FISH COMMUNITIES IN LAKES IN SUBREGION 2B

(UPPER PENINSULA OF MICHIGAN)

IN RELATION TO LAKE ACIDITY

U.S. Environmental Protection Agency
Office of Research and Development, Washington, DC
Environmental Research Laboratory, Corvallis, OR
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R.F. Cusimano
NSI Technology Services, Inc.
U.S. EPA Environmental Research Laboratory
Corvallis, Oregon

J.P. Baker
W.J. Warren-Hicks
V. Lesser
Kilkelly Environmental Associates

W.W. Taylor
M.C. Fabrizio
D.B. Hayes
Michigan State University

B.P. Baldigo
Lockheed Engineering and Sciences Company
Las Vegas, Nevada

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EXECUTIVE SUMMARY

The research described in this document represents one component of Phase II of the Eastern Lake Survey (ELS-II), a part of the National Surface Water Survey (NSWS). Surveys of fish community status were conducted in summer 1987 in 49 lakes in ELS Subregion 2B, the Upper Peninsula of Michigan. Subregion 2B was selected because of its (1) high proportion of acidic (9.8% with ANC $\leq$ 0 µeq/L) and low-pH lakes (9.4% with pH $\leq$ 5.0; 17.7% with pH $\leq$ 6.0), (2) relative lack of existing data on fish communities in lakes, and (3) diverse geological and hydrological conditions allowing optimal evaluation of the association between lake characteristics and fish community status. A companion study dealing with regional patterns in fish mercury content in Subregion 2B was conducted concurrently; results from this study will be presented in a subsequent report (U.S. Environmental Protection Agency [EPA], in prep.).

The NSWS is a survey, not a process-oriented, cause-and effect research program. The emphasis is on developing a regional perspective on the current status of aquatic resources with regard to potential impacts from acidic deposition. Regional surveys of fish community status are needed to quantify the proportion and types of fishery resources in lakes considered potentially sensitive to acidic deposition. In addition, survey correlations between fish community status and water chemistry may be used to evaluate dose-response relationships derived experimentally in laboratory or field bioassays. Thus, the specific objectives of this project were as follows:

- Estimate the percentage (by number and area) of lakes with few or no fish (i.e., with no fish caught in the survey) in Subregion 2B.
- Estimate the percentage (by number and area) of fish populations that occur in lakes with low acid neutralizing capacity (ANC), potentially susceptible to effects from acidic deposition.
- Determine the chemical characteristics of lakes with and without fish (as estimated by catch/no catch).
- Quantify the relationship between fish presence/absence and lake chemical and physical characteristics.
- Quantify the relationship between selected fish population characteristics (e.g., relative abundance and condition factors) and lake chemical and physical characteristics.

The lakes sampled in Subregion 2B during ELS-II to assess fish community status were a subset of the lakes sampled during Phase I of the Eastern Lake Survey (ELS-I). Lake selection involved a variable probability sampling design that (1) concentrated on lakes with low pH, (2) covered the full range of values for dissolved organic carbon (DOC), and (3) attempted to even-out the inclusion probabilities assigned in the ELS-I. Several categories of lakes were excluded from the ELS-II and the ELS-II target population in Subregion 2B: lakes < 1.5 m in depth, larger than 2000 ha, highly enriched with nutrients, or modified by recent in-lake management practices (e.g., recent fish stocking). Lakes smaller than < 4 ha in area were excluded from both the ELS-I and ELS-II target populations.

The 49 ELS-II lakes in Subregion 2B were sampled between 8 June and 30 August 1987. Fish communities were surveyed using gill nets, trap nets, beach seines, and angling. Coincident with the fish surveys, some data on lake physical and chemical parameters were collected (e.g., measures of aluminum speciation). For the most part, however, the ELS-II data on fish communities in lakes in Subregion 2B are interpreted relative to the ELS-I index of lake chemistry collected in fall 1984. It is recognized that the ELS-I data are not direct measures of chemical conditions during those specific times and locales critical to fish population response. It is assumed, however, that the ELS-I index chemistry is at least correlated with these water quality values of interest.

Duplicate surveys of fish communities were conducted for ten of the 49 ELS-II lakes between 31 August and 12 September 1987 as part of the quality assurance/quality control (QA/QC) protocol. Comparison of results from these duplicate surveys provides some information on sampling errors and variability. In general, measures of species richness (i.e., the number of fish species caught) and fish species presence/absence were similar in the duplicate samples. For species richness, all but one lake had a coefficient of variation (CV) < 50%; all but two of the ten lakes had a CV < 25%. The maximum deviation in species richness between the two samples was two species. Variations in numbers of fish caught and catch per unit effort (CPUE), on the other hand, were somewhat greater (coefficients of variation 10 to 140%). Many factors influence fish capture efficiency, thereby limiting the utility of CPUE as an index of relative fish abundance.

Fish were collected in 47 of the 49 lakes surveyed. The number of species caught per lake ranged between 0 and 13, with a median of three. Thirty-one fish species were caught in total. Yellow perch (Perca flavescens) was the most common species, collected in 31 lakes. Seven other fish species occurred in 10 or more lakes. In decreasing order of frequency, these species were largemouth bass (Micropterus salmoides), bluegill sunfish (Lepomis macrochirus), pumpkinseed sunfish (Lepomis gibbosus), white sucker (Catostomus commersoni), brown bullhead (Ictalurus nebulosus), golden shiner (Notemigonus crysoleucas), and northern pike (Esox lucius). The species caught are typical of those reported for lakes in the Upper Midwest as a whole (including northern Minnesota, Wisconsin, and Michigan).

Extrapolation of these results to the ELS-II target population in Subregion 2B suggests that 99.4% of the lakes in the area (in the defined target population) support fish (99.5% of the lake area). Game species occur in 83.7% of the lakes (95.7% by lake area); 16.6% of the lakes with game fish have ANC ≤ 50 μeq/L (4.0% by lake area). The most common fish species in the subregion are yellow perch (occurring in an estimated 69.8% of the lakes; 88.6% by lake area), white sucker (52.1% and 48.0% of the lakes, by number and area, respectively), and largemouth bass (50.8 and 49.2%).

For the 49 ELS-II lakes, the number of fish species caught per lake (species richness) was lower in seepage lakes (without inlets or outlets) than in nonseepage lakes, and also lower in lakes with lower pH, ANC, calcium (and other base cations), DOC, and silica and with higher levels of extractable aluminum. Many of these variables are themselves highly correlated, however, complicating interpretation of the association between fish community status and lake characteristics.

For several fish species and for cyprinid (minnow) and darter species as a group, lakes without fish had significantly lower levels of pH, ANC, calcium, base cations, silica, and sulfate; were smaller in size; and were more often seepage lakes than nonseepage lakes. In contrast, the distributional patterns for yellow perch, brook trout (Salvelinus fontinalis), central mudminnow (Umbra limi), and brook stickleback (Culaea inconstans) were not consistently associated with any of the measured lake physical or chemical characteristics. Brown bullhead distribution was also unrelated to variations in lake chemistry, although significantly associated with lake elevation. These results are generally consistent with other studies of fish species distribution and sensitivity to acidic conditions. Yellow perch, brown bullhead, brook trout, and central mudminnow are considered relatively acid tolerant, while cyprinids and darters are considered acid sensitive.

In contrast to the large number of variables associated with fish presence/absence and species richness, variations in the numbers of fish caught (and CPUE) among lakes appeared independent of lake characteristics. Only for yellow perch were any statistically significant associations identified: higher numbers of yellow perch were caught in lakes with lower pH, ANC, calcium, sum of the base cations, and silica, and with higher levels of extractable aluminum. Thus, yellow perch are not only tolerant of acidic conditions, but are actually more abundant in acidic waters with lower calcium and silica, perhaps as a result of reduced competition from other fish species.

Survey data alone cannot establish causality. Many factors influence fish distribution, abundance, and condition, and many of these factors are themselves interrelated and correlated. The observed results for the ELS-II in Subregion 2B are, however, consistent with existing hypotheses regarding factors that influence fish community status. For example, seepage lakes tend to have relatively depauperate fish communities, perhaps as a result of their relative isolation and reduced rates of fish colonization. Larger lakes tend to support more diverse fish communities, reflecting the generally greater habitat complexity in larger lakes. The ELS-II data also suggest a negative effect of low ionic strength (i.e., low concentrations of calcium and other base cations) and lake acidity (low pH and ANC) on several fish species and groups.

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1. INTRODUCTION AND BACKGROUND

1.1 THE NATIONAL SURFACE WATER SURVEY

In 1983, the U.S. Environmental Protection Agency (EPA) initiated the National Surface Water Survey (NSWS) to document the chemical and biological status of lakes and streams in regions of the United States potentially susceptible to acidic deposition. The NSWS was designed as a three-phase project:

- Phase I -- a synoptic survey of lake and stream chemistry.
- Phase II -- an evaluation of chemical variability and biological status for a subset of surface waters in selected regions sampled during Phase I.
- Phase III -- a long-term monitoring program to quantify future changes in the chemistry and biology of aquatic ecosystems characteristic of geographic regions of the United States. Phase III of the NSWS has since been subsumed within the broader EPA monitoring program, Temporally Integrated Monitoring of Ecosystems (TIME).

The NSWS consists of two major components: the National Lake Survey and the National Stream Survey. The National Lake Survey consists, in turn, of the Eastern Lake Survey (ELS) and Western Lake Survey (WLS). The research described in this document represents one component of Phase II of the Eastern Lake Survey (ELS-II).

Phase I of the ELS (ELS-I) was conducted in fall 1984, with the final results presented in three volumes (Linthurst et al. 1986, Overton et al. 1986, Kanciruk et al. 1986). The ELS-I had three primary objectives:

1. to determine the percentage (by number and area) and location of lakes that are acidic in potentially sensitive regions of the eastern United States,
2. to determine the percentage (by number and area) and location of lakes that have low acid neutralizing capacity (ANC) in potentially sensitive regions of the eastern United States, and
3. to determine the chemical characteristics of lake populations in potentially sensitive regions of the eastern United States and provide the data base for selecting lakes for future study.

