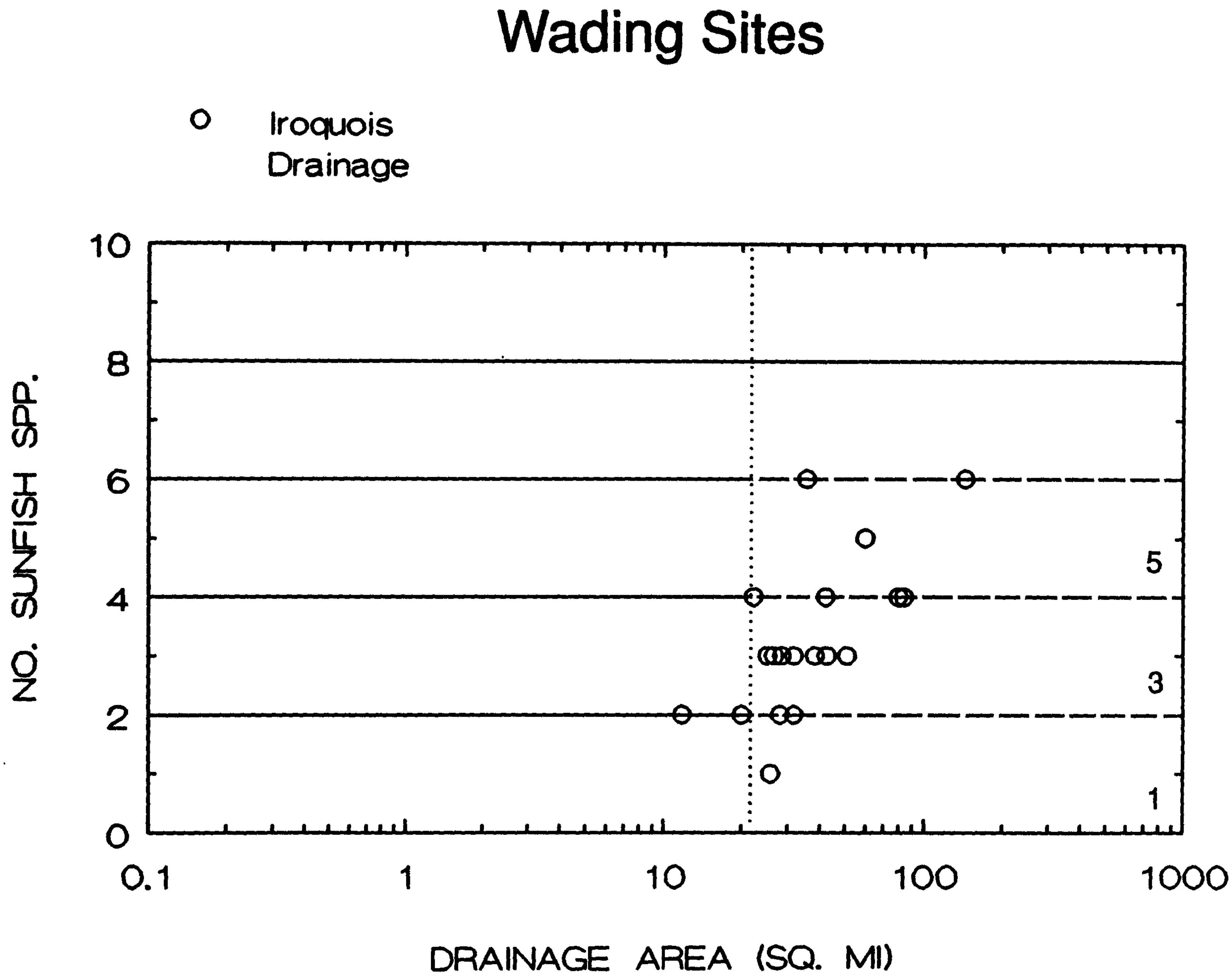

Fig. 14. Maximum species richness lines for determining trends in number of sunfish species with increasing drainage area for the Iroquois River drainage.

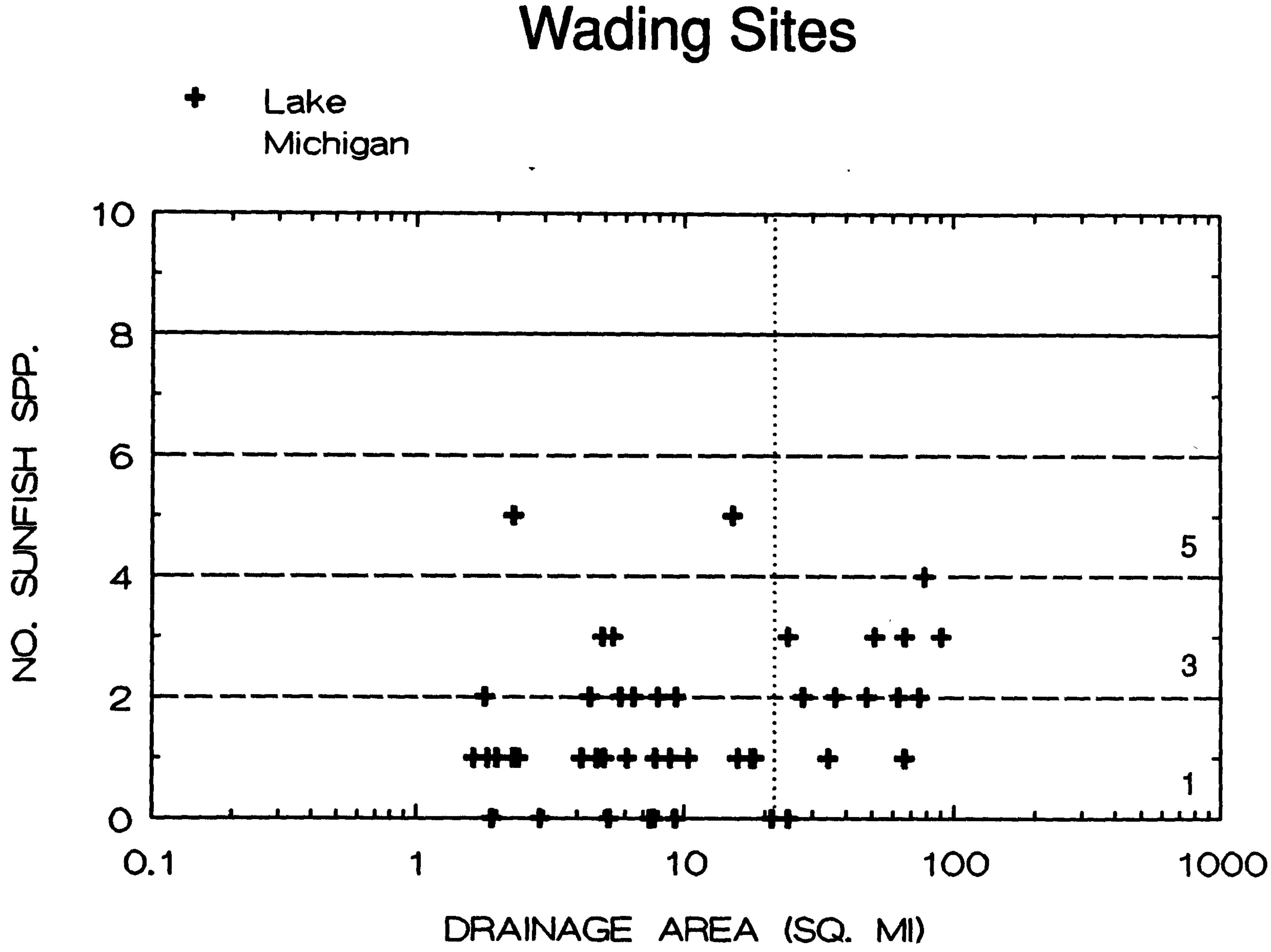

Fig. 15. Maximum species richness lines for determining trends in number of sunfish species with increasing drainage area for the Lake Michigan drainage.

Metric 4. Number of Minnow Species (Headwater, Lake Michigan Division Headwater Methods)
Number of Sucker Species (Wading Methods)
Number of Salmonid Species (East Branch Little Calumet River Division Headwater, Wading)

Impetus

The original Index of Biotic Integrity metrics included the number of sucker species (Karr 1981; Karr et al. 1986). Suckers represent a major component of the Indiana fish fauna since their total biomass usually ranks them among the highest contributors to the community. The general intolerance of most sucker species to habitat and water quality degradation (Phillips and Underhill 1971; Karr et al. 1986; Trautman 1981; Becker 1983) results in sensitivity at the higher end of environmental quality. Suckers due to their long life cycles (10-20 years) provides a long-term assessment of past environmental conditions. Of the nineteen species extant in Indiana, _Lagochila_ _lacera_ is considered extinct, seven species are widely distributed throughout the State (Table 10). Extant sucker genera include: _Cycleptus_, _Carpiodes_, _Catostomus_, _Erimyzon_, _Hypentilium_, _Ictiobus_, _Minytrema_, and _Moxostoma_.

Headwater Sites

The number of minnow species metric is substituted for the number of sucker species at headwater sites because of the expected low numbers of sucker species in small streams (OEPA 1987). The number of sucker species decreases rapidly with declining drainage area at sites with less than 20 square miles (Fig. 19). Examination of the Indiana data base suggested that the number of minnow species would serve as a suitable substitute. As many as ten different minnow species have been observed at locations with drainage areas under 5 square miles. The number of minnow species also correlates with increased environmental quality. Species including the hornyhead chub (_Nocomis biguttatus_), sand shiner (_Notropis_ _ludibundus_), and rosyface shiner (_Notropis rubellus_) are examples of minnow species which occur in high quality headwater streams. Species such as creek chub (_Semotilus_ _atromaculatus_), bluntnose minnow (_Pimephales_ _notatus_), and fathead minnow (_P._ _promelas_) are tolerant to both chemical degradation and stream desiccation. Environmental tolerance is represented at both ends of the continuum. A direct relationship exists between the number of minnow species and drainage area for Indiana basins (Fig. 16, 17, 18). Scoring is dependent on drainage area of the site. In Lake Michigan headwater tributaries the minnow metric is retained for the Lake Michigan Division (West Branch of the Little Calumet River and tributaries and Grand Calumet River). In the East Branch of the Little Calumet River Division the minnow metric is not used. Instead the number of salmonid species is substituted (see explanation below).

Table 10. Distributional characteristics of Indiana sucker species (family Catostomidae).

Species	Statewide	Small Streams	Large Rivers	Rare Taxa
Cycleptus elongatus			X	X
Carpiodes carpio			X	
C. cyprinus	X		X	
C. velifer	X		X	
Catostomus catostomus				X
C. commersoni	X	X	X	
Erimyzon oblongus		X		X
E. sucetta		X		
Hypentilium nigricans	X	X	X	
Ictiobus bubalus			X	
I. cyprinellus			X	
I. niger			X	
Lagochila lacera	EXTINCT			
Minytrema melanops	X		X	
Moxostoma anisurum	X		X	
M. carinatum			X	X
M. duquesnei	X		X	
M. erythrurum	X		X	
M. macrolepidotum	X		X	
M. valenciennesi			X	X

Wading Sites

A direct relationship exists between the number of sucker species and drainage area at wading sites. Scoring is thus dependent on the drainage area of the site and is accomplished using Fig. 19. No difference in expectations was observed for the Kankakee or Iroquois Rivers so the two basins were combined for this metric.

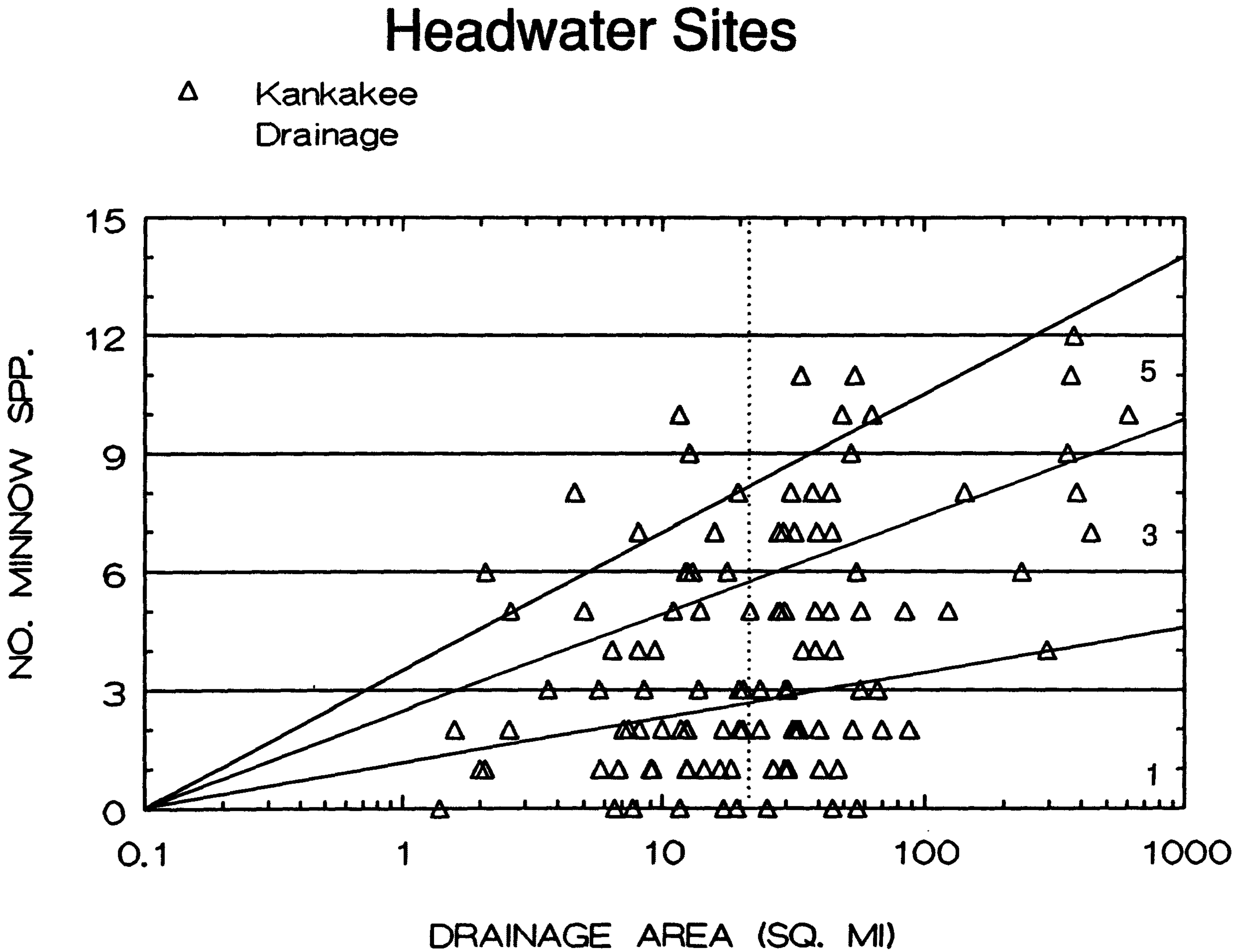

Fig. 16. Maximum species richness lines for determining trends in number of minnow species with increasing drainage area for the Kankakee River drainage.

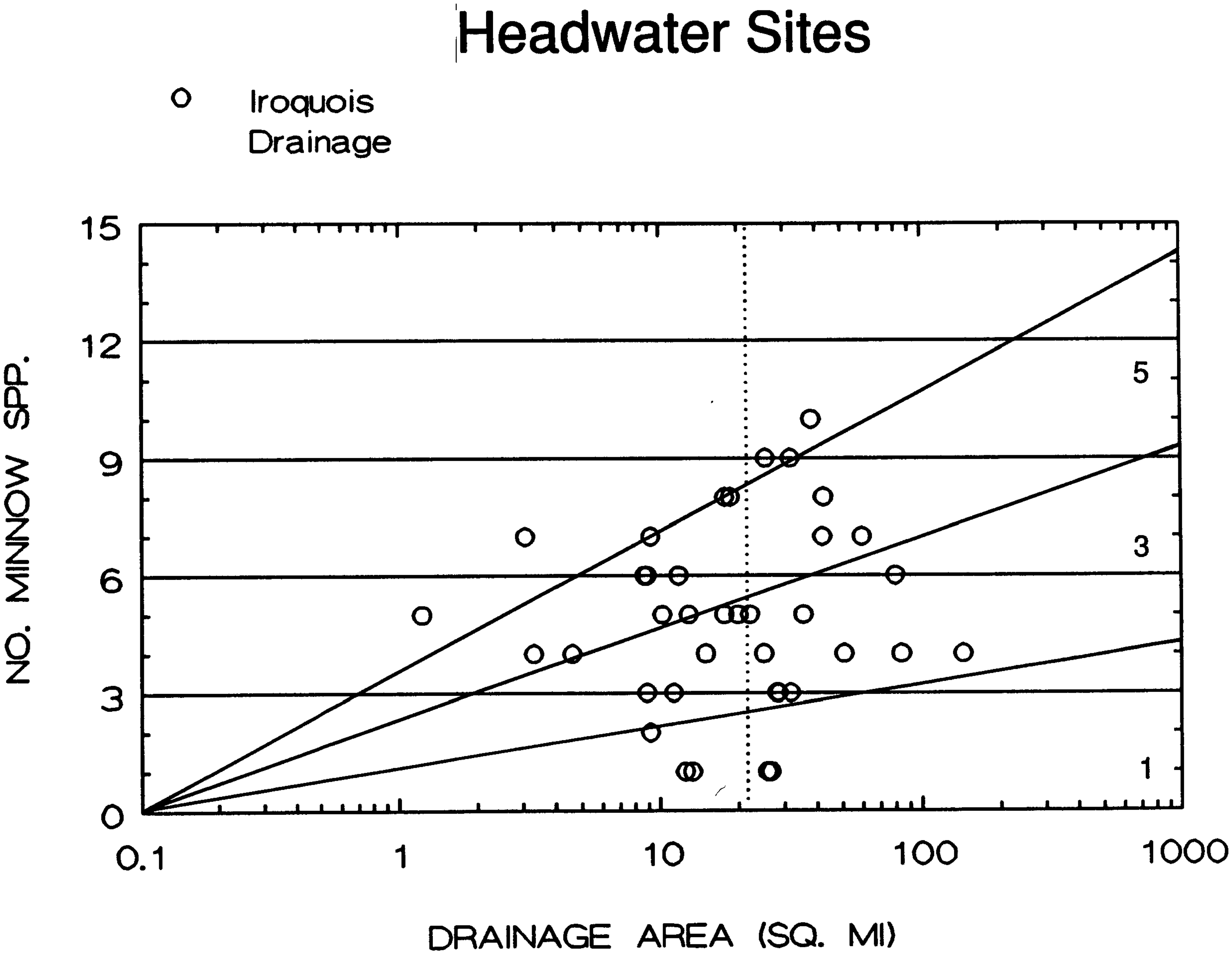

Fig. 17. Maximum species richness lines for determining trends in the number of minnow species with increasing drainage area for the Iroquois River.

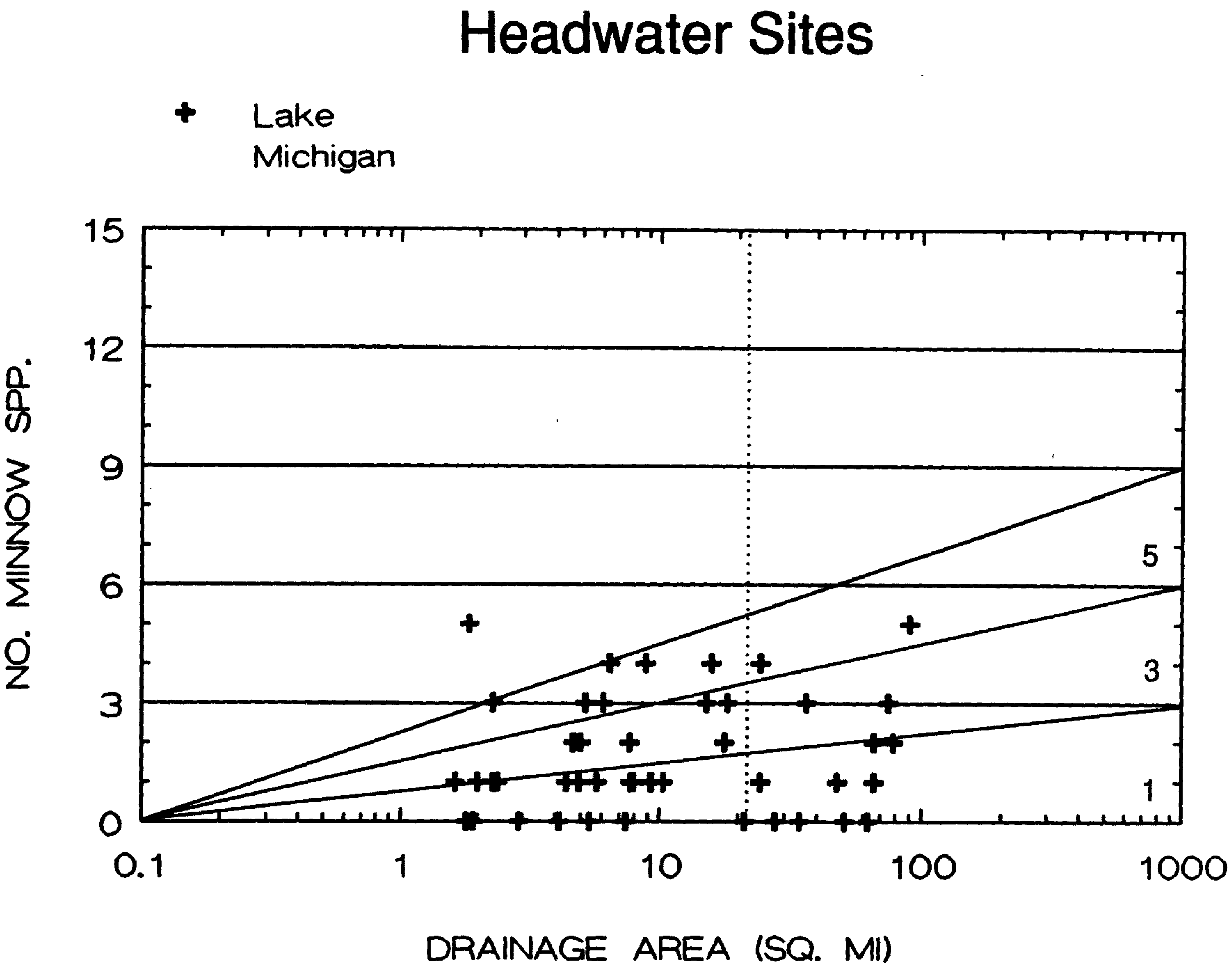

Fig. 18. Maximum species richness lines for determining trends in the number of minnow species with increasing drainage area for the Lake Michigan drainage.

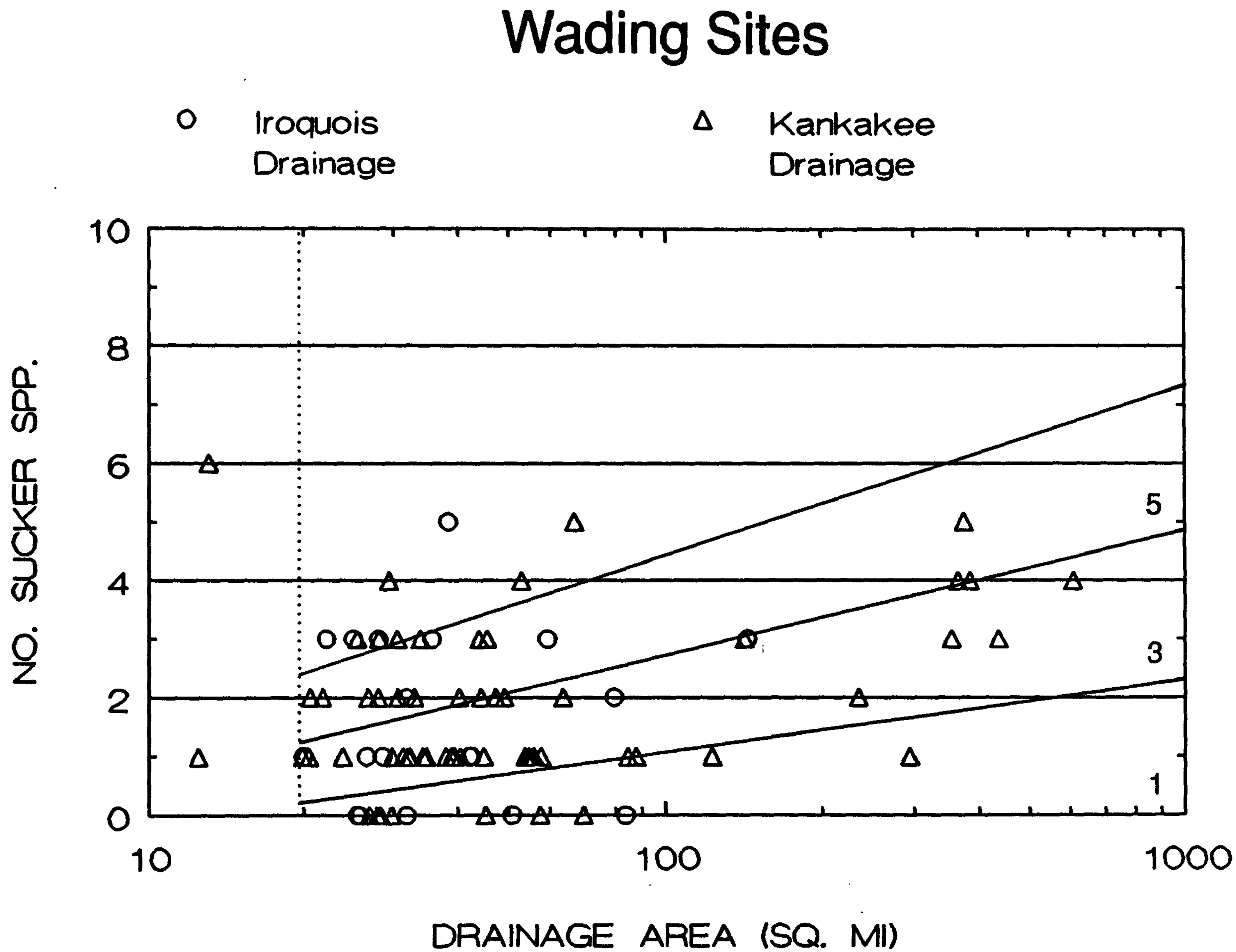

Fig. 19. Maximum species richness lines for determining trends in the number of sucker species with increasing drainage area for the Kankakee and Iroquois River drainages.

Lake Michigan Headwater and Wading Sites

Only a few species of sucker are expected, and usually only one (Catostomus commersoni) is ever common in most Lake Michigan tributaries. The presence of C. commersoni reduces the elucidation capacity of the index, since this species is considered tolerant, in evaluating water quality. Due to the low expected number of sucker species in the Lake Michigan drainage, this metric was replaced by the number of salmonid species. Salmonids are keystone species in Lake Michigan tributaries, their presence determines the remainder of the community's composition and its function. Salmonids are top-carnivores and because of the stocking of various strains in Indiana and adjacent States, they are present in Lake Michigan tributaries during all months of the year. Thermal avoidance is a particularly sensitive attribute salmonids exhibit. This makes them extremely important indicator organisms when evaluating the thermal barriers that industrial dischargers may establish between Lake Michigan and the tributaries. The presence of a number of salmonid species indicates good pool and quality habitat similar to the original intention of the sucker metric by Karr et al. (1986).

It was determined that an inverse relationship between number of salmonid species and drainage area was apparent, higher numbers exist in lower order streams of the East Branch of the Little Calumet Division (Fig. 20). A total of seven species occur in the drainage including the genera Oncorhynchus, Salvelinus, and Salmo. Stocking of these genera are common, however, possibly two of these species (Salvelinus fontinalis and S. namaycush) were native to the area. Caution must be exercised in determining whether species collected were newly stocked or residents. If only small specimens, all the same size, are collected in high numbers, these probably represent recently stocked individuals and should not be used in the biotic analysis. Likewise, collections should not be conducted during known peak spawning migrations since transient individuals are present in much greater abundance than usual. Indications of black or hooked mouths in males of several species are good indications that sampling was conducted at an inappropriate time.

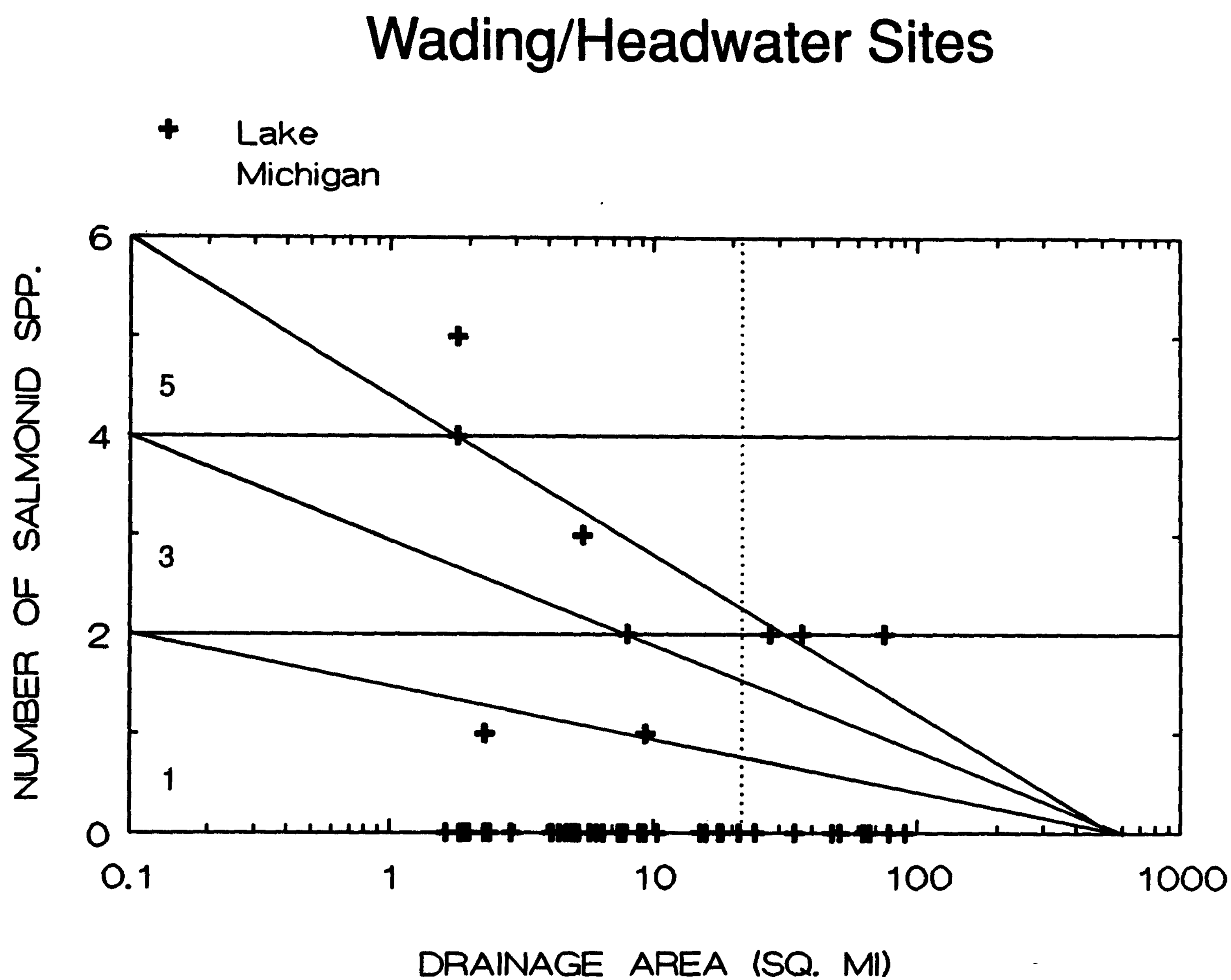

Fig. *20.* Maximum species richness lines for determining trends in number of salmonid species with increasing drainage area for Lake Michigan.

Metric 5. Number of Sensitive Species (All Methods)

Impetus

The number of sensitive species metric distinguishes between streams of highest quality. Designation of too many species as intolerant will prevent this metric from discriminating among the highest quality resources. Only species that are highly intolerant to a variety of disturbances were included in this metric so it will respond to diverse types of perturbations (Table 11; see Appendix A for species specific information).

The criteria for determining intolerance is based on the numerical and graphical analysis of Ohio's regional data base, Gerking's (1945) documentation of historical changes in the distribution of Indiana species, and supplemental information from regional ichthyofaunal texts (Pflieger 1975; Smith 1979; Trautman 1981; Becker 1983; Burr and Warren 1986). Intolerant taxa are those which decline with decreasing environmental quality and disappear, as viable populations, when the aquatic environment degrades to the "fair" category (Karr et al. 1986). The intolerant species list was divided into three categories, all are included in this metric for scoring:

1). common intolerant species (I): species which are intolerant, but are widely distributed in the best streams in Indiana;

2). uncommon or geographically restricted species (S): species that are infrequently captured or that have restricted ranges;

3). rare or possibly extirpated species (R): intolerant species that are rarely captured or which lack recent status data.