To accomplish these objectives, a water sample was collected during fall overturn at 1.5 m depth over the deepest point in the lake from 1612 lakes within 11 subregions in the northeastern, southeastern, and upper midwestern regions of the United States (Figure 1-1). A suite of chemical variables and physical attributes thought to influence or be influenced by surface water acidification was measured for each lake. Lakes sampled were selected by a systematic random process from the population of lakes in

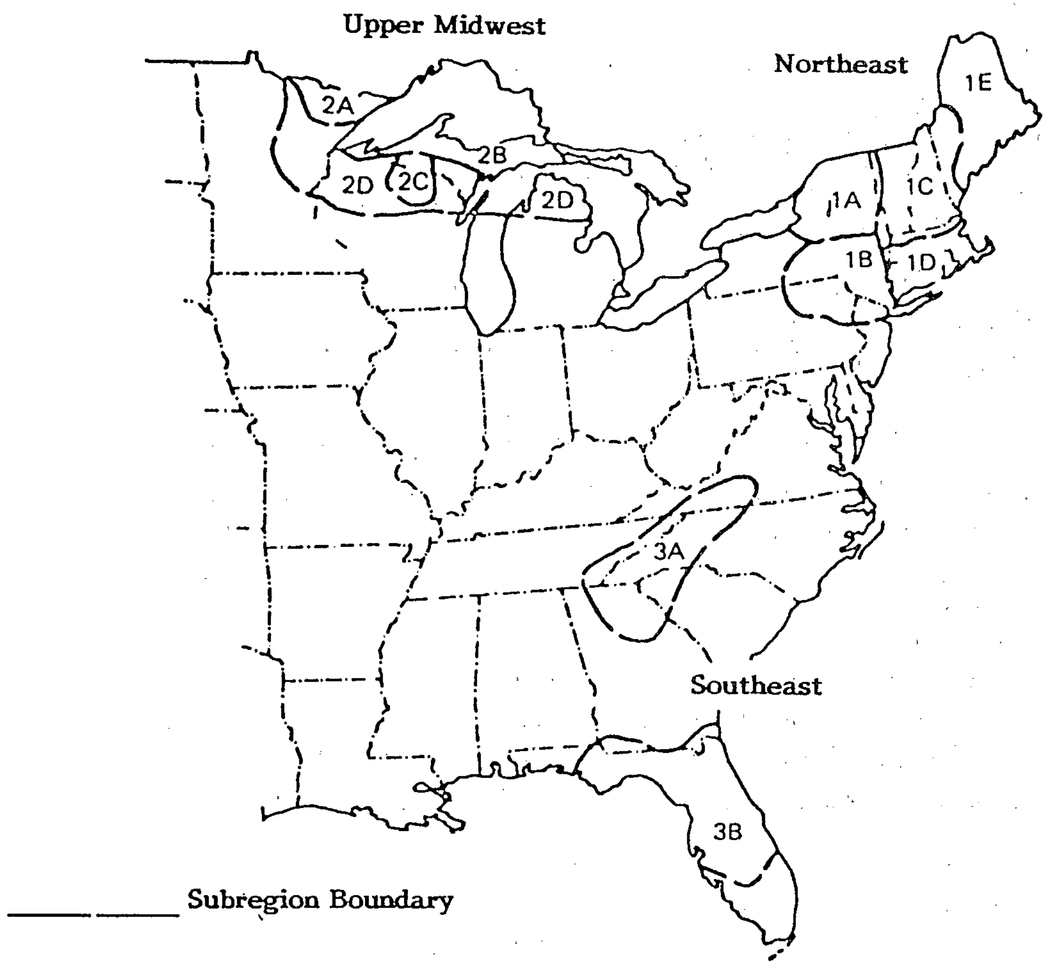


Figure 1-1. Subregions surveyed during Phase I of the Eastern Lake Survey.

the areas studied. Thus, the ELS-I data base provides the basis for regional estimates of the chemical status of lakes within a specific region or subregion.

Three subregions sampled during ELS-I had the highest frequency and number of acidic (defined by an ANC ≤ 0 μeq/L) and low pH lakes (Table 1.1):

1. Subregion 3B (Florida), with an estimated 476 (22.7%) acidic lakes, 259 (12.4%) lakes with pH ≤ 5.0, and 687 (32.7%) lakes with pH ≤ 6.0;

2. Subregion 1A (Adirondacks), with an estimated 181 (14.0%) acidic lakes, 128 (10.0%) lakes with pH ≤ 5.0, and 343 (26.6%) lakes with pH ≤ 6.0; and

3. Subregion 2B (Upper Peninsula of Michigan), with an estimated 119 (11.3%) acidic lakes, 99 (9.4%) lakes with pH ≤ 5.0, and 185 (17.7%) lakes with pH ≤ 6.0.

Table 1.1. Population Percentage Estimates for Selected pH and ANC Criteria, from Phase I of the Eastern Lake Survey (Lakes ≤2000 ha) (Linthurst et al. 1986, Landers et al. 1988)

Region/Subregion	Number of Lakes	ANC (μeq/L)[a]			pH	
		≤0	≤50	≤200	≤5.0	≤6.0
Northeast (1)						
Adirondacks (1A)	1290	14.0	37.8	73.0	10.0	26.6
Poconos/Catskills (1B)	1479	5.9	13.5	40.9	0.8	7.8
Central New England (1C)	1483	4.2	23.3	67.6	1.7	12.9
Southern New England (1D)	1318	6.5	22.6	57.3	5.0	14.6
Maine (1E)	1526	1.6	14.7	66.8	0.5	4.8
Upper Midwest (2)						
Northeastern Minnesota (2A)	1457	0.0	5.2	52.1	0.0	1.4
Upper Peninsula of Michigan (2B)	1050	11.3	19.6	41.7	9.4	17.7
Northcentral Wisconsin (2C)	1480	8.7	41.8	57.1	2.1	27.7
Upper Great Lakes Area (2D)	4515	0.0	9.8	31.3	0.0	4.5
Southeast (3)						
Southern Blue Ridge (3A)	258	0.0	1.4	34.3	0.0	0.4
Florida (3B)	2098	22.7	39.8	55.1	12.4	32.7

a Population estimates based on recalculated ANC values (Hillman et al., in prep.)

Subregion 2B, encompassing the majority of the Upper Peninsula of Michigan plus a small portion of northern Wisconsin, was selected for the ELS-II survey of fish community status because of (1) the high proportion of acidic and low pH lakes in the subregion, (2) the relative lack of existing data on fish communities in lakes in the area, and (3) the diversity of geological and hydrological conditions in the subregion, allowing optimal evaluation of the association between lake characteristics and fish community status.

1.2 PROJECT OBJECTIVES

The NSWS is a survey, not a process-oriented, cause-and-effect research program. The emphasis is on developing a regional perspective on the current status of aquatic resources with regard to potential impacts from acidic deposition. Regional surveys of fish community status are needed to quantify the proportion and types of fishery resources in lakes considered potentially susceptible to or impacted by acidic deposition. In addition, survey correlations between fish community status and water chemistry may corroborate, in a field situation, dose-response relationships derived experimentally in laboratory and field bioassays. The study described in this document is unique in providing data on fish community status for a defined probability sample of lakes using consistent sampling techniques across a broad region.

The specific objectives of the project are as follows:

- Estimate the percentage (by number and area) and location of lakes with few or no fish (i.e., with no fish caught in the survey) in Subregion 2B (Upper Peninsula of Michigan).
- Estimate the percentage (by number and lake area) of fish populations (by species) that occur in lakes in Subregion 2B with low ANC, potentially susceptible to effects from acidic deposition.
- Determine the chemical characteristics of lakes with and without fish (as estimated by catch/no catch).
  - Do lakes with no fish caught (or without certain fish species) have significantly lower pH (and/or higher aluminum [Al], lower calcium [Ca], or lower dissolved organic carbon [DOC] levels) than do lakes with fish?
- Quantify the relationship between fish presence/absence (by species) and lake chemical and physical characteristics.
  - Are the pH, inorganic Al, and Ca levels associated with the absence of fish species comparable to levels toxic to fish in laboratory and field bioassays?
- Quantify the relationship between selected fish population characteristics (e.g., relative abundance and condition factors) and lake characteristics.

In conjunction with this study of fish community status in lakes in the Upper Peninsula of Michigan, data were also collected on fish mercury content, to assess the relationship between lake characteristics and mercury bioaccumulation. Results from this component of the project are reported in a separate document (EPA, in prep.).

1.3 REPORT FORMAT

The report is divided into 11 sections:

- **Section 1, Introduction and Background**
- **Section 2, Lake Selection** — provides an overview of the statistical sampling design for the ELS-I and the procedures for selecting the subset of lakes sampled in ELS-II.

- **Section 3, Field Implementation** -- describes the field sampling methodology for water chemistry and fish communities.

- **Section 4, Quality Assurance/Quality Control (QA/QC)** -- summarizes the QA/QC results for field sampling and laboratory analyses.

- **Section 5, Lake Physical Characteristics** -- describes the physical characteristics of the lakes sampled, relative to the physical characteristics of lakes in the region as a whole.

- **Section 6, Lake Chemical Characteristics** -- summarizes results from water chemistry measurements for ELS-II relative to results for ELS-I, and for the lakes sampled in ELS-II relative to the population of lakes in the region as a whole.

- **Section 7, Fish Community Status** -- describes the characteristics of fish communities in lakes in the region, including information on species composition, relative abundance, and fish condition factors.

- **Section 8, Association Between Fish Community Status and Lake Characteristics** -- discusses the degree to which among-lake variations in fish community characteristics are associated with variations in lake chemistry and other lake characteristics.

- **Section 9, Regional Population Estimates** -- provides regional estimates of the percentage (by number and lake area) of lakes with few or no fish in Subregion 2B, and the proportion of the fishery resource in low-ANC waters.

- **Section 10, Discussion and Summary**

- **Section 11, References**

Two appendices are provided under separate cover (Volume II): Appendix A describes in further detail the QA/QC protocols for measurements of water chemistry, and Appendix B summarizes the data collected during ELS-I and ELS-II for each lake sampled during the ELS-II.

2. LAKE SELECTION

2.1 EASTERN LAKE SURVEY - PHASE I

The lakes sampled in Subregion 2B to assess fish community status were a subset of the lakes sampled during ELS-I. Procedures for lake selection for the ELS-I survey were described in Linthurst et al. (1986) and Landers et al. (1988) and are summarized below.

2.1.1 The Target Population

The study area for ELS-I was restricted to those areas of the United States where the majority of lakes were expected to have ANC < 400 μeq/L, as delineated on the national map of surface water alkalinity prepared by Omernik and Powers (1983) (see Figure 1-1). Within this study area, all lakes appearing on 1:250,000-scale topographic maps from the U.S. Geological Survey (USGS) were identified and labeled. These lakes define the "statistical frame" or "frame population." Lakes with a surface area of < 4 ha (and up to 10 ha on some maps) are generally not shown on maps of this scale and thus were not considered in the survey. The target population of lakes, for which regional estimates are computed, consists of the frame population minus several categories of non-interest lakes. Categories of non-interest lakes excluded from the ELS-I target population include the following:

- **No lake present** -- lakes initially identified on 1:250,000-scale maps that did not appear on larger-scale maps (1:25,000- or 1:62,500-scale maps) or that were found to be dry during the site visit.
- **Flowing water** -- sites identified as flowing water (streams, rivers) on larger-scale maps or during the site visit.
- **Bay/Estuary (high conductance)** -- lakes appearing as ocean embayments or estuaries or with a measured specific conductance > 1500 μS/cm.
- **Urban/Industrial/Agricultural** -- lakes surrounded by or adjacent to intense anthropogenic activities.
- **Marsh/Swamp** -- lakes appearing as swamps or marshes on larger-scale maps.
- **Too Shallow** -- lakes that were too shallow to collect a clean water sample, free of debris and sediment.
- **Too Small** -- lakes less than 4 ha in area based on the larger-scale maps.
- **Other** -- lakes that were inaccessible due to a permanent feature of the lake (e.g., power lines that prevented helicopters from landing safely).

In Subregion 2B, the frame population consists of 1698 lakes, with an estimated 1050.0 lakes in the target population (Table 2.1). The majority of the lakes eliminated from the frame population were either too small (< 4 ha) or too shallow.