Commonly occurring intolerant species made up 5-10% of the common species in Indiana. This was a recommended guideline of Karr (1981) and Karr et al. (1986). Although the addition of species designated uncommon or rare sensitive species (categories 2 and 3), inflates the number of intolerant species above the 10% guideline, nowhere in the State do all of the species coexist at the same time. Indiana taxa within the Central Corn Belt Plain were below Ohio criteria for Intolerant taxa expectations. In order to evaluate streams in the Central Corn Belt Plain, only the sensitive species metric will be used until further resolution is possible with the addition of adjacent ecoregion sampling. Until more sampling is completed or improvements in water quality warrants it, the intolerant classification metric of Ohio will not be used. The sensitive metric that is used only in the headwater sites in Ohio (Ohio EPA 1987) will be included for all stream classifications in Indiana.

Headwater Sites

The number of intolerant taxa is a modification of the original index developed by Ohio EPA (1987). The metric includes moderately intolerant species when sampling at headwater sites. This combination is called sensitive species since few intolerant taxa are expected in headwater streams. The moderately intolerant species meet most of the established criteria of Ohio EPA (1987). Sensitive species require permanent pools so use of this metric will distinguish between streams with ephemeral characteristics. An absence of these species would indicate a severe anthropogenic stress or loss of habitat due to fluctuating water levels. This metric varies with basin specific drainage area and scoring is conducted using criteria in Fig. 21, 22, and 23.

Wading Sites

The expected number of intolerant species was anticipated to increase with drainage area among the wading sites, however, such a positive trend is not evident in Central Corn Belt Plain data. Intolerant taxa are scarce and may even decrease at larger wading sites. In order to provide meaningful stream reach comparisons in Indiana, the sensitive species metric is currently retained for wading sites until further evaluation can be completed.

Table 11. List of Indiana fish species considered to be sensitive to a wide variety of environmental disturbances including water quality and habitat degradation.

Sensitive Species

Common Name	Scientific Name
Ohio lamprey	Ichthyomyzon bdellium
Northern brk lamprey	I. fossor
Least brook lamprey	Lampetra aepyptera
American brk lamprey	L. appendix
Paddlefish	Polyodon spatula
Goldeye	Hiodon alosoides
Mooneye	H. tergisus
Redside dace	Clinostomus elongatus
Streamline chub	Erimystax dissimilis
Gravel chub	E. x-punctata
Speckled chub	Extrarius aestavalis
Bigeye chub	Hybopsis amblops
Pallid shiner	H. amnis
Rosefin shiner	Lythrurus ardens
Hornyhead chub	Nocomis biguttatus
River chub	N. micropogon
Pugnose shiner	Notropis anogenus
Popeye shiner	N. ariommus
Bigeye shiner	N. boops
Ironcolor shiner	N. chalybaeus
Blacknose shiner	N. heterodon
Blackchin shiner	N. heterolepis
Sand shiner	N. ludibundis
Silver shiner	N. photogenis
Rosyface shiner	N. rubellus
Weed shiner	N. texanus
Mimic shiner	N. volucellus
Pugnose minnow	Opsopoeodus emiliae
Longnose dace	Rhinichthys cataractae
Blue sucker	Cycleptus elongatus
Highfin carpsucker	Carpiodes velifer
Northern hogsucker	Hypentilium nigricans
Silver redhorse	Moxostoma anisurum
River redhorse	M. carinatum
Black redhorse	M. duquesnei
Golden redhorse	M. erythurum
Shorthead redhorse	M. macrolepidotum
Greater redhorse	M. valenciennesi
Mountain madtom	Noturus eleutherus
Slender madtom	N. exilis
Stonecat	N. flavus
Brindled madtom	N. miurus
Freckled madtom	N. nocturnus
Northern cavefish	Amblyopsis spelaea
Southern cavefish	T. subterraneus
Northern studfish	Fundulus catenatus
Starhead topminnow	F. dispar
Brook silverside	Labidesthes sicculus
Rock bass	Ambloplites rupestris
Longear sunfish	Lepomis megalotis
Smallmouth bass	Micropterus dolomieui
Western sand darter	Ammocrypta clara
Eastern sand darter	A. pellucida
Greenside darter	Etheostoma blennioides
Rainbow darter	E. caeruleum
Bluebreast darter	E. camurum
Harlequin darter	E. histrio
Spotted darter	E. squamiceps
Tippecanoe darter	E. tippecanoe
Variegate darter	E. variatum
Banded darter	E. zonale
Logperch	Percina caprodes
Channel darter	P. copelandi
Gilt darter	P. evides
Slenderhead darter	P. phoxocephala
Dusky darter	P. sciera

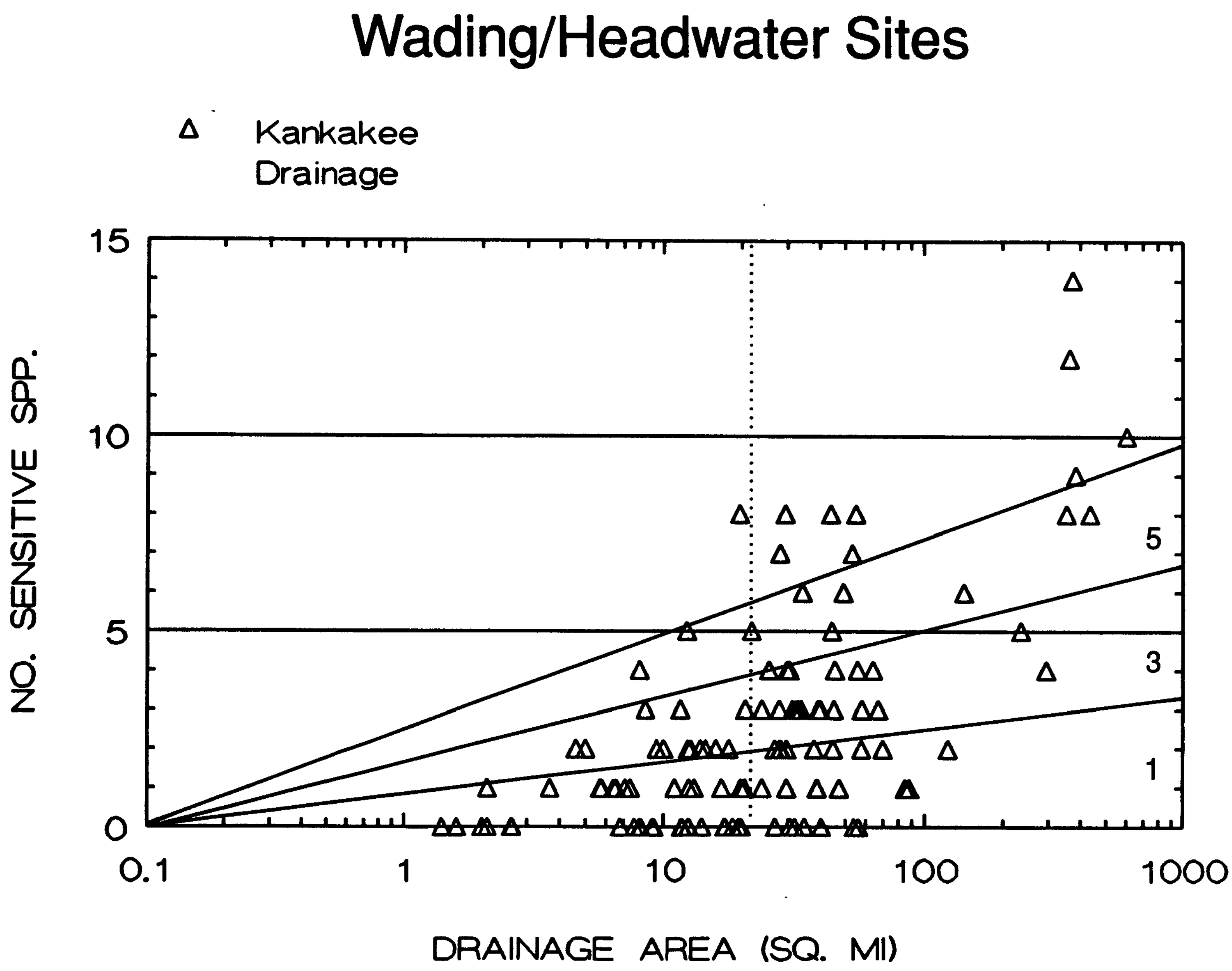

Fig. *21.* Maximum species richness lines for determining trends in number of sensitive species with increasing drainage area for the Kankakee River drainage.

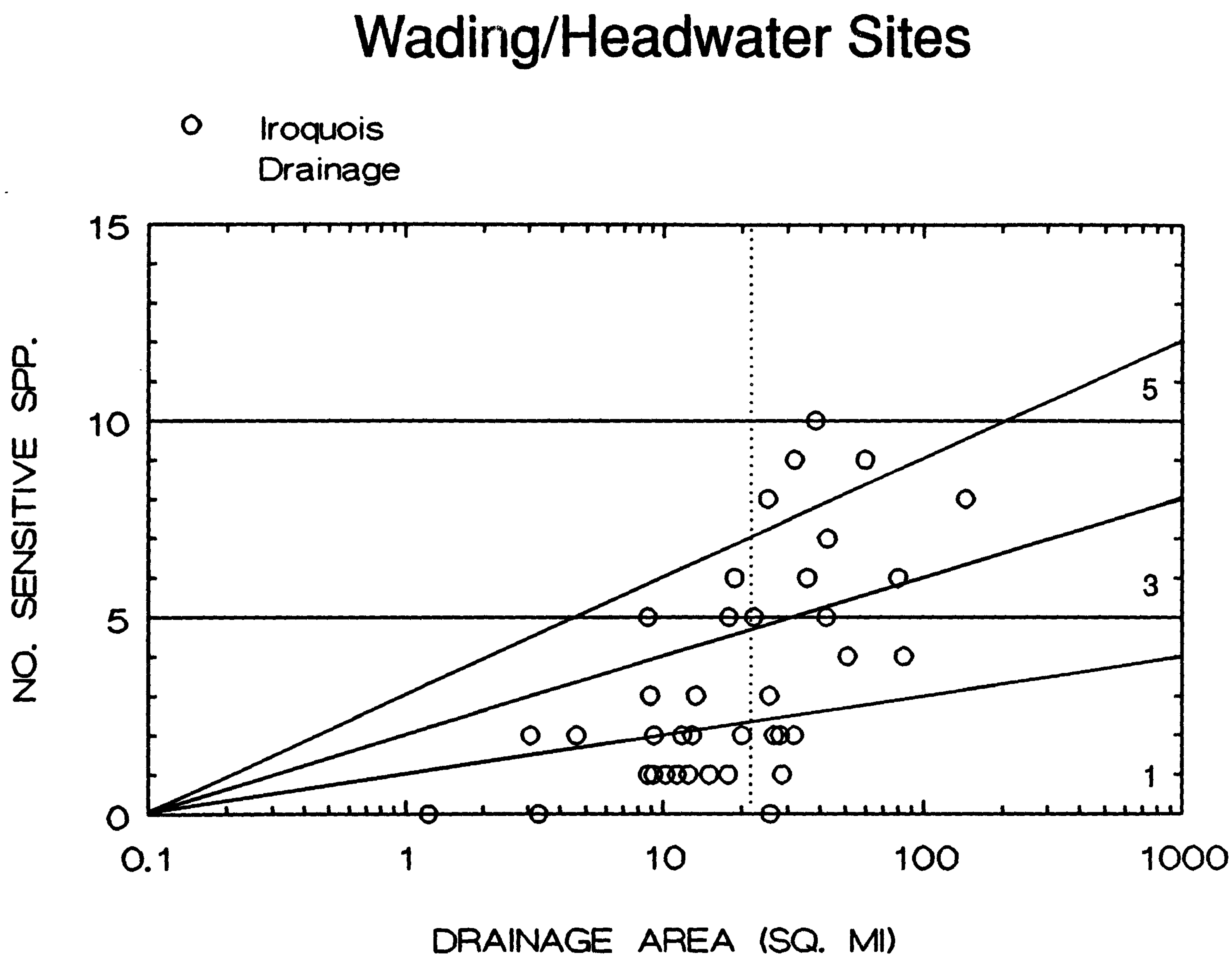

Fig. 22. Maximum species richness lines for determining trends in number of sensitive species with increasing drainage area for the Iroquois River drainage.

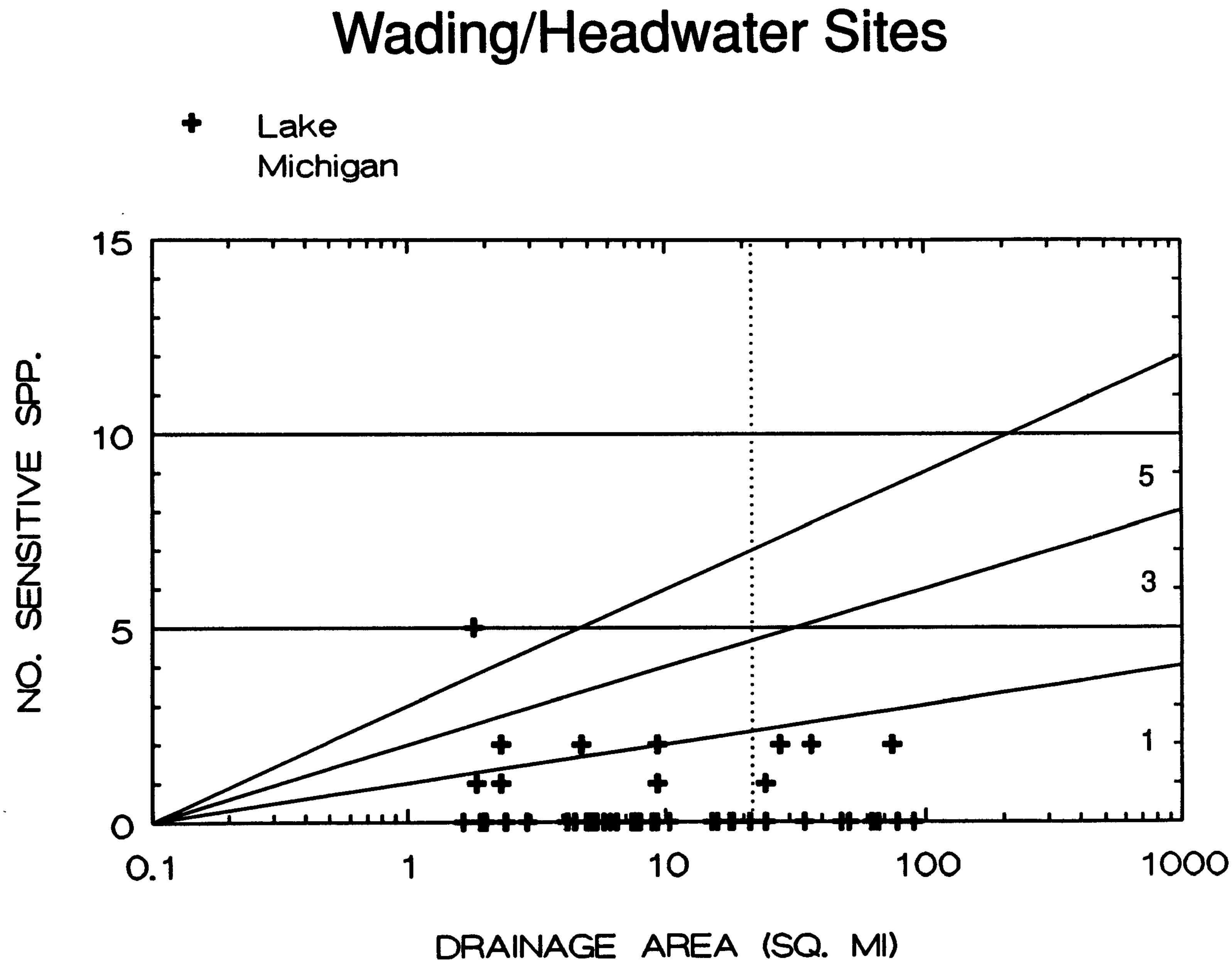

Fig. *23.* Maximum species richness lines for determining trends in number of sensitive species with increasing drainage area for the Lake Michigan drainage.