Table 2.1. Description of the Sample and Target Population for the Eastern Lake Survey - Phase I (ELS-I) and Phase II (ELS-II) for Subregion 2B, the Upper Peninsula of Michigan

Exclusion Category	Stratum 2B1	Stratum 2B2	Stratum 2B3	Subregion Total
Lakes in the ELS-I frame population	118	250	1330	1698
Lakes in the ELS-I probability sample	74	100	80	254
ELS-I weighting factor (W1)	1.878	2.579	17.208	
Lakes sampled for ELS-I	41	57	48	146
Lakes sampled for ELS-I within the ELS-II target population	36	45	24	105
Estimated target population size ($\hat{N}$)				
ELS-I	77.0	147.0	826.0	1050.0
ELS-II	67.61	116.1	413.0	596.7
Standard error of $\hat{N}$				
ELS-I	4.89	9.83	71.69	72.5
ELS-II	2.72	6.27	58.46	58.9
Estimated lake area (ha) of the target population ($\hat{A}$)				
ELS-I	893	2,776	30,357	34,026
ELS-II	811	1,777	12,493	15,081
Standard error of $\hat{A}$				
ELS-I	90	500	10,842	10,854
ELS-II	77	269	4,601	4,609

2.1.2 Statistical Design

The sampling plan for ELS-I used a stratified design with equal allocation of sample lakes among strata. Lakes were selected from each stratum by systematic sampling of an ordered list following a random start.

The three regions, Northeast, Southeast, and Upper Midwest (Figure 1-1), represented the first level of stratification. Subregion, the second stratification factor, identified areas within each region that were expected to be relatively homogeneous with respect to water quality, physiography, vegetation, climate, and soils. Four subregions were defined in the Upper Midwest region (Region 2): 2A (Northeastern Minnesota), 2B (Upper Peninsula of Michigan), 2C (Northcentral Wisconsin), and 2D (Upper Great Lakes Area) (Figure 1-1). Eleven subregions were defined in total: four in the Upper Midwest, five in the Northeast, and two in the Southeast.

The third stratification factor, alkalinity map class, differentiated among areas within each subregion based on the range of surface water alkalinity values expected to dominate in different areas. The alkalinity map classes chosen were < 100 μeq/L (class 1), 100-200 μeq/L (class 2), and > 200 μeq/L (class 3). Spatial representations of the three alkalinity classes within each subregion were derived from preliminary versions of regional surface water alkalinity maps prepared by Omernik and Kinney (1985), Omernik and Griffith (1985), and Omernik (1985). All three alkalinity map classes were found within each of the 11 subregions. Thus, a total of 33 strata was defined. Strata are coded by region, subregion, and alkalinity map class; for example, 2B1 designates the Upper Midwest Region (2), the Upper Peninsula of Michigan Subregion (B), and alkalinity map class 1.

Map class boundaries according to region, subregion, and alkalinity class were identified on 1:250,000-scale USGS maps. All lakes represented on the map were assigned a unique number, numbered consecutively according to location within the mapping unit. Within each stratum, lakes were selected for sampling as a systematic random sample. Non-target lakes, as defined in Section 2.1.1, were then eliminated by examining larger-scale maps or during field operations. Approximately 50 lakes in the target population were sampled per stratum, with a total of 146 lakes sampled in Subregion 2B (Table 2.1, Figure 2-1).

For extrapolation from the sample of lakes to the target population within a subregion or region, the sample data must be weighted by stratum-specific weights. The

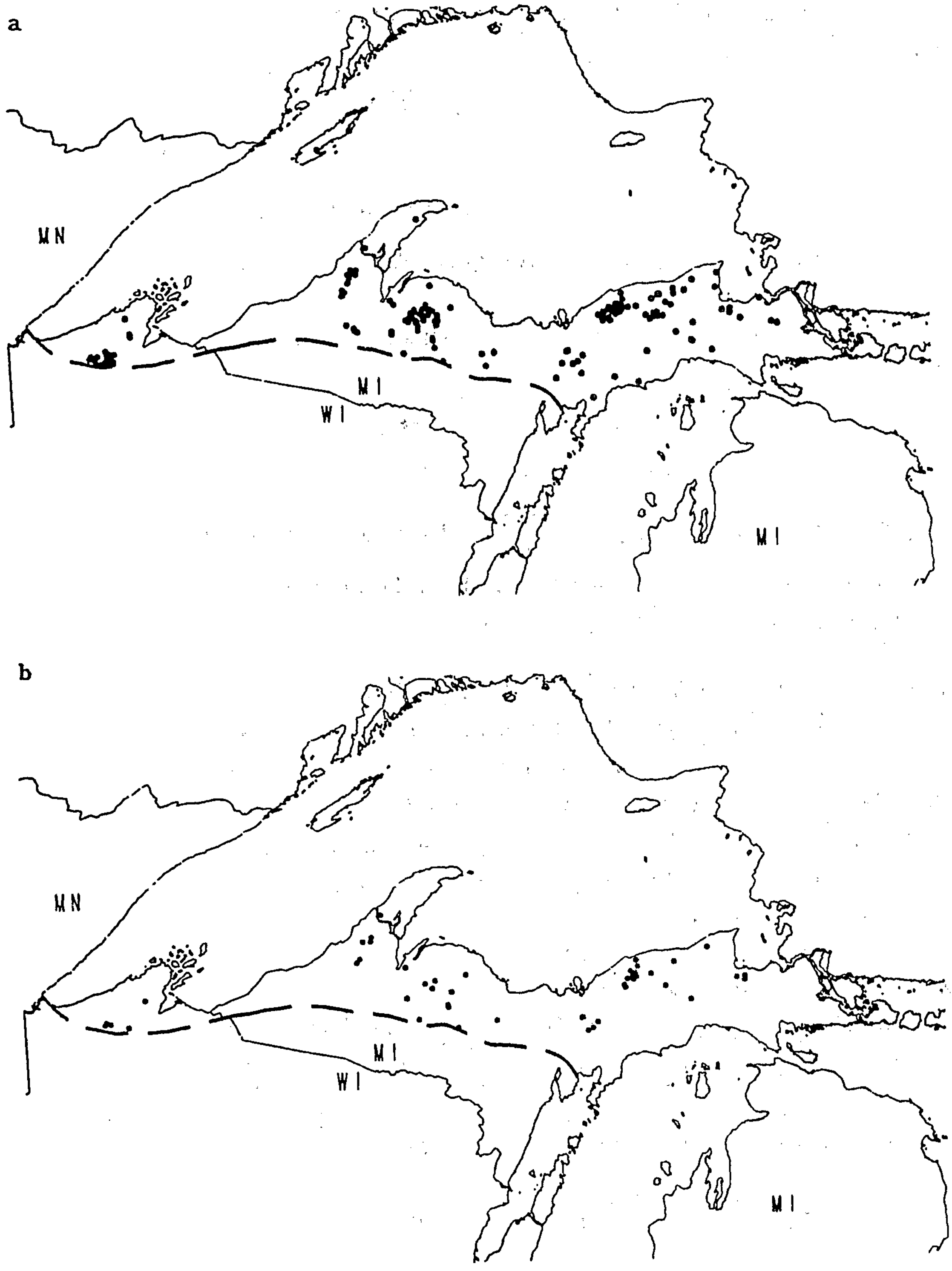


Figure 2-1. Geographic distribution of the lakes sampled in Subregion 2B during (a) ELS-I and (b) ELS-II.

ELS-I weighting factors (W1) for Subregion 2B are presented in Table 2.1 and are calculated as follows:

$$W1 = \frac{N^*}{n^*}$$

where:

N^* = the number of lakes in the frame population, and

n^* = the number of lakes in the original ELS-I probability sample (including non-interest lakes).

The estimated ELS-I target population size ($\hat{N}$) for each stratum is then calculated as:

$$\hat{N} = W1(n^{***})$$

where:

n^{***} = the number of lakes sampled during ELS-I in the target population.

Procedures for calculating the variance and standard errors of population estimates are outlined in Linthurst et al. (1986).

2.2 SURVEYS OF FISH COMMUNITY STATUS (ELS-II)

Fifty lakes in Subregion 2B were selected for surveys of fish community status as part of ELS-II. Lakes to be surveyed were selected as a variable probability systematic sample from among those lakes sampled during ELS-I. This approach is consistent with the probability sampling frame used during ELS-I and was designed to optimize assessment of the influence of key water chemistry variables on fish community status and fish mercury content.

2.2.1 The Target Population

The ELS-I target population (Section 2.1.1) was further refined to eliminate classes of lakes considered of little or no interest relative to the ELS-II objectives:

- shallow lakes (site depth < 1.5 m), subject to winterkill and therefore unlikely to support a significant fishery resource;
- very large lakes (> 2000 ha), likely to exhibit considerable spatial variability and thus difficult to adequately characterize both chemically and biologically;

- lakes highly enriched with nutrients that may distort the chemical composition of the lakes and confound data interpretation; criteria include any of the following:

  - total phosphorus (P) > 90 μeq/L
  - nitrate (NO_3) > 50 μeq/L
  - ammonia (NH_4) > 30 μeq/L
  - turbidity > 7 NTU
  - Secchi depth < 0.5 m

- lakes modified by recent in-lake management practices resulting in a disturbance of either biota or lake chemistry (e.g., recent stocking, lake liming, rotenone treatment, dam removal);

- lakes modified by anthropogenic disturbances to such an extent that the results would not be representative of other lakes in the population (e.g., major wastewater treatment plant discharge into the lake);

- reservoirs less than 10 years old that may have experienced recent, major influxes and mobilization of mercury associated with flooding land surfaces; and

- lakes heavily impacted by road salt or chloride (Cl) from other anthropogenic sources (Cl > 100 μeq/L), given that high levels of Cl may enhance mercury mobilization and mask any potential influence of lake acidity on mercury bioaccumulation.

Of the 146 lakes in Subregion 2B sampled in ELS-I, 41 were eliminated based on the above exclusion criteria. Many of the lakes excluded (61%) were too shallow, with a site depth < 1.5 m (Table 2.2). From the remaining 105 lakes sampled in ELS-I, 50 lakes were selected for sampling in ELS-II, as described in Section 2.2.2.

The ELS-II target population size can be estimated in the same manner as described in Section 2.1.2 for the ELS-I target population, adjusting for the change in the number of ELS-I lakes sampled within the ELS-II target population. The weighting factors per stratum do not change. The estimated size of the redefined ELS-II target population is 596.7 lakes, as opposed to an estimated target population for ELS-I of 1050.0 lakes, in Subregion 2B (Table 2.1).

2.2.2 Statistical Design

Lake pH, inorganic Al, Ca, and DOC are considered the four chemical variables most likely to influence fish community status and fish mercury content in acidic lakes (Driscoll at al. 1980, Brown 1983, Altshuller and Linthurst 1984, Quinn and Bloomfield

Table 2.2. **Numbers of ELS-I Lakes Excluded from the ELS-II Target Population in Subregion 2B**

Exclusion Category[a]	Stratum			Subregion Total
	2B1	2B2	2B3	
Site Depth <1.5 m	1	6	18	25
Lake Area >2000 ha	0	0	0	0
High Nutrients				
P >90 μeq/L	0	0	1	1
NO_3 >50 μeq/L	0	0	0	0
NH_4 >30 μeq/L	0	0	0	0
Turbidity >7 NTU	0	0	0	0
Secchi Depth <0.5 m	0	1	0	1
Modified by Recent In-Lake Management	4	4	44	12
Anthropogenic Disturbances	0	0	0	0
Recent Reservoir	0	0	1	1
Cl >100 μeq/L	0	1	3	4
Total No. Lakes	5	12	24	41

[a] Lakes may fit within more than one exclusion category; thus, the total number of lakes excluded may be less than the sum of the individual categories.

1985). Levels of inorganic Al were not measured during ELS-I (Linthurst et al. 1986). Levels of Ca and pH measured during ELS-I in Subregion 2B were highly correlated (Figure 2-2). Thus, pH and DOC (Figure 2-3) were chosen as the two most important factors to consider in lake selection.

The objectives of the sampling design were to select a probability subsample of lakes from the ELS-I sample for Subregion 2B that (1) concentrated on lakes with low pH, (2) covered the full range of DOC values, and (3) attempted to even-out the inclusion probabilities (i.e., the inverse of the weighting factor) assigned in ELS-I. The following methodology was used to select a subsample of 50 lakes for ELS-II from the 105 lakes sampled during ELS-I in the ELS-II target population.

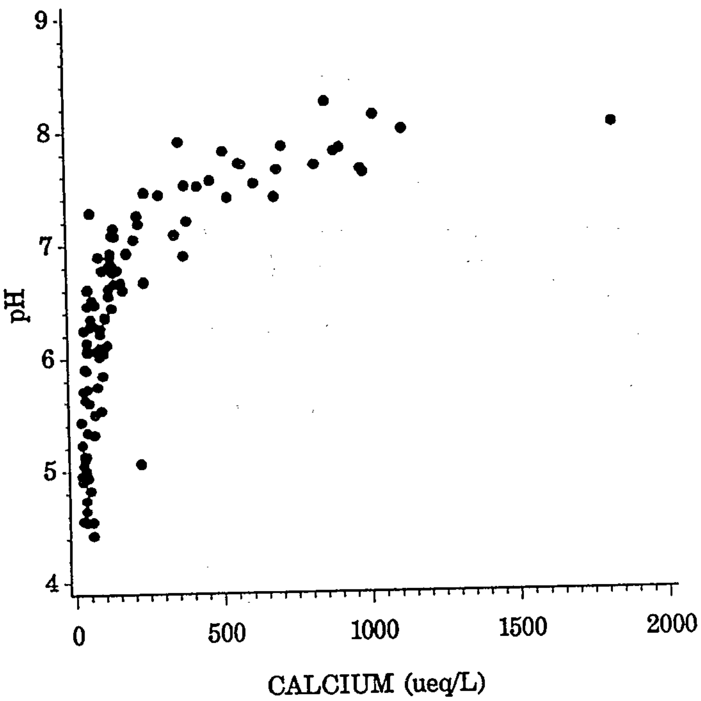


Figure 2-2. **Relationship between pH and Ca for the 105 lakes in Subregion 2B sampled during ELS-I and in the ELS-II target population.**

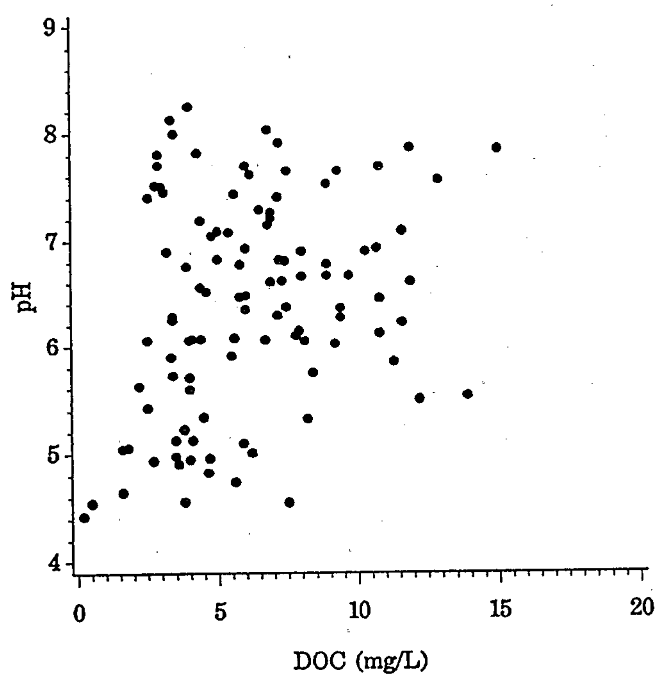


Figure 2-3. **Relationship between pH and DOC for the 105 lakes in Subregion 2B sampled during ELS-I and in the ELS-II target population.**

For each lake, the function z_i was calculated:

$$z_i = (pH^{-7}) * W1 * 10^4$$

where pH is the lake pH (closed system) measured in ELS-I, and W1 is the ELS-I weighting factor (Table 2.1). Inclusion of $(pH)^{-7}$ in the calculation of z_i increases the probability of selecting lakes with lower pH levels, i.e., those lakes most likely to have fish communities potentially impacted by acidification or higher levels of fish mercury content resulting from lake acidity. The constant, 10^4, is an arbitrary value used to adjust the scale of the function.

The 105 lakes were then ordered by DOC, and lakes to be sampled during ELS-II were selected from this ordered list by randomly picking a starting point and choosing every Kth lake, where the distance between lakes is z_i. The sampling interval (K) for selection of the systematic sample is defined by

$$K = \frac{\sum z_i}{n}$$

where:

n = the number of lakes to be selected.

Thus, lakes for ELS-II were selected using a variable probability systematic procedure with an inclusion probability for each lake proportional to z_i (Cochran 1977).

A number of lakes with low pH and/or a high value for W1 had $z_i > K$; as a result, the probability of choosing these lakes in the sample is 100%. It was necessary, therefore, to identify these lakes and to remove them from the lake list prior to initiating the variable probability systematic sample selection. The initial value for K (K_1) with n=50 was 0.39114. All lakes with z_i exceeding this value (n=11) were edited from the lake list and were automatically included in the ELS-II sample. A new value for K (K_2) was calculated based on the 94 lakes remaining and with n=39 (50-11). Ten additional lakes had z_i values exceeding the new value of K (K_2=0.23889), and thus were also edited from the lake list and were included in the ELS-II sample. The process was repeated a third time, with a third recalculated value for K (K_3=0.22638). Two lakes had $z_i > K_3$. Thus, 23 lakes were assigned to the ELS-II subsample with a conditional inclusion probability (p_c) of 1, leaving 27 lakes to be drawn based on a variable probability systematic sample from the remaining 82 ELS-I lakes (K_4=0.22581).

For the 23 lakes selected with a p_c of 1, the ELS-II weighting factor (W2) equals the ELS-I weighting factor (W1). For all other ELS-II lakes, the weighting factor is calculated as

$$W2 = W1 \frac{K_4}{z_i}$$

Values for z_i, W1, and W2 for the 50 lakes in Subregion 2B selected for sampling during ELS-II are listed in Table 2.3. The estimated size ($\hat{N}$) and area ($\hat{A}$) of the ELS-II target population of lakes, based on this sample of 50 lakes and the ELS-II weighting factors, are as follows:

$$\hat{N} = 642.3$$

$$\text{Std. Error } (\hat{N}) = 100.4$$

$$\hat{A} = 22{,}008 \text{ ha}$$

$$\text{Std. Error } (\hat{A}) = 10{,}920 \text{ ha}$$

The distinction between these estimates and those in Table 2.1 derived from the ELS-I weighting factors (W1) for the 105 ELS-I lakes in the ELS-II target population should be noted.

At the request of the Michigan Department of Natural Resources, Lake 2B1-065 (Penegor Lake) was deleted from the list of lakes to be surveyed to avoid interference with an ongoing study of fish populations in the lake. Excluding this lake from the survey does not require redefinition of the ELS-II target population. Thus, 49 lakes in Subregion 2B were sampled during ELS-II (Figure 2-1).

Table 2-3. List of Lakes Selected for ELS-II in Subregion 2B

Lake ID	DOC	pH	ELS-I Weighting Factor (W1)	z_i[a]	ELS-II Weighting Factor (W2)
2B1-016	11.30	5.85	1.878	0.08009	5.2947
2B1-022	3.35	5.90	1.878	0.07546	5.6197
2B1-035[b]	4.70	4.96	1.878	0.25429	1.8780
2B1-038[b]	3.80	4.56	1.878	0.45808	1.8780
2B1-039[b]	3.50	4.98	1.878	0.24722	1.8780
2B1-040[b]	5.60	4.74	1.878	0.34934	1.8780
2B1-041	4.10	5.13	1.878	0.20085	2.1114
2B1-042[b]	6.20	5.01	1.878	0.23705	1.8780
2B1-047[b]	0.50	4.55	1.878	0.46517	1.8780
2B1-048[b]	0.20	4.43	1.878	0.56088	1.8780
2B1-052[b]	4.00	4.95	1.878	0.25790	1.8780
2B1-061	1.60	5.05	1.878	0.22421	1.8914
2B1-064	1.80	5.06	1.878	0.22113	1.9178
2B1-065[c]	8.20	5.32	1.878	0.15571	2.7235
2B1-066[b]	1.60	4.65	1.878	0.39951	1.8780
2B2-004	7.90	6.14	2.579	0.07839	7.4290
2B2-007	2.50	5.43	2.579	0.18529	3.1430
2B2-024	8.40	5.75	2.579	0.12410	4.6927
2B2-038	7.40	6.81	2.579	0.03797	15.3385
2B2-044[b]	3.80	5.23	2.579	0.24096	2.5790
2B2-049[b]	5.90	5.10	2.579	0.28738	2.5790
2B2-055[b]	7.50	4.55	2.579	0.63881	2.5790
2B2-061	13.90	5.53	2.579	0.16307	3.5713
2B2-074	6.00	6.35	2.579	0.06195	9.4008
2B2-075	5.50	5.91	2.579	0.10241	5.6867
2B2-078	2.20	5.63	2.579	0.14384	4.0486
2B2-079	4.40	6.07	2.579	0.08494	6.8560
2B2-082	4.00	5.60	2.579	0.14933	3.9000
2B2-090[b]	3.50	5.13	2.579	0.27582	2.5790
2B2-098	10.30	6.90	2.579	0.03463	16.8150
2B2-100[b]	4.65	4.83	2.579	0.42055	2.5790
2B3-007[b]	4.40	6.56	17.208	0.32916	17.2080
2B3-008[b]	8.90	6.78	17.208	0.26129	17.2080
2B3-009	11.90	7.86	17.208	0.09285	41.8511
2B3-012	10.70	6.93	17.208	0.22418	17.3333
2B3-013[b]	2.70	4.94	17.208	2.39685	17.2080
2B3-020[b]	7.80	6.10	17.208	0.54755	17.2080
2B3-023	9.30	7.65	17.208	0.11223	34.6244
2B3-027	4.00	8.25	17.208	0.06615	58.7394
2B3-028	7.15	7.41	17.208	0.14028	27.6998
2B3-030[b]	4.49	5.34	17.208	1.38976	17.2080
2B3-031	6.80	8.03	17.208	0.07993	48.6137
2B3-034	6.17	7.62	17.208	0.11536	33.6849
2B3-037	3.46	8.00	17.208	0.08205	47.3565
2B3-051[b]	3.60	4.91	17.208	2.50127	17.2080
2B3-055	2.54	7.41	17.208	0.14028	27.6998
2B3-056[b]	8.00	6.90	17.208	0.23109	17.2080
2B3-057[b]	5.00	6.83	17.208	0.24819	17.2080
2B3-058[b]	3.40	6.25	17.208	0.46192	17.2080
2B3-071	4.80	7.05	17.208	0.19880	19.5467

a $z_i = W1*(pH^{-7})*10^4$.
b Lakes selected with $p_c=1$.
c Lake not surveyed at the request of the Michigan Department of Natural Resources.