Metric 6. Percent Abundance of Tolerant Species (All Methods)

Impetus

This metric is a modification of the original index metric, the percentage of green sunfish (Karr et al. 1986), by Ohio EPA (1987). This metric detects a decline in stream quality from fair to poor categories. The green sunfish, Lepomis cyanellus, is a species that is often present in moderate numbers in many Midwest streams and can become a dominant member of the community in cases of degradation or poor water quality. A tolerance to disturbed environments enables the green sunfish to survive and reproduce even under perturbed conditions. Although the green sunfish is widely distributed in the Midwest, it is most commonly collected in low order streams. This introduces an inherent bias for moderate to large rivers. Karr et al. (1986) suggested additional species could be substituted for the green sunfish if they responded in a similar manner. Several species in Indiana meet this criteria of increasing in proportion with increasing degradation of stream. This increase in the number of tolerant species increases the sensitivity of this metric for various sized streams and rivers. Since different species have habitat requirements that are correlated with stream size, composition of the tolerant species metric does not change with drainage area.

Indiana's tolerant species are listed in Table 12. This list is based on a numerical and graphical analysis of Indiana catch data and historical changes in the distribution of fishes throughout Indiana (Gerking 1945). Tolerant species were selected based on the following criteria:

1). present at poor or fair sites: Based on our data base of Indiana collections these species are commonly collected at sites ranked either fair or poor.

2). historically increases in abundance: Based on historical collection information (Gerking 1945) these species increase in abundance and have not indicated any reduction in distribution.

3). increased tolerance to degraded conditions: these species increased in community dominance when environmental conditions shifted from good to fair or poor environmental quality.

Headwater and Wading Sites

Headwater and wading sites were scored together for this metric for the Kankakee and Iroquois drainages (Fig. 24). No relationship was evident for drainage areas greater than 100 square miles, but an inverse relationship became apparent for sites with drainage sizes less than 100 square miles. Lake Michigan sites were scored separately because of the higher proportion of tolerant taxa (Fig. 25).

Table 12. List of Indiana fish species considered to be highly tolerant to a wide variety of environmental disturbances including water quality and habitat degradation.

Tolerant Species

Common Name	Scientific Name
Central mudminnow	Umbra limi
White sucker	Catostomus commersoni
Goldfish	Carassius auratus
Redfin shiner	Cyprinella lutrensis
Carp	Cyprinus carpio
Golden shiner	Notemigonus crysoleucas
Bluntnose minnow	Pimephales notatus
Fathead minnow	Pimephales promelas
Blacknose dace	Rhinichthys atratulus
Creek chub	Semotilus atromaculatus
Yellow bullhead	Ameiurus natalis
Brown bullhead	Ameiurus nebulosus
Eastern Banded killifish	Fundulus diaphanus diaphanus
Green sunfish	Lepomis cyanellus

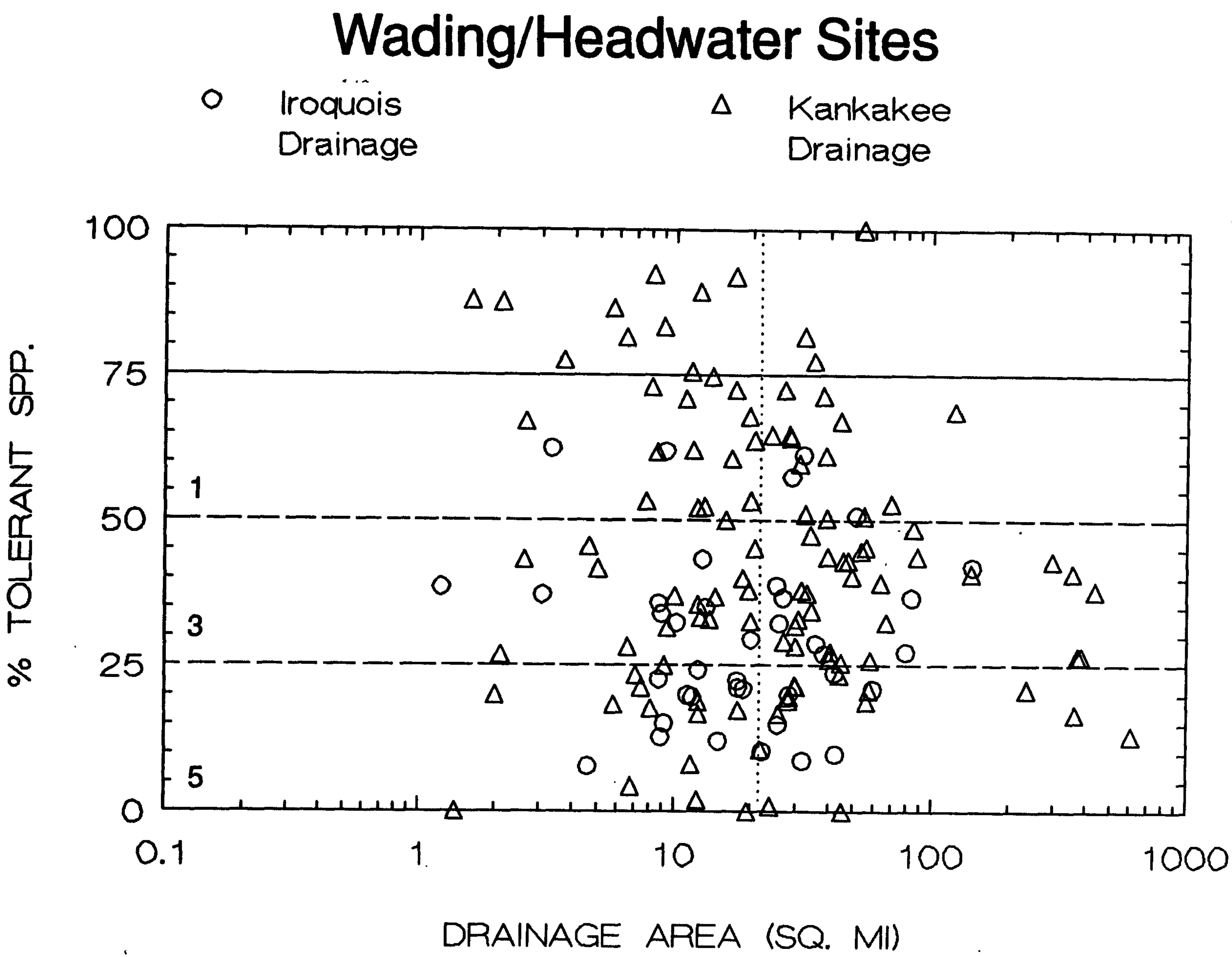

Fig. 24. Maximum species richness lines for determining trends in the proportion of tolerant species with increasing drainage area for the Kankakee and Iroquois River drainage.

Wading/Headwater Sites

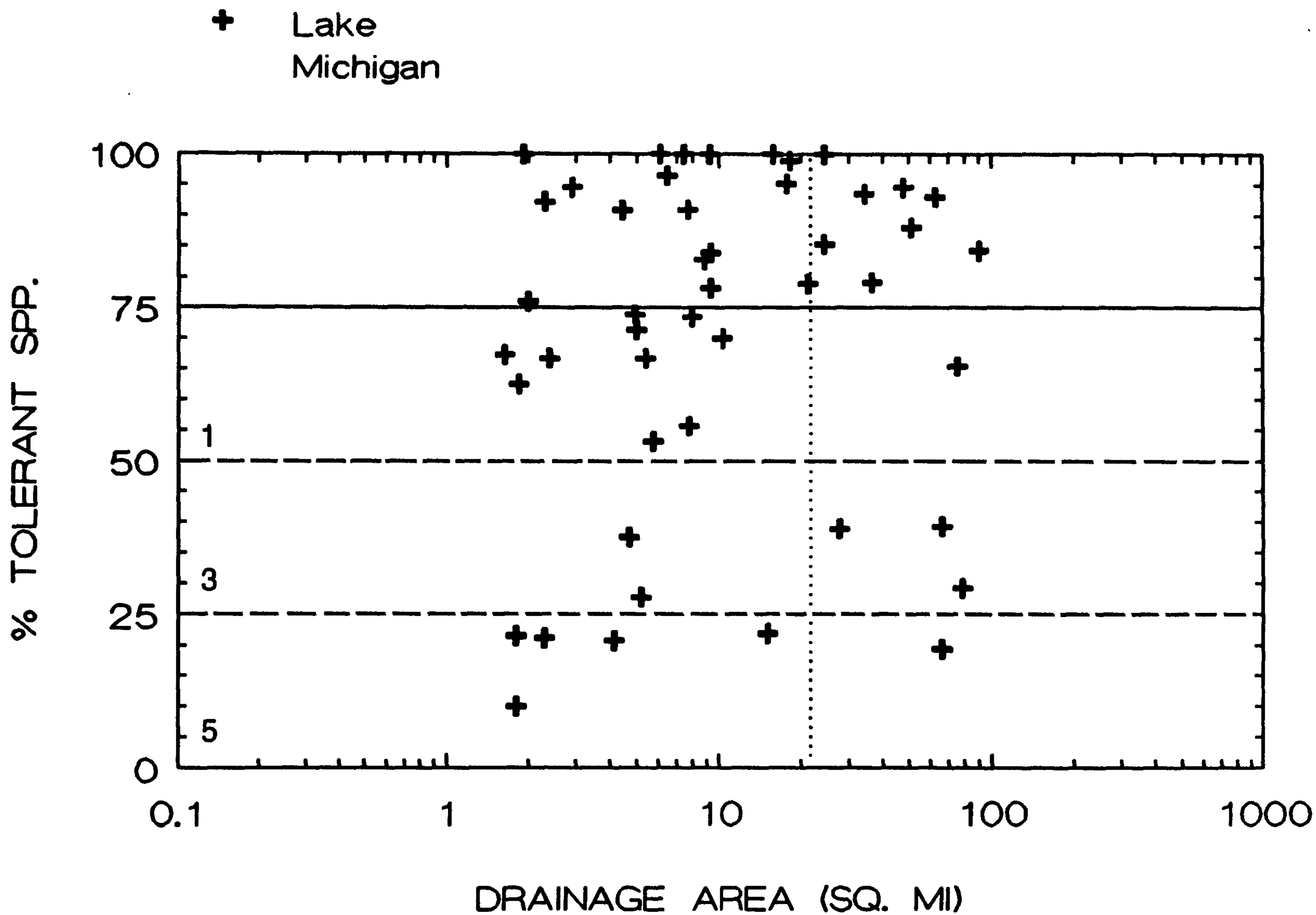

Fig. 25. Maximum species richness lines for determining trends in the proportion of tolerant species with increasing drainage area for Lake Michigan.

Metric 7. Proportion of Omnivores (All Methods)

Impetus

The definition of an omnivore follows that of Karr (1981) and Karr et al. (1986), which requires species to take significant quantities of both plant and animal materials (including detritus) and have the ability, usually indicated by the presence of a long gut and dark peritoneum, to utilize both. Omnivores are species whose diets include at least 25% plant and 25% animal foods. Fishes which do not feed on plants but on a variety of animal material are not considered omnivores. Dominance of omnivores suggests specific components of the food base are less reliable, increasing the success of more opportunistic species. Specialized filter-feeders are not included in this metric after Ohio EPA (1987) since these species are sensitive to environmental degradation, e.g. paddlefish, Polyodon spathula and lamprey ammocoetes, Lampetra and Ichthyomyzon. Species which tended to shift diet due to degraded environmental conditions were also not included as omnivores, e.g. Semotilus atromaculatus and Rhinichthys atratulus. This metric evaluates the intermediate to low categories of environmental quality (Table 13; see Appendix B for species specific feeding guild classification).

Headwater and Wading Sites

Due to minor changes in omnivore classification, only those species which consistently feed as omnivores were included in our analysis. These values differ from the omnivore percentages of Karr et al. (1986) but resemble Ohio EPA's (1987) classification. A relationship with drainage area was found for sites less than 20 square miles (Fig. 26), but reached an asymptote or slightly declined with increasing drainage areas.

Table 13. List of Indiana fish species considered to be omnivores.

Omnivores

Common Name	Scientific Name
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*D. petenense*
Central mudminnow	*Umbra limi*
Goldfish	*Carassius auratus*
Grass carp	*Ctenopharyngodon idella*
Carp	*Cyprinus carpio*
Cypress minnow	*Hybognathus hayi*
Central silvery minnow	*H. nuchalis*
Eastern silvery minnow	*H. regius*
Silver carp	*Hypopthalmichthys molitrix*
Bluntnose minnow	*Pimephales notatus*
Fathead minnow	*P. promelas*
Bullhead minnow	*P. vigilax*
River carpsucker	*Carpiodes carpio*
Quillback	*C. cyprinus*
Highfin carpsucker	*C. velifer*
White sucker	*Catostomus commersoni*

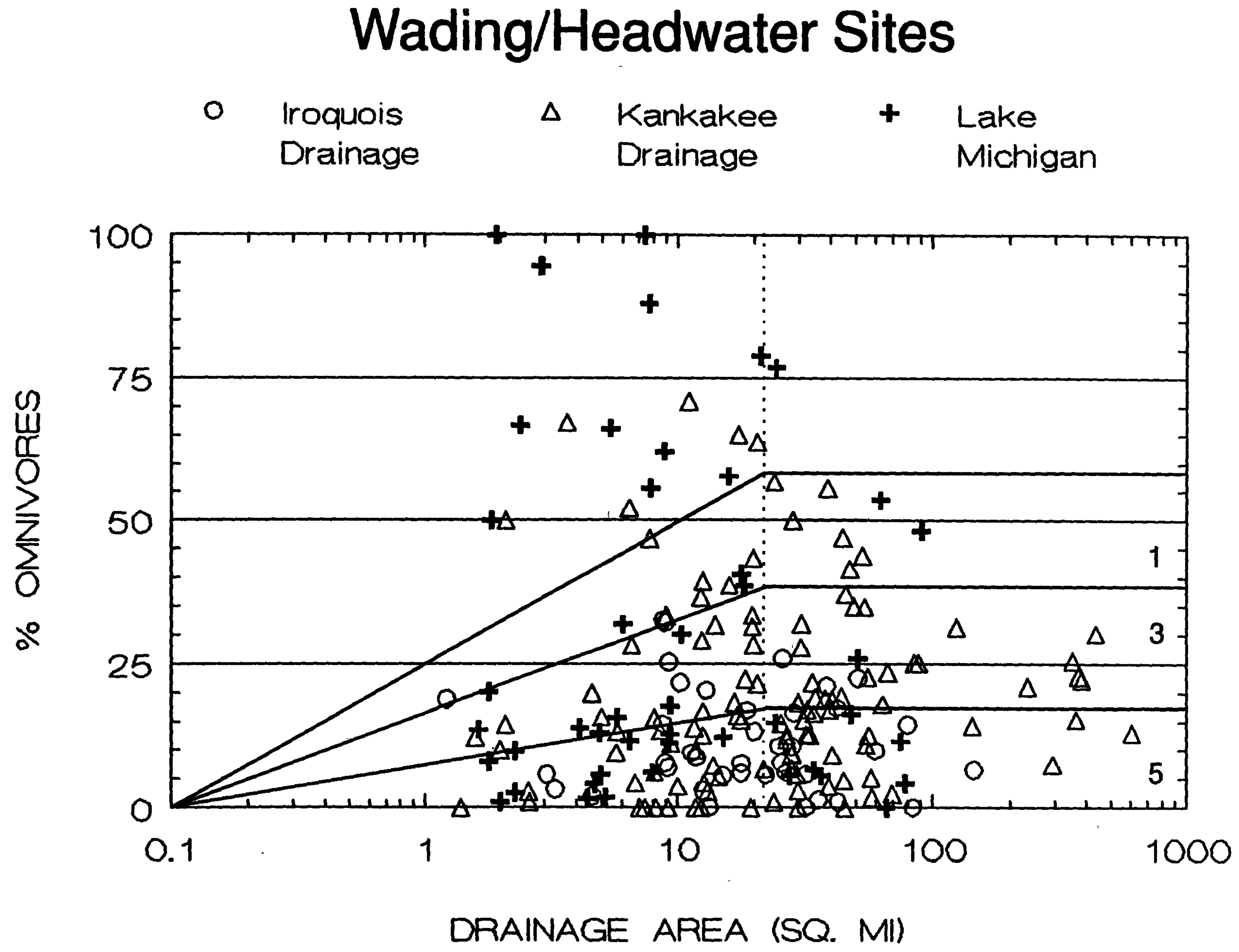

Fig. 26. Maximum species richness lines for determining trends in the proportion of omnivores with increasing drainage area for the Central Corn Belt Plain ecoregion.

Metric 8. Proportion of Insectivores (All Methods)

Impetus

The proportion of insectivores is a modification of Karr et al.'s (1986) original metric, proportion of insectivorous cyprinidae. This metric is intended to respond to a lowering of the benthic macroinvertebrate community which comprises the primary food base for most fishes. As disturbance increases, the diversity of insect larvae decreases, triggering an increase in the omnivorous trophic level. This metric thus varies inversely with metric 7 with increased environmental degradation. The inclusion of all insectivorous species was based on the observation that all regions of Indiana do not possess high proportions of insectivorous cyprinids in high quality streams. This metric was recalibrated following the recommendation of Karr et al. (1986; see Appendix B for species specific classification).