3. FIELD IMPLEMENTATION

Field activities at each lake included (1) an initial lake reconnaissance; (2) in situ measurements of pH, conductivity, dissolved oxygen (DO), temperature, and Secchi depth; (3) collection of water and sediment samples for subsequent chemical analysis; (4) sampling of fish communities; and (5) preservation of a sample of fish for analysis of tissue mercury content. Procedures for field sampling were described in detail in the Field Training and Operations Manuals for the study (Fabrizio and Taylor 1987, Hagley et al. 1987) and are summarized below. Activities and analyses specific to the study of fish mercury content are described in EPA (in prep.).

3.1 FIELD PERSONNEL

Biological and chemical sampling operations were conducted concurrently. Personnel from Michigan State University conducted fish sampling operations. Personnel from Lockheed Engineering & Sciences Company collected water samples, sediment samples, and in situ chemistry measurements. The 49 lakes were sampled by two field crews, with five individuals per crew. All field personnel participated in a two-day field training program (27-28 May 1987) on the field sampling protocol and QA/QC procedures. This program provided hands-on experience with gear deployment, fish handling procedures, fish identification, fish measurements, boat and trailer handling, and proper data entry. Field crew leaders were given additional training in lake reconnaissance, QA/QC procedures, and personnel management.

3.2 SAMPLING PERIOD

The 49 ELS-II lakes in Subregion 2B were sampled between 8 June and 30 August 1987 (Table 3.1). Ten lakes were resurveyed as part of the QA/QC protocol (Section 4) between 31 August and 12 September 1987. In general, each lake was sampled over a two-day period. Routine water sampling and fish net placement occurred on the first day. During the second day, nets were retrieved and fish measured and processed.

Subregion 2B was subdivided into three zones corresponding with the location of the three field base stations in Munising, MI; L'Anse, MI; and Iron River, WI. Within a given zone, lake order for sampling was originally assigned at random to minimize potential biases associated with any change in fish capture efficiency over time. Some alteration of this predetermined schedule was necessary, however, due to problems with lake access and a delay in initiating field sampling.

Table 3.1. Sampling Dates (1987) and Fish Sampling Effort Per Lake

Lake ID	Area (ha)	Sampling Date	Units of Effort[a]			
			Gill Net	Trap Net	Seine	Angling
2B1-016	4.2	24-25 Jun	3[b]	3	0[c]	2
2B1-022	8.6	24-25 Jun	3	3	0[c]	2
		31 Aug-1 Sep	3	3	4	2
2B1-035	4.3	5-6 Aug	3	3	4	2
2B1-038	6.3	20-21 Aug	3	3	4	2
		10-11 Sep	3	3	4	2
2B1-039	15.7	18-19 Jun	3	3	0[c]	1[c]
2B1-040	4.5	18-19 Jun	3	3	0[c]	2
2B1-041	19.7	10-11 Aug	4	4	5	2
2B1-042	8.3	5-6 Aug	3	3	4	2
2B1-047	16.7	13-14 Aug	3	3	4	2
2B1-048	49.8	12-13 Aug	6	6	6	2
2B1-052	4.5	12-13 Aug	3	3	3[c]	2
2B1-061	6.4	24-25 Aug	3	3	4	2
2B1-064	8.5	20-21 Aug	3	3	4	2
2B1-066	14.7	6-7 Aug	3	3	4	2
2B2-004	8.1	22-23 Jun	3	3	0[c]	2
2B2-007	6.3	16-17 Jul	3	3	4	2
2B2-024	8.1	8-9 Jul	3	3	4	2
2B2-038	5.5	27-28 Aug	3	3	4	2
2B2-044	4.7	24-25 Aug	3	3	4	2
2B2-049	5.0	30-31 Jul	3	3	0[c]	2
		8-9 Sep	3	3	3[c]	2
2B2-055	4.9	30-31 Jul	3	3	4	2
2B2-061	20.6	1-2 Jul	4	4	5	2
2B2-074	11.0	23-24 Jun	3	3	4	2
		1-2 Sep	3	3	4	2
2B2-075	9.5	26-27 Jun	3	3	0[c]	2
		31 Aug-1 Sep	3	3	4	2
2B2-078	4.5	13-14 Jul	3	3	3[c]	2
		2-3 Sep	3	3	4	2
2B2-079	9.0	22-23 Jul	3	3	4	2
2B2-082	4.4	13-14 Jul	3[d]	3	4	2
2B2-090	5.5	14-15 Jul	3	3	4	2

(continued)

Table 3.1. Continued

Lake ID	Area (ha)	Sampling Date	Units of Effort[a]			
			Gill Net	Trap Net	Seine	Angling
2B2-098	26.2	6-7 Jul	1[c]	4	0[c]	2
2B2-100	12.7	2-3 Jul	3	2[c]	4	2
		8-9 Sep	3	3	4	2
2B3-007	11.6	20-21 Jul	3	3	4	2
2B3-008	4.4	27-28 Aug	3	3	0[c]	2
2B3-009	262.3	3-4 Aug	8	8	8	2
2B3-012	16.7	6-7 Jul	3	3	4	2
2B3-013	4.6	17-18 Aug	3[d]	3	4	2
2B3-020	9.7	15-16 Jul	3	3	0[c]	2
2B3-023	63.2	29-30 Jun	7[e]	7	8	2
2B3-027	21.7	30 Jun-1 Jul	4	4	5	2
2B3-028	32.3	8-9 Jun	5[b]	5	5	2
2B3-030	14.7	15-16 Jun	3	3	4	2
2B3-031	38.0	10-11 Aug	5	5	5	2
2B3-034	16.8	11-12 Jul	3	3	3[c]	2
2B3-037	7.6	28-29 Jul	3	3	4	2
		11-12 Sep	3	3	4	2
2B3-051	6.6	17-18 Aug	3	3	4	2
2B3-055	5.5	28-29 Jul	3	3	4	2
2B3-056	9.1	22-23 Jul	3	3	4	2
2B3-057	18.5	7-8 Jul	3	3	0[c]	2
		3-4 Sep	3	3	4	2
2B3-058	13.2	9-10 Jul	3	3	4	2
		2-3 Sep	3	3	4	2
2B3-071	21.7	15-16 Jun	4	4	5	2

a Units of effort:
Gill net and trap net -- Number of nets set overnight
Seine -- Number of hauls
Angling -- Hours

b Problems setting gear, with potential reductions in gear effectiveness.

c Sampling effort less than proposed (standard) sampling effort; see Table 3.3.

d One gill net set deeper than desired, but still fished effectively.

e All nets set during the day for a shorter period of time (10-13 h), but still fished effectively.

Twenty-seven lakes were sampled from the Munising base station: 6 lakes at the beginning of the sampling period (8 to 19 June) and 21 lakes at the end of the sampling period (28 July to 30 August). The five lakes in Wisconsin were sampled from the Iron River base station between 22 and 27 June. The 17 lakes near the L'Anse base station were sampled 29 June to 23 July.

It is not expected that the variation in sampling dates, distributed over the three-month sampling period, had a significant effect on the survey results or on the observed patterns in fish community status. Except for lake elevation (Spearman's rank correlation coefficient, $r=-0.41$), sampling date and lake characteristics were not significantly correlated (at $\alpha=0.05$ adjusted for 14 tests, $p > 0.0036$) (Table 3.2). Analyses to evaluate the potential influence of sampling date on sampling efficiency are discussed further in Section 4.2.

Table 3.2. Nonparametric Correlation Between Sampling Date and Lake Characteristics

Variable	Spearman's Rank Correlation Coefficient
Lake Area	-0.30
Depth	0.12
Elevation	-0.41*
Secchi Depth	0.22
pH	-0.33
Ca	-0.21
DOC	-0.32
Al, Extractable	-0.03
Sum Base Cations	-0.24
ANC	-0.31
Color	-0.21
SO_4	0.06
SiO_2	-0.13
Total P	-0.15

* Correlation coefficient significant at $\alpha=0.05$, adjusted for 14 tests, $p \leq 0.0036$.
Key: SO_4 = sulfate; SiO_2 = silica

3.3 INITIAL LAKE RECONNAISSANCE

Prior to initiating field sampling activities, a reconnaissance of the lake was conducted to select sites for deployment of fish sampling gear. Shoreline maps were prepared identifying the approximate extent and location of various features and habitat types in the lake littoral zone. Habitat types were defined based on the following characteristics: water depth; slope of the lake bottom; abundance and type of aquatic vegetation (emergent, submergent, floating); location of permanent inlets, outlets, shoals, or other physical features (docks, woody debris, beaver dams, etc.); DO; and temperature (see Section 3.4). These maps were not intended as an accurate depiction of littoral zone features, but as an aid for selecting specific sites for sampling. Bathymetric maps for the lake were also referenced, if available.

Appropriate sampling sites for fish were designated by the field crew leader and identified on the shoreline map. Sites selected were dispersed around the lake and included the following: a range of water depths and bottom slopes (e.g., shallow regions with a wide littoral zone and steeper shorelines and littoral zones); regions near major inlets; regions in the immediate vicinity of the lake outlet(s); sheltered bays and open promontories; and regions with different types of shoreline vegetation (e.g., coniferous forests, deciduous forests, marshes). More specific guidelines for selecting sampling sites were provided in the Fisheries Field Training and Operations Manual (Fabrizio and Taylor 1987). The objective was to sample the full diversity of lake habitats in order to collect as many fish species as possible within the limitations of the sampling gear.

3.4 IN SITU MEASUREMENTS

In situ measurements were taken at the ELS-I sampling site over the deepest part of the lake (Linthurst et al. 1986, Landers et al. 1988). In situ measurements consisted of Hydrolab determinations of water temperature, DO, pH, and specific conductance and determinations of Secchi transparency, air temperature, and site depth (Hagley et al. 1987). The Hydrolab was calibrated each morning prior to sampling, a field quality control check (QCC) was performed after arrival at the lake, and a final QCC was completed at the end of the day at the base site. Measurements with the Hydrolab were made first at 1.5 m below the water surface, then at 1.5 m above the lake bottom. If the temperature difference between these two depths was greater than 4 °C, the lake was considered stratified and a full vertical profile of measurements was conducted. Profile measurements were taken at 1-m intervals from 2.5 m to 10.5 m below the surface and at 2-m intervals from 10.5 m to 1.5 m above the lake bottom.

Depth graphs of temperature and DO were provided to the field crew leader to assist in selecting fish sampling locations. Hypoxic layers (with DO < 4 mg/L) were not fished. If a lake was determined to be thermally stratified, fish sampling sites were selected to include the thermocline and the upper hypolimnion.

3.5 COLLECTION OF WATER AND SEDIMENT SAMPLES

A routine water sample included two 60-mL polyethylene syringes (collected without exposure to air) for pH and Al analyses and one 500-mL polyethylene bottle for DOC, F, metals, and elements analyzed by inductively coupled plasma mass spectrometry. Additionally, water and sediment samples were collected in 2.5-L glass bottles and 60-mL Teflon jars, respectively, for mercury analyses (EPA, in prep.). Water samples were collected with a 6.2-L Van Dorn bottle at 1.5 m.

After water samples were collected, they were capped and stored in a cooler with frozen gel packs. Sediment samples for mercury analysis were placed in a separate cooler with frozen gel packs. The two syringe samples and the 500-mL aliquot of lake water were shipped from the base station to the Las Vegas processing laboratory within 24 hours from the time of collection.

3.6 FISH SURVEYS

3.6.1 <u>Sampling Gear and Effort</u>

Fish communities were sampled with four gear types: experimental gill net, modified Indiana trap net, beach seine, and hook and line (angling). Experimental gill nets consisted of five panels, each 7.6 m (25 ft) long and 1.8 m (6 ft) deep, of variable-dimension, monofilament nylon (25-, 38-, 51-, 64-, and 76-mm stretch mesh). Trap nets consisted of a 1.8 m by 0.9 m (6 ft by 3 ft) front box (19-mm stretch mesh) with two 6-m (20-ft) wings and a 15.2-m (50-ft) leader. Beach seines were 1.2 m (4 ft) deep and 7.6 m (25 ft) long of 4.8-mm woven mesh nylon. Angling was employed as a supplemental sampling procedure focusing on larger game fish, to be used for analysis of fish mercury content (EPA, in prep.). Detailed procedures and protocols for gear deployment and retrieval are outlined in the Fisheries Field Training and Operations Manual (Fabrizio and Taylor 1987).

With the exception of angling, the number of units of gear deployed varied as a function of lake area (Tables 3.1 and 3.3). Deviations from the proposed standard sampling effort occurred in some instances due to sampling problems or constraints imposed by the Michigan Department of Natural Resources or private owners. The sampling effort applied was lower than proposed in one lake each for gill nets, trap nets, and angling (Lakes 2B2-098, 2B2-100, and 2B1-039, respectively) (Table 3.1). Use of beach seines was limited by the availability of suitable shoreline areas for effective seining (i.e., shallow littoral areas without major obstructions or snags). Eleven of the 49 ELS-II lakes (22.4%) were not sampled with beach seines during the June-August survey (Table 3.1).

Table 3.3. Standard Fish Sampling Effort Per Lake

Lake Area (ha)	Experimental Gill Nets (number of overnight sets)	Trap Nets (number of overnight sets)	Beach Seines (number of 20-m hauls)	Angling (h)
<20	3	3	4	2
20-29	4	4	5	2
30-39	5	5	5	2
40-59	6	6	6	2
60-79	7	7	7	2
≥80	8	8	8	2

Gill nets and trap nets were set in the afternoon and retrieved the next morning, with one exception. In Bone Lake (2B3-023), the Michigan Department of Natural Resources requested that gill nets be set only during the day, for one day (10-13 hours per net). Nets were set for periods ranging between 10 and 29 hours, although, in most cases (87%), overnight sets lasted between 18 and 24 hours. In general, trap nets were deployed and retrieved before gill nets. Nets were tended in the same order in which they were set.

Seining and angling were conducted on the first day, usually in the afternoon. One unit of effort for the beach seine refers to one seine haul along approximately 20 m of shoreline. Each unit of effort was applied at a different sampling location. Angling effort involved two hours of hook and line fishing (one hour per each of two crew members) using Mr. Twister spinner bait lures cast from a boat at various locations around the lake. The time of day varied depending on the crew's schedule at the lake.

3.6.2 Field Measurements and Samples

Most fish collected were identified to species in the field. Specimens of questionable identity (e.g., apparent hybrids, uncommon species with limited distributions) or in taxonomically difficult groups (e.g., minnows, shiners) were preserved and returned to the base station for identification. These specimens were processed, identified, and coded to the lowest possible taxonomic level in the field, prior to preservation. The following references were used for fish identification: Scott and Crossman (1973), Eddy (1969), and Hubbs and Lagler (1947).

All individuals caught were counted by species. Partial specimens were handled by including all identifiable heads in the total count; pieces without heads and unidentifiable head segments were discarded. Numbers of fish caught were tallied by gear type, station (unit of sampling effort), and species on standard field data forms.

Game and index species were measured for length and weight and sampled for age estimation. The following were defined as game species:

walleye	Stizostedion vitreum
smallmouth bass	Micropterus dolomieui
largemouth bass	Micropterus salmoides
northern pike	Esox lucius
yellow perch	Perca flavescens
lake trout	Salvelinus namaycush
brook trout	Salvelinus fontinalis
rainbow trout	Oncorhynchus mykiss

Three species were defined as index species for mercury analyses:

yellow perch	Perca flavescens
white sucker	Catostomus commersoni
northern pike	Esox lucius

Other species were also measured for length and weight and sampled for age estimation if time permitted.

Total length measurements were tallied in 25-mm length intervals, by species and sampling unit. Individual lengths and weights were recorded and samples collected for age estimation for five fish (if available) per 25-mm length class per species. Fish were weighed using a spring balance (for individual or groups of fish > 0.5 kg) or portable electronic balance (for fish < 0.5 kg). Balances were zeroed prior to each use and checked for accuracy using a known weight at the beginning and end of each day and after every 30 fish. Weekly calibration checks were conducted with a series of known weights. Fish weight was recorded to the nearest 2 g for the spring scale and 1 g for the electronic balance; fish length was recorded to the nearest millimeter. Ten percent of the specimens (by species) were re-measured and re-weighed by a different crew member for estimates of precision (Section 4.2.1). Specimens re-weighed were not necessarily the same as those re-measured for length.

Scales, cleithra, or pectoral fin rays were collected to estimate fish age depending on the species:

walleye	scale
smallmouth bass	scale
largemouth bass	scale
northern pike	cleithrum
yellow perch	scale
lake trout	scale
brook trout	scale
rainbow trout	scale
white sucker	pectoral fin ray

Results from these analyses are presented in the report on fish mercury content (EPA, in prep.)

Selected specimens were preserved as a reference sample for the survey, including a set of representative specimens (up to three per species) for each species collected and any unidentified specimens or species of questionable identity. Species identifications were confirmed by Dr. L. Greenberg, ichthyologist, Michigan State University. No fish with obvious abnormalities were collected. Also, no species recognized by state agencies in Michigan and Wisconsin as rare, threatened, or endangered were encountered.

4. QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) procedures were implemented for all aspects of the ELS-II survey of fish community status in Subregion 2B. Major components of the QA/QC program were as follows:

- audits of field crews by supervisory personnel from Lockheed and Michigan State University to ensure compliance with the specified sampling protocol;
- a field and laboratory QA/QC program for all chemical analyses, including field and laboratory audit samples, field blanks, and field replicates;
- replicate measurements of fish length and weight and analyses for fish age estimation;
- duplicate sampling of fish communities in 10 lakes to quantify fish sampling variability (through time across the sampling period and between the two field crews); and
- rigorous data base verification and validation procedures, similar to those used during ELS-I.

4.1 WATER CHEMISTRY

The measurement methods and QA objectives for precision, accuracy, and detectability for physicochemical parameters measured during the ELS-I and ELS-II are summarized in Tables 4.1 and 4.2, respectively. The QA/QC procedures and results for the ELS-I were described in detail in Linthurst et al. (1986) and Drousé et al. (1986). Results from the ELS-II QA/QC program are summarized in Tables 4.3 and 4.4; the ELS-II procedures and protocol are described in Appendix A (Volume II).

The overall within-batch (system) precision for the sampling, processing, transportation, and analysis process for samples collected on a given day (defined as a batch) was estimated for 16 field replicates: four samples from each of four lakes. A field replicate is an additional sample collected at the lake site by the same field crew immediately after the routine sample is collected. The precision data quality objective (DQO) of 10% (Table 4.2) was achieved, except when analyte concentrations were less than ten times the required detection limit (Table 4.3).

The between-batch precision was estimated from multiple analyses of one natural and three synthetic samples analyzed on different days, i.e., within different batches (Table 4.3). The between-batch precision (expressed as the relative standard deviation) was generally larger than the within-batch precision for most parameters. The DQOs apply only to within-batch precision.

Table 4.1. **Quality Assurance Objectives for Precision, Accuracy, and Detectability, and Measurement Methods for Physicochemical Parameters Measured during ELS-I**

Parameter[a]	Units	Required Detection Limits	Precision Relative Standard Deviation Upper Limit[b] (%)	Accuracy Maximum Absolute Bias (%)	Method
Al, Total	µg/L	0.5	10 (<10) 20 (≤10)	10/20	EPA Method 202.2 (AAS)(furnace)
Al, Total Extractable	µg/L	5	10 (>10) 20 (≤10)	10/20	Extraction with 8-hydroxyquinoline into MIBK followed by AAS (furnace)
Acidity (BNC)	µeq/L	5	10	10	Titration with Gran plot
Alkalinity (ANC)	µeq/L	5	10	10	Titration with Gran plot
Ca	mg/L	0.01	5	10	EPA Method 215.1 -AAS (flame)
Cl	mg/L	0.01	5	10	Ion chromatography
True Color	Color Units[c]	0	±5[d]	—	Hatch Model CO-1 color determination
DIC	mg/L	0.05	10	10	Instrumental (similar to DOC)
DOC	mg/L	0.1	5 (>5) 10 (≤5)	10	EPA Method 415.2
F, Total	µg/L	5	5	10	Ion selective electrode
Fe	mg/L	0.01	10	10	EPA Method 236.1 - AAS (flame)
K	mg/L	0.01	5	10	EPA Method 258.1 - AAS (flame)
Mg	mg/L	0.01	5	10	EPA Method 242.1 - AAS (flame)

(continued)

Table 4.1. Continued

Parameter[a]	Units	Required Detection Limits	Precision Relative Standard Deviation Upper Limit[b] (%)	Accuracy Maximum Absolute Bias (%)	Method
Mn	mg/L	0.01	10	10	EPA Method 243.1 - AAS (flame)
Na	mg/L	0.01	5	10	EPA Method 273.1 - AAS (flame)
NH_4	mg/L	0.01	5	10	EPA Method 350.1
NO_3	mg/L	0.005	10	10	Ion chromatography
pH, Field	pH units	---	±0.1[d]	±0.1[d]	pH electrode and meter
pH, Analytical Laboratory	pH units	---	±0.05[d]	±0.1[d]	pH electrode and meter
P, Total	µg/L	2	10 (>10) 20 (>10)	10/20	USGS Method I-4600-78 or Modified USGS method
SiO_2	mg/L	0.05	5	10	USGS Method I-2700-78
SiO_4	mg/L	0.05	5	10	Ion chromatography
Specific conductance	µS/cm	e	1	5	EPA Method 120.1
Turbidity	NTU	2	10	10	Monitek Model 21 nephelometer

a Dissolved ions and metals determined, except where noted.
b Unless otherwise noted, this is the relative standard deviation for concentrations above 10 times the required detection limits.
c APHA platinum-cobalt units.
d Absolute precision goal in terms of applicable units.
e Blank must be ≤ 0.09 µS/cm.
Key: AAS = atomic absorption spectroscopy; BNC = base neutralizing capacity; DIC = dissolved inorganic carbon; Fe = iron; K = potassium; Mg = magnesium; Mn = manganese; Na = sodium.