Headwater and Wading Sites

Insectivorous species designation generally conforms to that provided in Karr et al. (1986), however, I concur with Ohio EPA in the elimination of the opportunistic feeding creek chub, Semotilus atromaculatus, and blacknose dace, Rhinichthys atratulus, from the insectivore designation. Leonard and Orth (1986) felt that the current trophic definitions of Karr et al. (1986) were rather arbitrary since they observed a negative correlation between insectivores and biotic integrity in a West Virginia stream. Scoring criteria indicated no relationship existed between drainage area and proportion insectivorous fishes in headwater and wading sites (Fig. 27). However, due to the proportional scarcity of true insectivorous fishes in small headwater streams, the criteria was lowered in order to provide a greater emphasis on their presence.

Wading/Headwater Sites

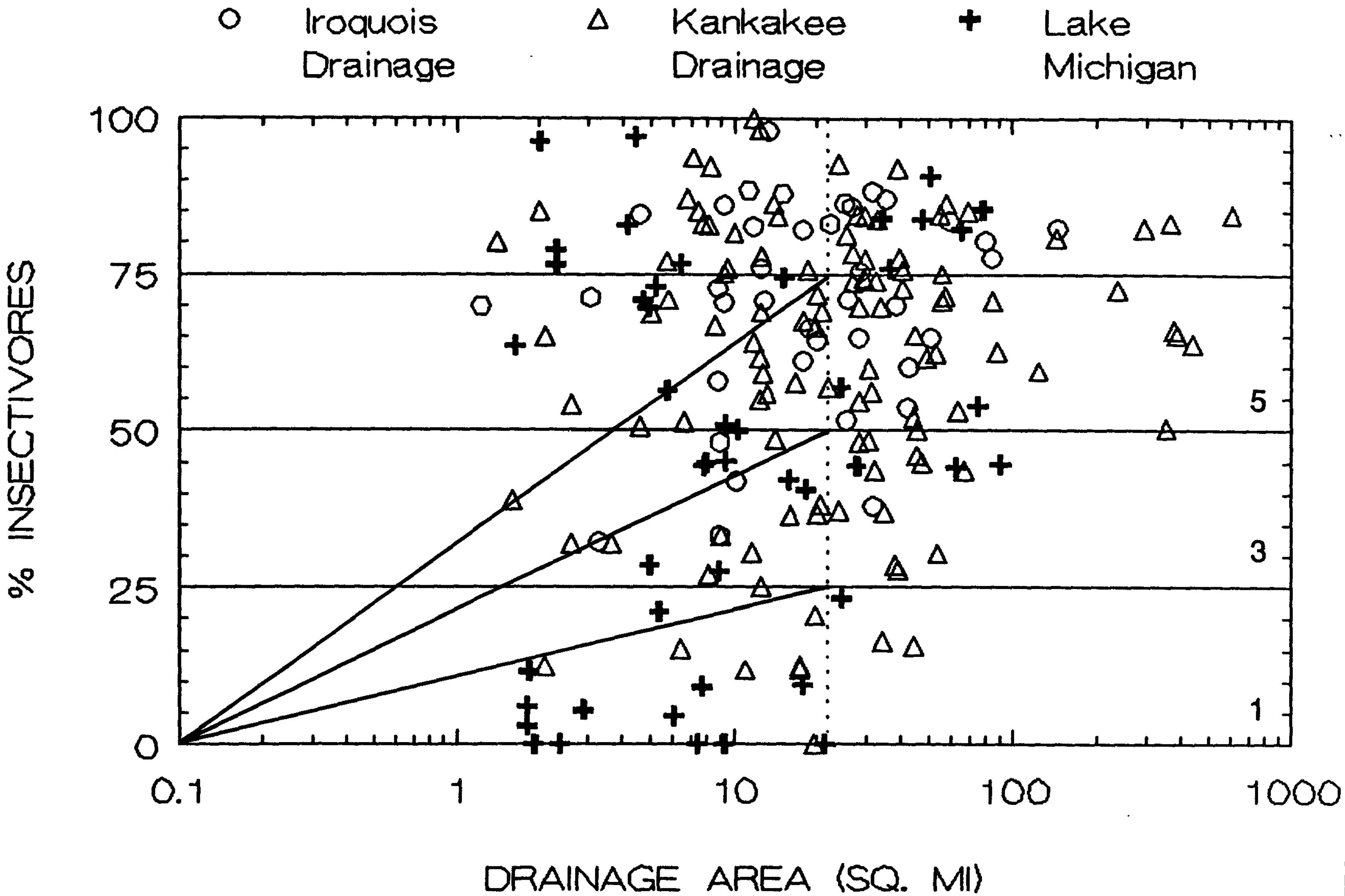

Fig. 27. **Maximum species richness lines for determining trends in the proportion of insectivores with increasing drainage area for the Central Corn Belt Plain ecoregion.**

Metric 9. Proportion of Pioneer Species (Headwater Methods, Lake Michigan Division)
Proportion of Carnivores (Wading Methods, East Branch Little Calumet River Division Headwaters)

Impetus

Karr (1981) developed the carnivore metric to measure community integrity in the upper trophic levels of the fish community. It is only in high quality environments that upper trophic levels are able to flourish. This metric includes individuals of species in which the adults are predominantly piscivores, although some may feed on invertebrates and fish as larvae or juveniles. Species which are opportunistic do not fit into this metric, e.g. creek chub or channel catfish, Ictalurus punctatus (Karr et al. 1986; Ohio EPA 1987). Karr et al. (1986) suggest that some members of this group may feed extensively on crayfish and other vertebrates, e.g. frogs.

Headwater Sites

Headwater systems generally do not have a high abundance of carnivores, and carnivores may not be able to persist there at all. The alternative metric developed by Ohio EPA (1987) indicates the permanence of the stream habitat. Smith (1971) identified a certain assemblage of small stream species which he termed "pioneer species" (Table 14). These are species which are the first to colonize sections of headwater streams after desiccation. These species also predominate in unstable environments affected by anthropogenic stresses and temporal desiccation. A high proportion of pioneer species indicates an environment temporally unavailable or stressed. The metric does not change with increases in drainage area (Fig. 28). In the East Branch of the Little Calumet River Division the entire fauna may be pioneer species yet contain high proportions of carnivores due to the presence of salmonid species. Within the Lake Michigan drainage, the carnivore metric was retained for headwater sites in the East Branch of the Little Calumet River Division (see explanation prior to metric sections), but the pioneer metric is applied to the Lake Michigan Division.

Wading Sites

Karr (1981) suggested that the proportion of carnivores should be a reflection of drainage area, however, neither Ohio EPA nor our study found such a correlation in streams greater than 20 square miles. The proportion of carnivores was visually determined from the current data base and approximated Karr et al.'s (1986) original numbers (Fig. 29). Separate criteria were established for the Lake Michigan tributary segments due to observed higher number of predator species (Fig. 30).

Table 14. List of Indiana fish species considered to be indicators of temporally unavailable or stressed habitats (Larimore and Smith 1963; Smith 1971).

Pioneer Species

Common Name	Scientific Name
Central stoneroller	*Campostoma anomalum*
Largescale stoneroller	*Campostoma oligolepis*
Silverjaw minnow	*Ericymba buccata*
Bluntnose minnow	*Pimephales notatus*
Fathead minnow	*Pimephales promelas*
Creek chub	*Semotilus atromaculatus*
Creek chubsucker	*Erimyzon oblongus*
Lake chubsucker	*Erimyzon sucetta*
Green sunfish	*Lepomis cyanellus*
Johnny darter	*Etheostoma nigrum*
Orangethroat darter	*Etheostoma spectabile*

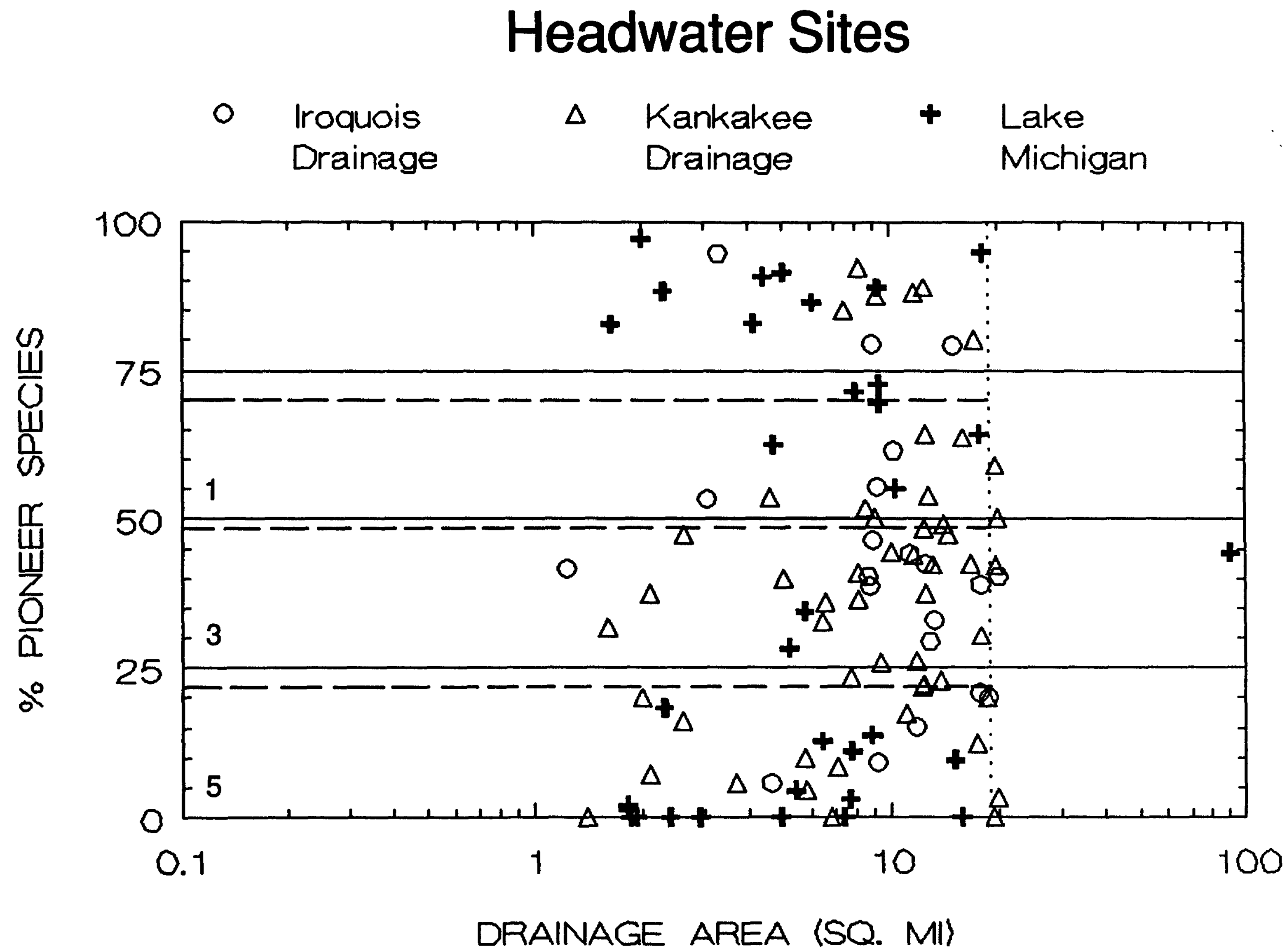

Fig. 28. Maximum species richness lines for determining trends in the proportion of pioneer species with increasing drainage area for the central Corn Belt Plain ecoregion.

Wading Sites

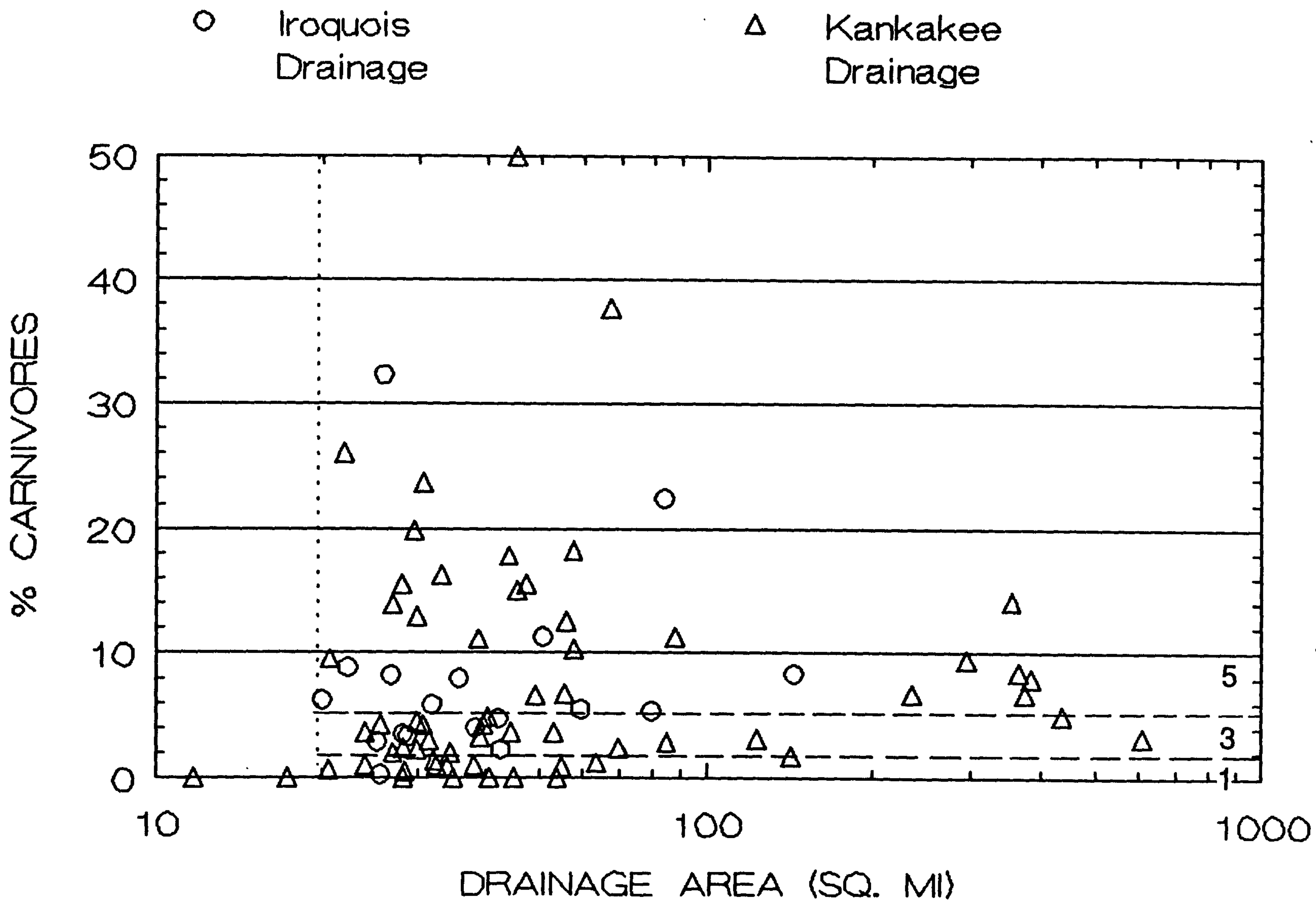

Fig.29. Maximum species richness lines for determining trends in the proportion of carnivores with increasing drainage area for the Kankakee and Iroquois drainage.