Table 4.2. **Quality Assurance Objectives for Precision, Accuracy, and Detectability and Measurement Methods for Physicochemical Parameters Measured during ELS-II in Subregion 2B**

Parameter	Units	Required Detection Limit	Precision Relative Standard Deviation Upper Limit[a] (%)	Accuracy Maximum Absolute Bias (%)	Method
Al, total monomeric[b]	µg/L	7	10 (>10) 20 (≤10)	10 (>10) 20(≤10)	Flow injection analysis
Al, non-labile monomeric[b]	µg/L	7	10 (>10) 20 (≤10)	10 (>10) 20 (≤10)	Flow injection analysis
DOC	mg/L	0.1	5 (>5) 10 (≤5)	10	EPA Method 415.2
F, total dissolved	µg/L	5	5	10	Ion Selective Electrode
Specific conductance	µS/cm	---	1	5	Hydrolab
pH, laboratory	pH units	---	±0.01[c]	±0.05[c]	pH electrode
pH, field	pH units	---	±0.1[c]	±0.1[c]	Hydrolab

a Unless otherwise noted, this is the relative standard deviation for concentrations above 10 times the required detection limit.

b Labile monomeric Al, an estimate of the inorganic Al fraction, is calculated as the difference between total monomeric Al and non-labile monomeric Al.

c Precision and accuracy in absolute units.

Table 4.3. Estimates of Precision for Physicochemical Parameters Measured during ELS-II

Lake ID or Sample Code	N	Mean	Standard Deviation	Relative Standard Deviation (%)	Type of Precision Estimate[a]
pH **Routine Data Range: 4.45–8.74**					
2B1-048	4	4.42500	0.02082	0.47	WB
2B2-061	4	5.58750	0.02630	0.47	WB
2B2-079	4	6.30500	0.06758	1.07	WB
2B3-009	4	8.17000	0.00816	0.10	WB
FN10	11	5.10455	0.06743		BB
LS6	6	4.28167	0.06882		BB
LS7	6	6.24333	0.11396		BB
LS8	6	8.52000	0.19204		BB
Total Monomeric Al (µg/L) **Routine Data Range: 124–207**					
2B1-048	4	205.75	1.328	0.65	WB
2B2-061	4	94.50	2.159	2.28	WB
2B2-079	4	14.52	1.756	12.09[b]	WB
2B3-009	4	24.85	6.648	26.75[b]	WB
FN10	11	133.91	4.059		BB
LS6	5	16.64	2.476		BB
LS7	6	117.90	4.785		BB
LS8	5	252.16	15.615		BB
Non-Labile Monomeric Al (µg/L) **Routine Data Range: 8.2–76.4**					
2B1-048	4	13.925	1.2500	8.98	WB
2B2-061	4	74.375	2.5851	3.48	WB
2B2-079	4	17.850	1.3000	7.28	WB
2B3-009	4	17.225	3.2253	18.72[b]	WB
FN10	11	39.982	5.7616		BB
LS6	5	14.200	2.1012		BB
LS7	6	10.333	5.1329		BB
LS8	5	18.920	3.5181		BB

(continued)

Table 4.3. Continued

Lake ID or Sample Code	N	Mean	Standard Deviation	Relative Standard Deviation (%)	Type of Precision Estimate[a]
DOC (mg/L) Routine Data Range: 0.4-21.8					
2B1-048	4	0.325	0.05000	15.38[b]	WB
2B2-061	4	21.500	0.35590	1.66	WB
2B2-079	4	4.000	0.31623	7.91	WB
2B3-009	4	4.775	0.41932	8.78	WB
FN10	11	3.200	0.17889		BB
LS6	5	1.100	0.07071		BB
LS7	5	7.420	0.20494		BB
LS8	5	14.520	0.42071		BB
Total F (µg/L) Routine Data Range: 5-76					
2B1-048	4	13.750	0.9574	6.96	WB
2B2-061	4	18.750	2.6300	14.03[b]	WB
2B2-079	4	6.250	2.0616	32.99[b]	WB
2B3-009	4	46.250	1.2583	2.72	WB
FN10	11	66.273	4.2916		BB
LS6	5	8.600	2.5100		BB
LS7	6	38.000	3.2863		BB
LS8	5	72.800	6.9785		BB

a WB - Within Batch
BB - Between Batch
b Concentration of the replicates was less than 10 times the required detection limit.

Table 4.4. Estimate of Laboratory Accuracy Using Synthetic Audits

Parameter	Theoretical Value	Mean Value	Relative Difference (%)
Audit Type: LS6			
Total Monomeric Al (μg/L)	10.0	16.64	66.40
DOC (mg/L)	0.30	1.10	266.67
F (μg/L)	10.0	8.6	14.00
pH	4.50	4.282	4.85
Audit Type: LS7			
Total Monomeric Al (μg/L)	125.0	117.9	5.68
DOC (mg/L)	7.50	7.42	1.07
F (μg/L)	40.0	38.0	5.00
pH	6.50	6.243	3.95
Audit Type: LS8			
Total Monomeric Al (μg/L)	250.0	252.16	0.86
DOC (mg/L)	15.00	14.52	3.20
F (μg/L)	80.0	72.8	9.00
pH	8.50	8.520	0.23

Results from the synthetic audit samples also provide estimates of the measurement accuracy (A), calculated as the relative percent difference:

$$A = \left| \frac{\bar{X} - T}{T} \right| *100$$

where:

$\bar{X}$ = the mean measured concentration for the audit sample, and

T = the theoretical value for the audit sample.

At concentrations near the detection limit (e.g., audit sample LS6), the values for relative percent difference for total monomeric Al, DOC, and total F were quite high (14-267%) (Table 4.4). For audit samples at middle to high concentrations, on the other hand, the absolute bias was below 10% for all parameters, indicating a reasonable level of accuracy within the DQOs (Table 4.2). The accuracy of measurements of non-labile monomeric Al could not be assessed, since the theoretical levels of non-labile monomeric Al in the audit samples were not known.

4.2 FISH SURVEYS

4.2.1 Field Measurements

Duplicate measurements of fish length and weight were conducted on a random 10% sample of fish. Differences in length measurements averaged 1.4 mm (standard deviation = 1.7 mm). Weight measures differed by an average of 2.1 g (standard deviation = 5.4 g). In most cases (72%), differences in length and weight between the duplicate measurements were < 1% of the mean, indicating a high level of precision for both measurements.

4.2.2 Duplicate Fish Surveys

In order to obtain an estimate of sampling variability, 10 of the 49 lakes were sampled twice over the three-month sampling period. All 49 lakes were sampled initially (standard sample) between 8 June and 30 August 1987. Resampling of the 10 lakes for QA/QC occurred between 31 August and 12 September. In general, the two surveys per lake were conducted by different field crews. Differences in results from the duplicate surveys reflect, therefore, the combined effect of several major sources of variation, including the sampling error for the ELS-II survey protocol, any trends through time in fish catchability, and crew-to-crew differences in sampling effectiveness. Given the effort required to complete a comprehensive fish survey per lake, it was not possible to conduct sufficient sampling to separately quantify the individual components of the total error term.

Several factors were considered in selecting lakes for resampling, including (1) the need for additional fish of certain species for mercury analysis, (2) the time of the first sample, and (3) the catch in the first sample (including lakes with few or no fish as well as lakes with relatively large numbers of fish caught). Thus, the 10 lakes were not selected at random, but were chosen based on examination of results from the initial fish survey.

Four major types of data were collected on fish communities in lakes in Subregion 2B:

1. species richness, i.e., the total number of fish species caught per lake;
2. presence/absence of individual fish species, estimated from the presence or absence of the species in the catch (catch/no catch);

3. relative fish abundance, estimated from the total number of fish caught (by species) or the catch per unit of sampling effort [catch per unit effort (CPUE)]; and

4. fish size and condition, based on measurements of fish length and weight.

Results from the duplicate surveys of the 10 QA/QC lakes are discussed below for each of these indices of fish community status.

Measures of species richness were not significantly different ($p > 0.05$) for the two sample periods, based on a Wilcoxon signed rank test (Hollander and Wolfe 1973). Equal values were recorded for 7 of the 10 lakes, while in 3 lakes species richness measured in the initial sample exceeded species richness in the second sample by one to two species (Table 4.5). In addition, measures of species richness in all 49 lakes were not significantly correlated ($p > 0.05$) with either sampling sequence (date) or the total number of fish caught per lake, based on a Spearman's rank correlation (Hollander and Wolfe 1973).

Czekanowski's similarity coefficient (S_c) (Bray and Curtis 1957) was calculated as a measure of the similarity in species composition in the two samples per lake (Table 4.5):

$$S_c = \frac{2\left(X_{jk}\right)}{X_j + X_k}$$

where:

X_j = the number of species in the first sample,

X_k = the number of species in the second sample, and

X_{jk} = the number of species common to both samples.

One lake had no fish caught in either survey (S_c undefined). Five lakes had exactly the same complement of species caught in both surveys ($S_c = 1.0$), and one additional lake had $S_c = 0.91$, indicating a high degree of similarity. Of the three remaining lakes, two had $S_c = 0.67$, while one had $S_c = 0$ (Lake 2B2-078, with one fish species caught during the initial survey but no fish caught in the duplicate sample). The types of fish species present in one but not both samples varied for each lake.

The Fisher exact test (Fleiss 1981) was used to evaluate potential trends in the presence/absence (catch/no catch) data by species. Four species occurred in a sufficient number of the 10 QA/QC lakes for calculation of a valid chi-square test: yellow perch, largemouth bass, northern pike, and bluegill sunfish. In each case, the proportion of lakes containing the species did not vary significantly ($p > 0.05$) between the duplicate surveys.

Table 4.5. **Summary of Results for Species Richness from Duplicate Surveys of Ten Lakes**

Lake ID	Sample Dates	Species Richness	Coefficient of Variation[a]	Similarity Coefficient[b]
2B1-022	25 Jun	4	47.1	0.67
	1 Sep	2		
2B1-038	21 Aug	0	-	-
	11 Sep	0		
2B2-049	30 Jun	1	0	1.0
	9 Sep	1		
2B2-074	24 Jun	3	0	1.0
	2 Sep	3		
2B2-075	27 Jun	4	0	1.0
	1 Sep	4		
2B2-078	14 Jul	1	141.4	0
	3 Sep	0		
2B2-100	3 Jul	1	0	1.0
	9 Sep	1		
2B3-037	29 Jul	11	0	0.91
	12 Sep	11		
2B3-057	8 Jul	7	23.6	0.67
	4 Sep	5		
2B3-058	10 Jul	1	0	1.0
	3 Sep	1		

a Coefficent of variation calculated as the standard deviation divided by the mean for the duplicate samples, assuming a normally distributed within-lake variance.

b Czekanowski's similarity coefficient defined as two times the number of species common to both samples divided by the sum of the number of fish species caught in the first sample plus the number caught in the second sample.