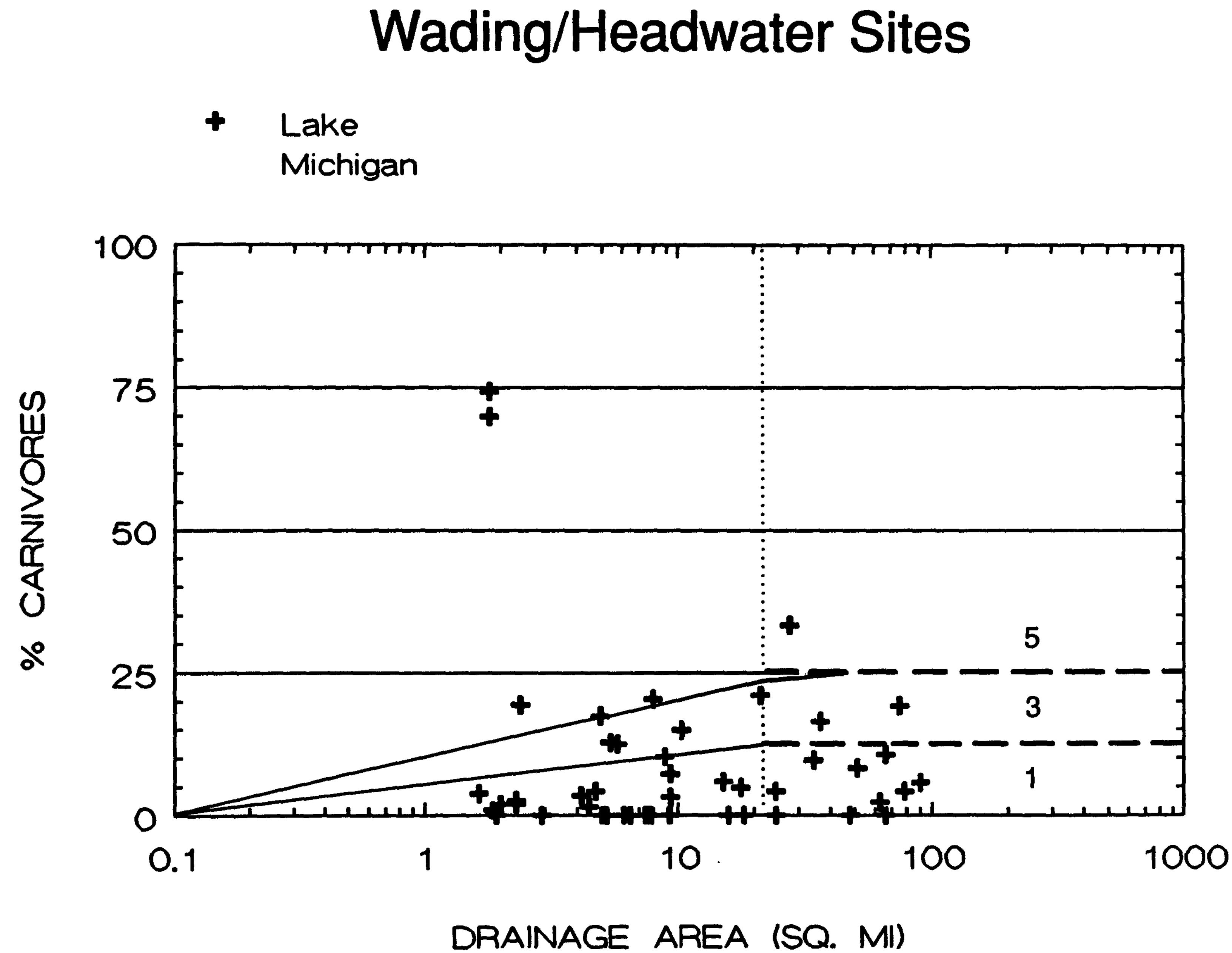

Fig. 30. Maximum species richness lines for determining trends in the proportion of carnivores with increasing drainage area for the Lake michigan drainage.

Metric 10. Number of Individuals in a Sample (All Methods)

Impetus

This metric evaluates populations and is expressed as catch per unit of effort. Effort is expressed by relative number of individuals per length of reach sampled, per unit of area sampled, or per unit time spent depending on the gear used. Karr et al. (1986) suggests that this metric is most sensitive at intermediate to low ends of the sensitivity continuum. When low numbers of individuals are observed the normal trophic relationships are generally disturbed enough to have severe effects on fish abundance. Because of this effect, scoring adjustments are encouraged for headwater streams in which less than 25 individuals are collected or 50 individuals in wadable streams (see next section for details). As integrity increases, total abundance increases and becomes more variable depending on the level of energy and other natural chemical factors limiting production. Under certain circumstances, e.g. channelization, increases in the abundance of tolerant fishes can be observed (Ohio EPA 1987). Lyons (personal communication) found that abundance, excluding tolerant species, was highest at fair quality sites and lower at excellent classified sites. Our catch per unit effort was determined based on the total number of individuals collected per 15 times the channel width without modification for tolerant taxa.

Headwater and Wading Sites

Drainage area proportionally affects the number of individuals caught at headwater and wading sites (Fig. 31). Since the relationship is not linear, a log-transformed analysis of the relative number of individuals was conducted. The expected numbers of individuals in "least impacted" stream levels off at 150 individuals. These "least impacted" sites were compared to a series of known impacted sites to derive the best and worst case situations. The number of individuals necessary to implement scoring adjustments was taken from Ohio EPA (1987). It is necessary to change most proportional metrics when fewer than 25 individuals are collected in headwater streams and 50 individuals in wading streams greater than 20 square miles drainage area (see scoring adjustments section for more information).

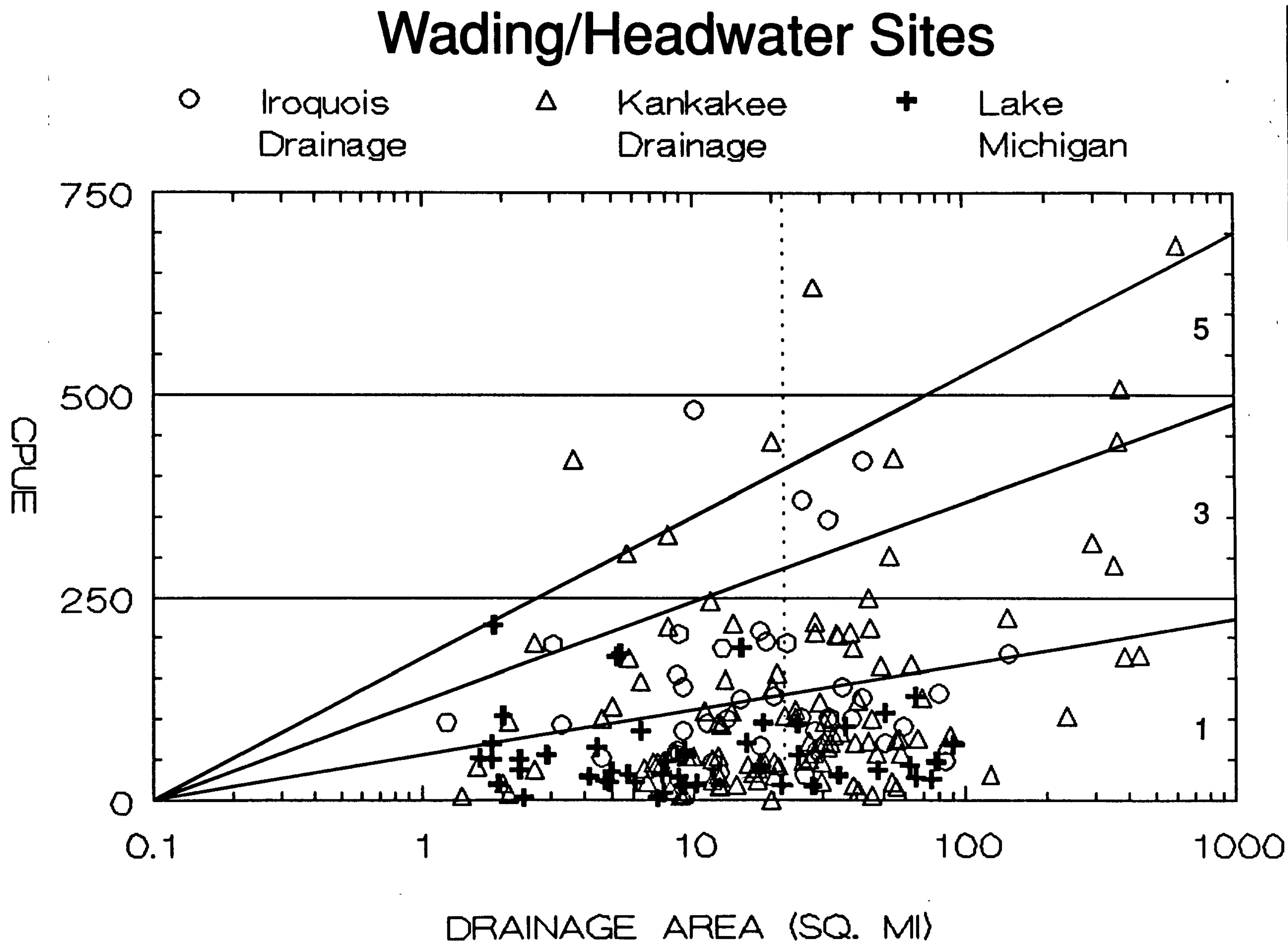

Fig. 31. Maximum species richness lines for determining trends in the catch per unit effort with increasing drainage area for the Central Corn Belt Plain ecoregion.

Metric 11. Proportion of Individuals as Simple Lithophilic Spawners (All Methods)

Impetus

This metric is a replacement for the original index metric, proportion of hybrids, by Ohio EPA (1987). The hybrid metric was abandoned since the original intent of the metric was to assess the extent to which degradation has altered reproductive isolation among species. Difficulties of identification, lack of occurrence often in headwater and impacted streams, and presence in high quality streams among certain taxa, e.g. cyprinids and centrarchids, caused a lack of sensitivity for the hybrid metric.

Spawning guilds have been shown to be affected by habitat quality (Balon 1975; Berkman and Rabeni 1987) and have been suggested as an alternative index metric (Angermeier and Karr 1986). Reproduction attributes of simple spawning behavior which requires clean gravel or cobble for success (i.e. lithophilous) are the most environmentally sensitive (Ohio EPA 1987). Simple lithophils broadcast eggs which then come into contact with the substrate. Eggs then develop in the interstitial spaces between sand, gravel, and cobble substrates without parental care. Berkman and Rabeni (1987) observed an inverted correlation between simple lithophil spawners and the proportion of silt in streams. Historically, some simple lithophil spawners have experienced significant range reductions due to increased silt loads in streams. Some simple lithophils do not require clean substrates for reproduction. Larvae of these species are buoyant, adhesive, or possess fast developing eggs with phototactic larvae which have minimal contact with the substrate (Balon 1975) and are not included in the above designation. Simple lithophils are sensitive to environmental disturbance, particularly siltation. Species specific designations are included in Table 15 (see Appendix C for species specific ratings).

Headwater and Wading Sites

No relationship with drainage area was observed at headwater or wading sites (Fig. 32). Scoring was completed using the alternate trisection method of Ohio EPA (1987). Simple lithophils are major components of the fish communities in these sized streams, indicating the importance of clean gravel and cobble substrates.

Table 15. List of Indiana species considered to be simple lithophilous spawners.

Simple Lithophils

Common Name	Scientific name
Paddlefish	Polyodon spatula
Lake sturgeon	Acipenser fulvescens
Shovelnose sturgeon	Scaphirhynchus platorynchus
Redside dace	Clinostomus elongatus
Lake chub	Couesius plumbeus
Streamline chub	Erimystax dissimilis
Gravel chub	E. x-punctata
Cent silvery minnow	Hybognathus hayi
Eastn silvery minnow	H. nuchalis
Bigeye chub	Hybopsis amblops
Pallid shiner	H. amnis
Striped shiner	Luxilus chrysocephalus
Rosefin shiner	Lythrurus ardens
Emerald shiner	Notropis atherinoides
Popeye shiner	N. ariommus
River shiner	N. blennius
Bigeye shiner	N. boops
Silver shiner	N. photogenis
Rosyface shiner	N. rubellus
Southn redbelly dace	Phoxinus erythrogaster
Blacknose dace	Rhinichthys atratulus
Longnose dace	R. cataractae
Blue sucker	Cycleptus elongatus
Longnose sucker	Catostomus catostomus
White sucker	C. commersoni
Northern hogsucker	Hypentilium nigricans
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	M. carinatum
Black redhorse	M. duquesnei
Golden redhorse	M. erythurum
Shorthead redhorse	M. macrolepidotum
Greater redhorse	M. valenciennesi
Burbot	Lota lota
Western sand darter	Ammocrypta clara
Eastern sand darter	A. pellucida
Rainbow darter	Etheostoma caeruleum
Bluebreast darter	E. camurum
Spotted darter	E. maculatum
Orangethroat darter	E. spectabile
Tippecanoe darter	E. tippecanoe
Variegate darter	E. variatum
Logperch	Percina caprodes
Channel darter	P. copelandi

Common Name	Scientific Name
Gilt darter	P. evides
Blackside darter	P. maculata
Slenderhead darter	P. phoxocephala
Dusky darter	P. sciera
River darter	P. shumardi
Sauger	Stizostedion canadense
Walleye	S. vitreum

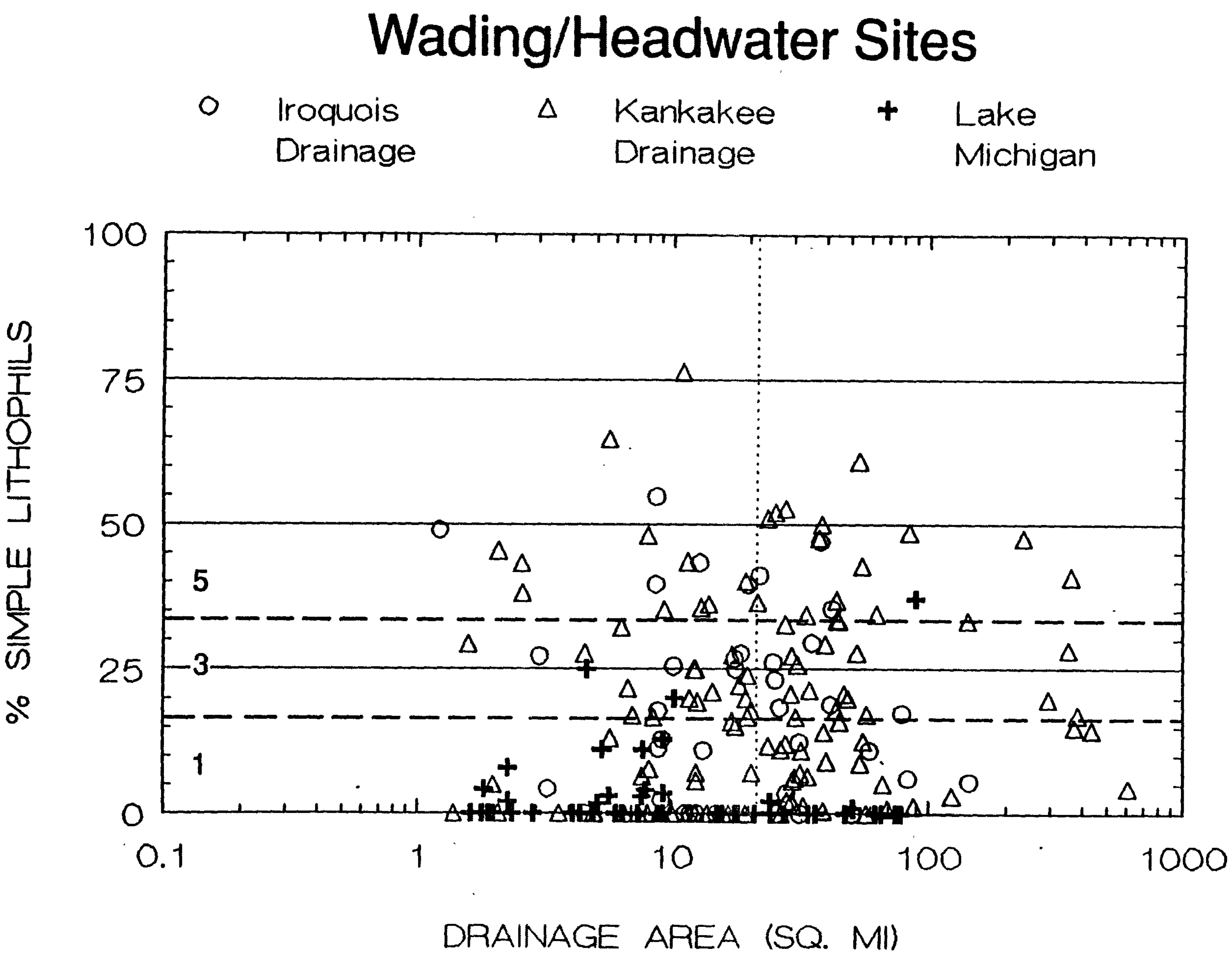

Fig. 32. Maximum species richness lines for determining trends in the proportion of simple lithophil species with increasing drainage area for the Central Corn Belt ecoregion.

Table 15. List of Indiana species considered to be simple lithophilous spawners.

Simple Lithophils

Common Name	Scientific name
Paddlefish	Polyodon spatula
Lake sturgeon	Acipenser fulvescens
Shovelnose sturgeon	Scaphirhynchus platorynchus
Redside dace	Clinostomus elongatus
Lake chub	Couesius plumbeus
Streamline chub	Erimystax dissimilis
Gravel chub	E. x-punctata
Cent silvery minnow	Hybognathus hayi
Eastn silvery minnow	H. nuchalis
Bigeye chub	Hybopsis amblops
Pallid shiner	H. amnis
Striped shiner	Luxilus chrysocephalus
Rosefin shiner	Lythrurus ardens
Emerald shiner	Notropis atherinoides
Popeye shiner	N. ariommus
River shiner	N. blennius
Bigeye shiner	N. boops
Silver shiner	N. photogenis
Rosyface shiner	N. rubellus
Southn redbelly dace	Phoxinus erythrogaster
Blacknose dace	Rhinichthys atratulus
Longnose dace	R. cataractae
Blue sucker	Cycleptus elongatus
Longnose sucker	Catostomus catostomus
White sucker	C. commersoni
Northern hogsucker	Hypentilium nigricans
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	M. carinatum
Black redhorse	M. duquesnei
Golden redhorse	M. erythurum
Shorthead redhorse	M. macrolepidotum
Greater redhorse	M. valenciennesi
Burbot	Lota lota
Western sand darter	Ammocrypta clara
Eastern sand darter	A. pellucida
Rainbow darter	Etheostoma caeruleum
Bluebreast darter	E. camurum
Spotted darter	E. maculatum
Orangethroat darter	E. spectabile
Tippecanoe darter	E. tippecanoe
Variegate darter	E. variatum
Logperch	Percina caprodes
Channel darter	P. copelandi

Common Name	Scientific Name
Gilt darter	P. evides
Blackside darter	P. maculata
Slenderhead darter	P. phoxocephala
Dusky darter	P. sciera
River darter	P. shumardi
Sauger	Stizostedion canadense
Walleye	S. vitreum

Indiana Ecoregions

Metric 12. Proportion of Individuals with Deformities, Eroded Fins, Lesions, and Tumors (All Methods)

Impetus

This metric evaluates the status of individual fish in the community using the percent occurrence of external anomalies and corresponds to the percent of diseased fish in Karr's (1981) original index. Studies of fish populations indicate that anomalies are either absent or occur at very low rates naturally, but reach higher percentages at impacted sites (Mills et al. 1966; Berra and Au 1981; Baumann et al. 1987). Common causes for deformities, eroded fins, lesions, and tumors are described by Allison et al. (1977), Post (1983) and Ohio EPA (1987). Primary causes result from bacterial, fungal, viral, and parasitic infections, neoplastic diseases, and chemicals. An increase in the frequency of occurrence of these anomalies is an indication of stress and environmental degradation caused by chemical pollutants, overcrowding, improper diet, excessive siltation, and other perturbations. The presence of black spot is not included in the above analyses since infestation varies in degree and may be a natural occurrence not related to environmental stress (Allison et al. 1977; Berra and Au 1981). Whittier et al. (1987) showed no relationship between Ohio stream quality and black spot. Other parasites are also excluded due to the lack of consistent relationship with environmental degradation.

In Ohio and in the current study, the highest incidence of deformities, eroded fins, lesions, and tumors occurred in fish communities downstream from dischargers of industrial and municipal wastewater, and areas subjected to the intermittent stresses from combined sewers and urban runoff. Leonard and Orth (1986) found this metric to correspond to increased degradation in streams in West Virginia. Karr et al. (1986) observed this metric to be most sensitive at the lowest extremes of the index of biotic integrity.

All Sites

The scoring criteria used for this metric follows Ohio EPA (1987) and was developed by analyzing wading data. For wading sites, the median score was rounded to the nearest 0.1% for the highest expected score and 90th percentile value. According to Ohio protocols, if a single fish in a sample of less than 200 fish was captured with anomalies this would have been enough to exceed the established criterion. Ohio EPA scoring modifications enable a single fish at a site to be present to score a "5" and two fish at a site to score a "3" when less than 200 individuals are collected.

Scoring Modifications

Samples with extremely low numbers in the catch can present a scoring problem in some of the proportional metrics unless adjustments are made to reduce the possibility of rewarding degraded sites. Aquatic habitats impacted by anthropomorphic disturbances may exhibit a disruption in the food base and comprise very few individuals. At such low population sizes the normal structure of the community is unpredictable (Ohio EPA 1987). Based on Ohio EPA experiences, the proportion of omnivores, insectivorous fishes, and percent individuals affected by anomalies do not always match expected trends. Although scores are expected to deviate strongly from those of high quality areas, this is not always observed. Rather, at times the opposite metric score is achieved due to low numbers of individuals or absence of certain taxa.

Scoring very degraded sites without modifying scoring criteria for the proportional metrics can overrate the total index score for these sites. Scoring modifications proposed by Ohio EPA (1987) were adopted for evaluating Indiana sites with low numbers of individuals.

Proportion of omnivores for wading sites is assigned a score of "1" if less than 50 total individuals are collected, likewise for headwater sites, if less than 25 individuals are collected. When 50 to 150 individuals are collected, but are dominated (> 50%) by such species are creek chub and blacknose dace a "1" can be assigned when dominated by generalist feeders. This is left up to the biologists best professional judgement when at the site.

Proportion of insectivores is scored a "1" when a high proportion of insectivores is observed when less than 50 individuals are collected. At sites with 50 to 150 individuals this metric can be scored "1" if this metric is dominated (> 50%) by either striped shiner, common shiner, or spotfin shiner, species that can act as omnivores under certain conditions (Angermeier 1985).

Proportion of top carnivores metric should be scored a "1" when dominated by high numbers (> 50%) of grass pickerel in impacted wading areas.

Proportion of simple lithophils always scores a "1" at sites with less than 50 total individuals. Based on Ohio EPA data (1987) this is rarely different from its score without the adjustment.

Proportion of individuals with deformities, erosion, lesions and tumor anomalies are scored a "1" when less than 50 individuals are collected. A high proportion of young fishes may also be sufficient reason to score a "1" since they will not have had sufficient time to develop anomalies from exposure to chemical contaminants.

Proportion of pioneering species is scored a "1" at headwater sites if less than 50 individuals are collected at drainage areas greater than 8 square miles, and 25 individuals at drainage areas less than 8 square miles.

No scoring adjustments are necessary for proportion of tolerant species.

RESULTS AND DISCUSSION

Kankakee River Basin

A total of 112 sites were sampled in the Kankakee River basin during Central Corn Belt Plain ecoregion sampling during 1990. A total of 82 species were collected (Table 16) and were numerically dominated by cyprinid species. The headwaters of the Kankakee River were depauperate of cyprinids, and instead were comprised of carnivores and benthic insectivores.

The overall water quality of the Kankakee River ranges between a low of very poor (score of 12; numerous sites) to excellent (score of 57; Yellow River) based on Index of Biotic Integrity scoring criteria developed during the current investigation (Fig. 33a). An increasing trend was evident in going from headwater to higher order tributaries in the overall water quality of the Kankakee basin. The number of sites approximated a normal curve based on water quality determination from index scores. The following was the percent occurrence of total Kankakee stations (112) within each index classification: excellent 1.78% (2 stations); good 16.07% (18 stations); fair 36.6% (41 stations); poor 28.57% (32 stations); very poor 16.07% (18 stations); no fish 0.89% (1 station). The sites which had low index values were primarily attributed to poor habitat and to a limited extent low dissolved oxygen levels. The Yellow River, a main tributary component of the upper Kankakee River, had very high index of biotic integrity scores for almost all sites sampled. This River deserves extra protection to ensure that the quality of the resource continues for future generations.

Two stream types appear to exist in the Kankakee basin, those which possess stream flow, few aquatic macrophytes, and stable riparian bank vegetation, and those which have little to no flow causing the accumulation of soft substrates, heavy aquatic macrophyte growth, and little canopy cover. These latter streams contain several species of concern; Notropis chalybaeus, N. texanus, N. heterolepis, and N. heterodon. High numbers of these intolerant taxa existed in these macrophyte chocked areas. The biological criteria developed during the current study recognizes the importance of these habitats for the maintenance of the species plus a number of other low-gradient taxa distributed in the Kankakee basin.

Due to possible improvement in water quality and habitat since Gerking's survey, two darters have been added to the Kankakee River drainage, while only a single darter species has been extirpated from the basin. Rainbow darter, Etheostoma caeruleum, previously occurred in the headwaters of the Kankakee, but not during the current investigation. An equally plausible explanation of the discovery of new species, is the better coverage of the area and the use of a more effective gear type. New additions to the fauna include the bluntnose darter, E. chlorosoma, and orangethroat darter, E. spectabile. A number of studies have correlated the presence of darter species with a

Table 16. Species list of taxa collected in the Kankakee, Iroquois, and Lake Michigan drainages, Indiana during ecoregion sampling 1990.

	Drainage		
	Kankakee	Iroquois	Lake Michigan
Petromyzontiformes-lampreys			
Petromyzontidae - lamprey			
Ichthyomyzon bdellium (Jordan), Ohio lamprey	X		
I. fossor Reighard and Cummins, northern brook lamprey	X		
Lampetra aepyptera (Abbott), least brook lamprey	X		X
L. appendix (DeKay), American brook lamprey	X		X
Lepisosteiformes - gars			
Lepisosteidae - gars			
L. osseus Linnaeus, longnose gar	X		
Amiiformes - bowfin			
Amiidae - bowfin			
Amia calva Linnaeus, bowfin	X		X
Clupeiformes - herring, shad			
Cluepidae - herring			
A. pseudoharengus (Wilson), alewife			X
Dorosoma cepedianum (Lesueur), gizzard shad	X	X	X
Salmoniformes - trout, salmon, whitefish			
Salmonidae - salmon and whitefish			
Oncorhynchus mykiss Walbaum, rainbow trout	X		X
O. kisutch (Walbaum), coho salmon			X
O. tshawytscha (Walbaum), chinook salmon			X
Salvelinus fontinalis (Mitchell), brook trout			X
Salmo salar (Walbaum), Atlantic salmon	X		X
S. trutta Linneaus, brown trout			X
Osmeridae - smelt			
Osmerus mordax (Mitchill), rainbow smelt			X
Umbridae - mudminnows			
Umbra limi (Kirtland), central mudminnow	X	X	X
Esocidae - pikes			
Esox americanus Gmelin, grass pickerel	X	X	X
E. lucius Linnaeus, northern pike	X	X	
Cypriniformes - carps and minnows			
Cyprinidae - carps and minnows			
Campostoma anomalum (Rafinesque), stoneroller			X
C. oligolepis Hubbs and Greene, largescale stoneroller	X	X	
Carassius auratus (Linneaus), goldfish			X
Cyprinella lutrensis (Baird and Girard), red shiner	X	X	
C. spiloptera Cope, spotfin shiner	X	X	X
C. whipplei (Girard), steelcolor shiner		X	
Cyprinus carpio Linneaus, carp	X	X	X
Ericymba buccata Cope, silverjaw minnow	X	X	
Luxilus chrysocephalus (Rafinesque), striped shiner	X	X	
L. cornutus (Mitchell), common shiner	X		X
Lythrurus umbratilis (Girard), redfin shiner	X	X	
Nocomis biguttatus (Kirtland), hornyhead chub	X	X	X
Notemigonus crysoleucus (Mitchell), golden shiner	X	X	X
Notropis atherinoides Rafinesque, emerald shiner			X
N. chalybaeus (Cope), ironcolor shiner	X		

	Drainage		
Cyprinidae (Continued)	Kankakee	Iroquois	Lake Michigan
N. dorsalis (Agassiz), bigmouth shiner	X		
N. heterodon (Cope), blacknose shiner	X		
N. heterolepis Eigenmann and Eigenmann, blackchin shiner	X		
N. hudsonius (Clinton), spottail shiner			X
N. ludibundus Cope, sand shiner	X	X	X
N. rubellus (Agassiz), rosyface shiner	X	X	
N. texanus (Girard), weed shiner	X		
N. volucellus (Cope), mimic shiner	X	X	
Phenacobius mirabilis (Girard), suckermouth minnow	X		
Phoxinus erythrogaster (Rafinesque), south redbelly dace	X		
Pimephales notatus (Rafinesque), bluntnose minnow	X	X	X
P. promelas Rafinesque, fathead minnow	X	X	X
P. vigilax (Baird and Girard), bullhead minnow	X	X	
Rhinichthys atratulus Agassiz, blacknose dace	X		X
R. cataractae (Valenciennes), longnose dace			X
Semotilus atromaculatus (Mitchill), creek chub	X	X	X
Catostomidae - suckers and buffalo			
Carpiodes carpio (Rafinesque), river carpsucker	X	X	
C. cyprinus (Lesueur), quillback	X	X	
Catostomus commersoni Lacepede, white sucker	X	X	X
E. sucetta (Lacepede), lake chubsucker	X	X	X
Hypentilium nigricans (Lesueur), northern hogsucker	X	X	
Ictiobus bubalus (Rafinesque), smallmouth buffalo	X	X	
I. cyprinellus (Valenciennes), bigmouth buffalo	X	X	
Minytrema melanops (Rafinesque), spotted sucker	X	X	
Moxostoma anisurum (Rafinesque), silver redhorse	X	X	
M. duquesnei (Lesueur), black redhorse	X		
M. erythurum (Rafinesque), golden redhorse	X	X	
M. macrolepidotum (Lesueur), shorthead redhorse	X	X	
M. valenciennesi Jordan, greater redhorse	X		
Siluriformes - bullhead and catfish			
Ictaluridae - bullhead and catfish			
Ameiurus melas (Rafinesque), black bullhead	X	X	X
A. natalis (Lesueur), yellow bullhead	X	X	X
A. nebulosus (Lesueur), brown bullhead	X	X	
Ictalurus punctatus (Rafinesque), channel catfish	X	X	X
Noturus flavus Rafinesque, stonecat	X		
N. gyrinus (Mitchill), tadpole madtom	X	X	X
Percopsiformes - cavefish, pirate perch, trout-perch			
Apherododeridae - pirate perch			
Aphredoderus sayanus (Gilliams), pirate perch	X	X	X
Atheriniformes - topminnows, silversides			
Fundulidae - topminnows			
Fundulus dispar (Agassiz), northern starhead topminnow	X		X
F. notatus (Rafinesque), blackstripe topminnow	X	X	X
F. olivaceus (Storer), blackspotted topminnow	X		
Atherinidae - silversides			
Labidesthes sicculus (Cope), brook silverside	X	X	X
Gasterosteiformes - sticklebacks			
Gasterosteidae - sticklebacks			
Culaea inconstans (Kirtland), brook stickleback			X

Central Corn Belt Plain Ecoregion

	Drainage		
	Kankakee	Iroquois	Lake Michigan
Perciformes - basses, sunfish, perch, darters			
Centrarchidae - black bass and sunfish			
Ambloplites rupestris (Rafinesque), rock bass	X	X	X
Lepomis cyanellus Rafinesque, green sunfish	X	X	X
L. gibbosus (Linnaeus), pumpkinseed	X	X	X
L. gulosus (Cuvier), warmouth	X		X
L. humilis (Girard), orangespotted sunfish	X	X	X
L. macrochirus Rafinesque, bluegill	X	X	X
L. megalotis (Rafinesque), longear sunfish	X	X	
Micropterus dolomieui Lacepede, smallmouth bass	X	X	
M. salmoides (Lacepede), largemouth bass	X	X	X
Pomoxis annularis Rafinesque, white crappie	X	X	X
P. nigromaculatus (Lesueur), black crappie	X	X	X
Percidae - perch and darters			
Etheostoma chlorosoma (Hay), bluntnose darter	X		X
E. flabellare Rafinesque, fantail darter	X		
E. microperca Jordan and Gilbert, least darter	X		X
E. nigrum Rafinesque, johnny darter	X	X	X
E. spectabile (Agassiz), orangethroat darter	X	X	
E. zonale (Cope), banded darter	X	X	
Perca flavescens (Mitchill), yellow perch			X
Percina caprodes (Rafinesque), logperch	X		
P. maculata (Girard), blackside darter	X	X	X
P. phoxocephala (Nelson), slenderhead darter	X	X	
Cottidae - sculpins			
Cottus bairdi Girard, mottled sculpin	X	X	X
Total Number of Species	82	56	55

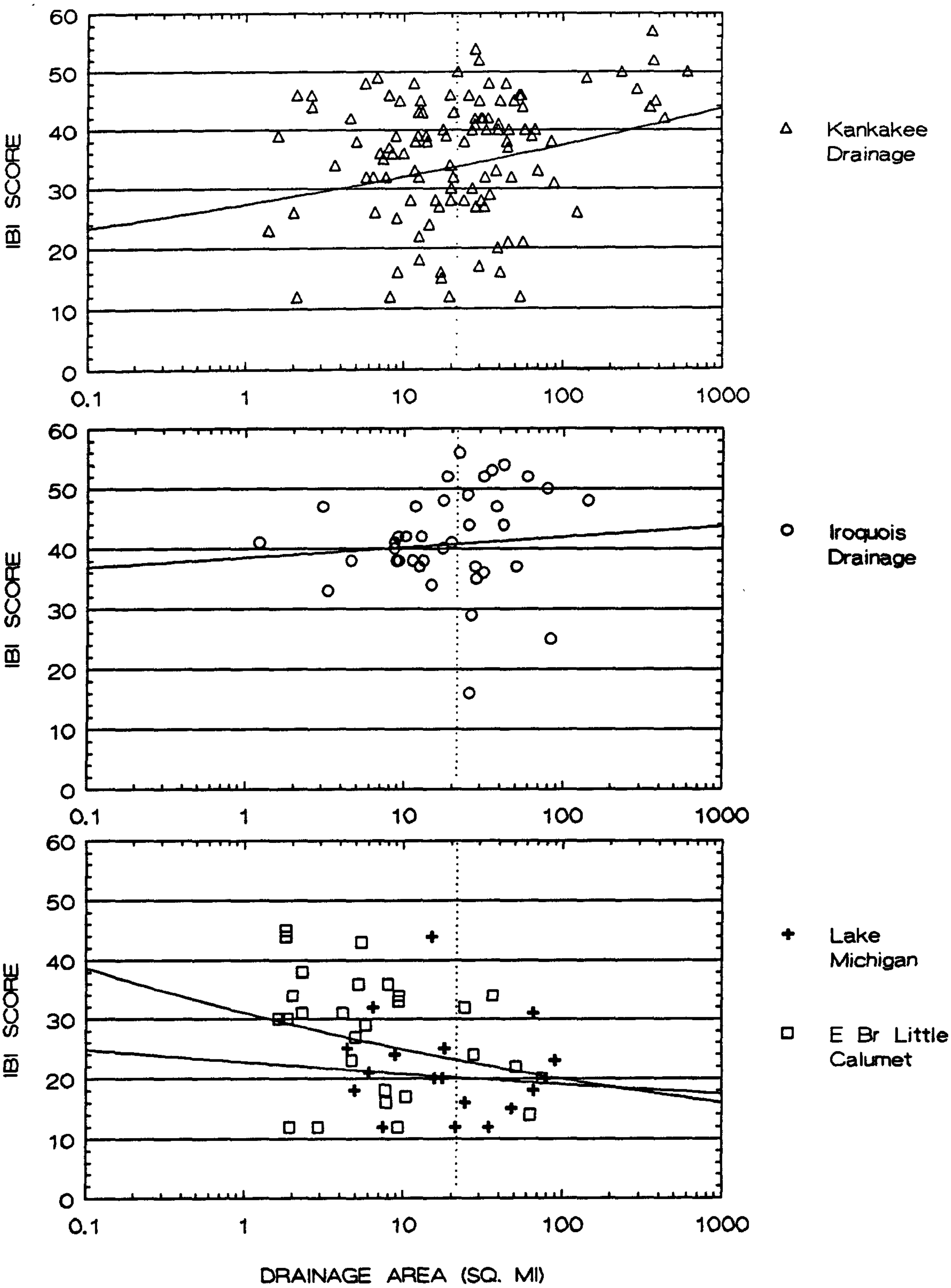

Fig. 33. **Trends in water resources based on the Indiana Index of Biotic Integrity with increasing drainage area for the Central Corn Belt Plain ecoregion.**

quality resource (Gerking 1945; Larimore and Smith 1963; Kuehne and Barbour 1983).

Gerking (1945) found 9 sunfish and 7 sucker species, while we found 11 sunfish and 11 sucker species. The abundance of sunfish generally conforms to an increase in quality pool development, while sucker abundance correlates with run habitat. Although, much of the Kankakee basin has been and continues to be dredged in order to maintain agricultural ditches, a high proportion of the sites have recovered and have the resemblance of a quality riffle, run, and pool habitat. The ability of species colonization from the mainstem Kankakee into most tributary segments enables the recovery of most stream reaches even after periods of severe degradation. The number of sunfish species should not have substantially differed between seining and shocking techniques, however, sucker species composition may have dramatically been skewed using seine methods.

Iroquois River Basin

A total of 37 headwater and wading sites were sampled in the Iroquois River basin during Central Corn Belt Plain ecoregion sampling. A total of 56 species were collected (Table 16) and were numerically dominated by catfish species. The headwaters of the Iroquois River, Oliver ditch and Ryan ditch, were depauperate of cyprinids, instead were comprised of bullheads and centrarchids. These areas were generally degraded due to fluctuating flows and prohibited few species from maintaining permanent residence.

The overall water quality of the Iroquois River ranged between a low of very poor (score of 16; one station) to a high of excellent (score of 56; one station) based on Index of Biotic Integrity scoring criteria developed during the current investigation (Fig. 33b). The biotic integrity of the Iroquois River basin did not vary much with increasing drainage area. Like the Kankakee basin, the number of Iroquois basin sites approximated a normal curve with respect to water quality as determined from index scores. The following was the percent occurrence of total Iroquois stations (37) within each index classification: excellent 5.41% (2 stations); good 29.73% (11 stations); fair 45.95% (17 stations); poor 16.22% (6 stations); very poor 2.70% (1 station). Fish were collected at all sites in the Iroquois basin. Sites which had low index values were primarily attributed to poor habitat. The low flows of some tributaries caused the accumulation of soft substrates in adjacent riffle and pools effectively reducing available habitat, likewise dredged streams reduced habitat complexity. Sugar Creek was an exceptional stream in the Iroquois basin. Curtis and Carpenter Creek, main tributary components of the middle to upper Iroquois River, had very high index of biotic integrity scores for almost all sites sampled.

Species of concern collected in the Iroquois River include the presence of the tolerant Cyprinella lutrensis, a species known from Illinois but previously unknown from Indiana. High numbers of these tolerant taxa existed in most of the ditches feeding the mainstem Iroquois.

Only a single darter species has been added to the drainage list since the last survey completed by Gerking (1945). Blackside darter, Percina maculata, previously unreported from the drainage was collected at a number of sites during the current investigation.

Gerking (1945) found 5 sunfish and 3 sucker species, while we found 5 sunfish and 7 sucker species. The increase in sucker taxa is likely due to the same reason as the Kankakee River, the recovery of dredged ditches, greater number of stations sampled, or better gear efficiency. The Iroquois basin has been and continues to be dredged in order to maintain agricultural irrigation capability. A high proportion of the sites have recovered and have the resemblance of a quality riffle, run, and pool habitat. The ability of species colonization from the mainstem Iroquois into tributary segments is less than the Kankakee since several lowhead dams exist on the River, and greater contributions of groundwater cause natural fluctuations in flow during various seasons.

Lake Michigan Basin

Water quality trends evident in the Lake Michigan basin will be categorized into the two stream divisions (East Branch Little Calumet River and other Lake Michigan drainage tributaries) in order to facilitate presentation.

East Branch Little Calumet River Division

This division of the Lake Michigan drainage includes Burns Ditch, the East Branch of the Little Calumet River and its tributaries (e.g. Salt Creek, Reynold's Creek, and the unnamed tributary in the Rivers headwater).

A total of 28 headwater and wading sites were sampled in the East Branch Little Calumet River division during Central Corn Belt Plain ecoregion sampling. A total of 48 species were collected (Table 13) and were numerically dominated by centrarchid species. The headwaters of the East Branch of the Little Calumet River, Reynold's Creek and the unnamed tributary, possessed high biological integrity comprised of many salmonid species and more tolerant species from Lake Michigan. These areas were the best observed in this basin segment although they only achieved a fair evaluation for water resource classification.

The overall water quality of the East Branch Little Calumet River division ranged between a low of very poor (score of 12; three stations) to a high of fair (score of 45; one station) based on Index of Biotic Integrity scoring criteria developed during the current investigation (Fig. 33c). The biotic integrity of the East Branch Little Calumet River division declined with increasing drainage area. Unlike the other basin segments, the number of sites approximated a highly skewed curve (towards degraded conditions) with respect to water quality as determined from index scores. The following was the percent occurrence of total East Branch Little Calumet River Division stations (28) within each index classification: fair 14.29% (4 stations); poor

46.43% (13 stations); very poor 39.29% (11 stations). Fish were collected at all sites in the division. Sites which had low index values were primarily because of poor habitat and anthropogenic influences from industrial and municipal dischargers. The low flows of some tributaries caused the accumulation of soft substrates in adjacent riffle and pools, effectively reducing available habitat, likewise dredged streams reduced habitat complexity. Reynold's Creek was an exceptional stream in the East Branch division. The unnamed tributary in the Little Calumet headwaters, and the Little Calumet headwaters near the Indiana Dunes National Lakeshore's Heron Rookery had relatively high index of biotic integrity scores.

Species previously uncollected in the State appearing in the basin division included Atlantic salmon, Salmo salar, which either emigrated through Michigan stocking efforts or were accidentally stocked by State personnel. New drainage records include the American brook lamprey L. appendix and the largescale stoneroller Campostoma oligolepis. The lamprey occurred at several high quality wading sites while the largescale stoneroller was ubiquitous. No specimens of the parasitic sea lamprey were collected.

Only a single darter species has been added to the drainage list since the last survey completed by Gerking (1945). Blackside darter, Percina maculata, previously unreported from the drainage, was collected at a single site during the current investigation. No other taxa additions were found during the current investigation.

Lake Michigan Basin Division

This division of the Lake Michigan drainage includes the Grand Calumet River basin, the West branch of the Little Calumet River and its tributaries (e.g. Deep River, Turkey Creek, and Hart Ditch).

A total of 20 headwater and wading sites were sampled in the Lake Michigan division during Central Corn Belt Plain ecoregion sampling. A total of 36 species were collected (Table 13) and were numerically dominated by centrarchid species. Nowhere in this division were there outstanding reference locations, however, the single location which scored the highest was on the Little Calumet River at Cline Avenue. This area was the best observed in this basin segment although it only achieved a fair evaluation for water resource classification.

The overall water quality of the Lake Michigan division ranged between a low of very poor (score of 12; numerous stations) to a high of fair (score of 44; one station) based on Index of Biotic Integrity scoring criteria developed during the current investigation (Fig. 33c). The biotic integrity of the Lake Michigan division was relatively degraded throughout, but a declining trend was evident with increasing drainage area. Unlike the other basin segments, the number of sites approximated a highly skewed curve (towards degraded conditions) with respect to water quality. The following was the percent occurrence of total Lake Michigan Division stations (20) within each index classification: fair 5.0% (1 station); poor 10.0% (2 stations); very poor 85.0% (17 stations). Fish were collected at all sites in the division. Sites which had low index values were due to poor habitat and toxic influences caused by industrial and urban land uses. The low flows of some tributaries caused the accumulation of soft substrates effectively reducing available habitat, likewise dredged streams reduced habitat complexity.

Species previously uncollected in the drainage division included bluntnose darter, Etheostoma chlorosoma, which may either be due to their rare occurrence or were misidentified as johnny darters in previous investigations. This species was only collected from Deep River.

The West Branch of the Little Calumet River has a peculiar flow regime with a portion of the River flowing eastward towards Burns Ditch and a westward flowing segment towards Illinois. The hydrologic division between the two occurs near Indianapolis Boulevard depending on Lake Michigan level. The eastward flowing segment has relatively better quality potential than the westward flowing segment. The barriers to overall improvements in water resource quality include the presence of landfills, and frequent oil and hazardous waste spills into the river. Waste diversions from municipalities also are quite frequent resulting in only the most tolerant taxa existing as a resident community. The headwaters of Deep River are extremely degraded and can be attributed to municipalities along the upper portions of Niles Ditch, Main Beaver Dam Ditch, and Turkey Creek.

The Grand Calumet River has been a well studied basin with numerous investigations conducted over the past three decades (USEPA 1985; Simon et al. in press). Previous attempts at evaluating the biological integrity of the basin were based on criteria developed for the adjacent northeastern sections in Illinois (Bickers et al. 1988; IEPA 1989) since no equivalent study had been completed in Indiana. The current study is that evaluation which quantifies the expected natural variation in the Lake Michigan basin. Based on the historic data set, similar trends in water quality were observed between the current and past surveys. The overall quality of the River is very poor even though a high proportion of cattail marsh wetland lies along the basins margins. Overall, habitat is not the limiting factor in the improvement of this basin since enough refuges exist to facilitate the colonization of impacted areas after the perturbations have been removed. The high degree of industrialization along the Rivers banks is the principal cause of toxic influence impacting the aquatic community.

Reference Sites

Few natural areas remain in the Central Corn Belt Plain ecoregion. The list of candidate sites is based on superior Index of Biotic Integrity scores, typical habitat for the ecoregion, and professional judgement (Table 17).

Table 17. Reference sites determined using fish communities for the Central Corn Belt Plain ecoregion.

Kankakee River	**Yellow River:** Marshall County: at South Redwood Road bridge, 4.5 mi SW Plymouth, Union Twp., T 33N R 1E S 35. lat. 86° 23′ 35" long. 40° 16′ 14" (site: 90-108).
	Carpenter Creek: Jasper County: at 680 W bridge, Carpenter Twp., 2.5 mi N Remington. T 27N R 7W S 12. lat. 87° 10′ 23" long. 40° 47′ 55" (site: 90-134).
	Wolf Creek: Jasper County: at 1450 N bridge, 2 mi N Wheatfield, Wheatfield Twp., T 32N R 6W S 14. lat. 87° 04′ 42" long. 41° 13′ 38" (site: 90-157).
	Yellow River: Marshall County: at Upas Road bridge, 7.5 mi SW Plymouth, Union Twp., T 33N R 1E S 31. lat 86° 27′ 14" long. 41° 16′ 23" (site: 90-109).
	Bice Ditch: Jasper County: at CR 1000 S (SR 16) bridge, 4.75 mi S Rensselaer, Milroy Twp., T 28N R 6W S 22. lat. 87° 05′ 30" long. 40° 52′ 00" (site: 90-136).
	Yellow River: Marshall County: at North Hickory Road bridge, 5.5 mi S Breman, German Twp., T 34N R 3E S 28. lat 86° 11′ 39" long. 41° 21′ 06" (site: 90-107).
Iroquois River	**Sugar Creek:** Benton County: at SR 71 bridge, 4 mi SW Earl Park, York Twp., T 26N R 9W S 31. lat. 87° 29′ 09" long. 40° 39′ 39" (site: 90-164).
	Sugar Creek: Benton County: at 200 W bridge, 4 mi E Earl Park, Richland Twp. T 26N R 8W S 17. lat. 87° 19′ 37" long. 40° 41′ 38" (site: 90-166).
	Curtis Creek: Jasper County: at SR 114 bridge, 5.5 mi W Rensselear, Newton Twp., T 29N R 7W S 19. lat. 87° 15′ 32" long. 41° 56′ 26" (site: 90-170).
	Sugar Creek: Benton County: at CR 500 W Road, 0.5 mi N Earl Park, Richland Twp., T 26N R 9W S 14. lat. 87° 25′ 11" long. 40° 41′ 56" (site: 90-167).
	Iroquois River: Jasper County: at CR 700 W bridge; 6.75 mi NW Rensselear, Union Twp., T 30N R 7W S 23. lat. 87° 10′ 50" long. 41° 01′ 59" (site: 90-151).

Table 17. Reference sites determined using fish communities for the Central Corn Belt Plain ecoregion (continued).

	Beaver Creek: Newton County: at CR 600 W bridge, 3.25 mi W Morocco, Beaver Twp., T 29N R 10/9 W S 24/19. lat. 87° 30′ 29" long. 40° 57′ 10" (site: 90-124).
Lake Michigan	**Reynold's Creek:** LaPorte County: at Snyder Road bridge, 1.5 mi W SR 421 and US 80/90 intersection, New Durham Twp. T 36N R 4W S 6. lat. 86° 55′ 21" long. 41° 35′ 53" (East Branch Little Calumet Division; site: 90-205).
	Little Calumet River: Porter County: at CR 600 E bridge, 3.75 mi S Pines, Indiana Dunes National Lakeshore Heron Rookery, Pine Twp., T 37N R 5W S 25. lat. 86° 57′ 06" long. 41° 37′ 38" (East Branch Little Calumet Division; site: 90-199).
	Unnamed Tributary Little Calumet River: Porter County: at old CR 1300 N bridge, 4.25 mi S Pine, Pine Twp., T 37N R 4W S 36. lat. 86° 56′ 48" long. 41° 37′ 03" (East Branch Little Calumet Division; site: 90-303).
	Little Calumet River: Lake County: at SR 912 (Cline Ave.), Gary, Calumet Twp. T 36N R 9W S 24 (Lake Michigan Division; site: 90-189).
	Deep River: Lake County: at County Line Road and Old Lincolnway, Deep River County Park at walkbridge, 2 mi N Merrillville, Ross Twp., T 35N R 7W S 16/21. lat. 87° 13′ 16" long. 41° 28" 36" (Lake Michigan Division; site: 90-184).

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