All of the above analyses indicate that the sampling errors associated with measuring species richness and fish species presence/absence in the ELS-II were relatively minor and are not likely to measurably bias comparisons of fish community status among lakes.

Results from the duplicate samples for total fish catch and CPUE are summarized in Table 4.6. Given the high degree of variability in fish catch rates for angling and beach seines, only fish collected using gill nets and trap nets are included in these analyses. CPUE is calculated as the mean per net per hour fished. Coefficients of variation for CPUE calculated per hour per net tended to be equal to or less than the coefficients of variation for CPUE calculated on a per net (per overnight set) basis.

Table 4.6. **Summary of Results for Fish Catch (All Species Combined) for the Duplicate Surveys of Ten Lakes**

		Total Catch[a]		CPUE (fish/h/net)			
				Gill Net		Trap Net	
Lake ID	Sample Dates	Mean	Coefficient of Variation (%)	Mean	Coefficient of Variation (%)	Mean	Coefficient of Variation (%)
2B1-022	25 Jun	28	51.4	0.13	45.2	0.27	80.1
	1 Sep	60		0.07		0.98	
2B1-038	21 Aug	0	-	0	-	0	-
	11 Sep	0		0		0	
2B2-049	30 Jun	792	27.0	10.45	53.3	1.26	70.8
	9 Sep	538		4.73		3.80	
2B2-074	24 Jun	3000	87.5	0.50	44.5	67.23	100.5
	2 Sep	706		0.97		11.38	
2B2-075	27 Jun	129	21.5	0.83	42.5	1.12	23.1
	1 Sep	95		0.44		1.56	
2B2-078	14 Jul	1	141.4	0	-	0.01	141.4
	3 Sep	0		0		0	
2B2-100	3 Jul	204[a]	15.2	2.47	64.4	1.49	47.1
	9 Sep	253		0.93		2.98	
2B2-037	29 Jul	238	72.3	1.29	13.7	2.28	98.8
	12 Sep	77		1.06		0.40	
2B3-057	8 Jul	97	105.7	0.37	57.7	1.33	111.9
	4 Sep	14		0.16		0.16	
2B3-058	10 Jul	2403	43.7	4.91	10.0	27.52	57.2
	3 Sep	4555		4.26		64.85	

a Total catch based on gill and trap nets only. All lakes were fished with three gill nets and three trap nets each date. However, in the 3 July sample for lake 2B2-100, fish were lost from one of the three trap nets and thus could not be included in the value for total catch.

Values for total catch and CPUE in trap nets and gill nets were not significantly different ($p > 0.05$) between the two sample dates, based on the Wilcoxon signed rank test. In addition, no significant trend in fish catch over time was detected for the 49-lake data set ($p > 0.05$, Spearman's rank correlation).

The coefficient of variation for the duplicate measures of catch ranged between 15.2% and 141.4% for total catch, 9.5% and 141.4% for trap-net CPUE, and 10.0% and 64.4% for gill-net CPUE. In six of eight lakes with fish caught in both surveys in both gear types, the variance in CPUE (and coefficient of variation) for trap nets exceeded that for gill nets. The variability in fish catch (and CPUE) was also generally higher in lakes with more fish caught (Figure 4-1).

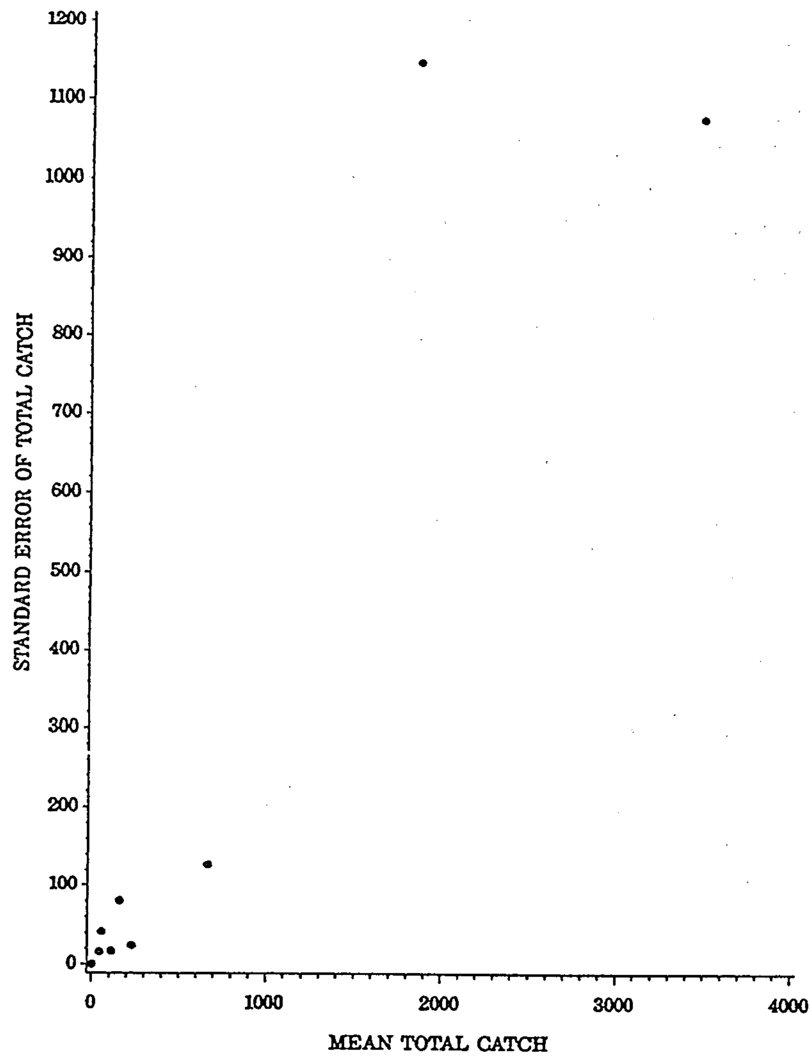


Figure 4-1. Standard error for the duplicate measures of total catch, as a function of the mean catch per lake.

Assuming a constant capture (sampling) efficiency (q), the numbers of fish caught (C) per unit sampling effort (f) (i.e., the CPUE) should be directly proportional to fish abundance in the lake (N):

$$C = q*f*N$$

A large number of factors, however, influence fish capture efficiency, many of which cannot be controlled by simply standardizing sampling methods, season, effort, and location. As a result, for a constant N, the variability in CPUE is typically quite high, making detection of patterns among lakes, or over time in a given lake, difficult (Ricker 1975, Bannerot and Austin 1983). The variability in catch and CPUE observed for the ELS-II data is not atypical of that observed in most fisheries data sets. Although the data are limited (only 10 lakes with duplicate samples), there is no indication of bias or trends in capture efficiency that might result in misinterpretation of the survey results.

Four lakes had a sufficient number of a given species caught and measured to compare estimates of fish size and condition factors from the duplicate surveys (Table 4.7): yellow perch in lake 2B2-049; yellow perch in lake 2B2-100; yellow perch and largemouth bass in lake 2B2-075; and yellow perch, largemouth bass, white sucker, and northern pike in lake 2B3-037. Differences in fish length, weight, and condition in the duplicate samples (paired by species, by lake) were not significant ($p > 0.05$, Wilcoxon signed rank test).

Table 4.7. Comparison of Fish Length, Weight, and Condition Factors for the Duplicate Surveys of Ten Lakes

Species	Lake ID	Sample Dates	N	Total Length (mm) Mean	Total Length (mm) Std. Dev.	Weight (g) Mean	Weight (g) Std. Dev.	Condition Factor[a] Mean	Condition Factor[a] Std. Dev.
Yellow Perch	2B2-049	30 Jun	44	138.6	24.8	29.7	15.0	1.03	0.08
		9 Sep	37	148.6	46.3	44.9	52.6	1.01	0.10
	2B2-075	27 Jun	32	124.7	17.3	19.9	13.0	0.95	0.06
		1 Sep	14	153.8	46.7	44.6	41.1	0.90	0.12
	2B2-100	3 Jul	42	159.0	26.1	43.6	19.3	1.02	0.08
		9 Sep	39	155.1	27.4	41.3	21.8	1.00	0.09
	2B3-037	29 Jul	43	128.6	33.0	25.8	29.5	0.97	0.10
		12 Sep	20	117.3	6.1	14.8	2.2	0.91	0.06
Largemouth Bass	2B2-075	27 Jun	7	250.6	60.9	240.7	156.8	1.31	0.12
		1 Sep	9	143.1	114.3	133.0	264.7	1.24	0.14
	2B3-037	29 Jul	6	103.8	25.4	15.0	13.4	1.15	0.17
		12 Sep	5	197.2	146.8	360.8	706.0	1.35	0.28
White Sucker	2B3-037	29 Jul	12	306.9	82.7	334.3	217.8	1.04	0.19
		12 Sep	11	284.6	70.1	299.0	217.6	1.09	0.07
Northern Pike	2B3-037	29 Jul	7	632.0	75.0	1462.9	485.7	0.56	0.06
		12 Sep	9	651.7	120.3	1675.2	1278.4	0.55	0.10

[a] Assumming isometric growth, the condition factor = $(\text{weight}*10^5)/(\text{total length})^3$ (Anderson and Gutreuter 1983)

5. LAKE PHYSICAL CHARACTERISTICS

Lakes in the Upper Peninsula of Michigan (Subregion 2B) were among the smallest (median area = 11 ha) and shallowest (median depth = 2.9 m) of any subregion sampled during the ELS-I (Linthurst et al. 1986, Eilers et al. 1988). Since very shallow lakes, considered unlikely to support a significant fishery, were excluded from the ELS-II studies in Subregion 2B (see Section 2.2.1), ELS-II median depths were somewhat greater than ELS-I medians. Median values for lake depth for the ELS-II target population and for lakes sampled during ELS-II were 6.1 and 4.3 m, respectively (Table 5.1). The exclusion of shallow lakes from the ELS-II extended to both small and large lakes, however, so lake areas from ELS-I to ELS-II remained fairly similar: median values of 11 ha for the ELS-I target population, 13 ha for the ELS-II target population, and 9 ha for lakes sampled during ELS-II (Table 5.1). Lake area and lake depth (as estimated by the ELS-I site depth) were not significantly correlated ($p > 0.05$, Spearman's rank correlation) in the ELS-I data set for Subregion 2B.

Table 5.1. Physical Characteristics of Lakes in Subregion 2B, for the ELS-I Target Population ($\hat{N}$=1050), ELS-II Target Population ($\hat{N}$=597), and the 49 Lakes Sampled During ELS-II

	ELS-I Target Population		ELS-II Target Population		Lakes Sampled in ELS-II	
Variable	**Median**	**Range**	**Median**	**Range**	**Median**	**Range**
Lake Area (ha)	11	4-578	13	4-262	9	4-262
Site Depth (m)	2.9	0.9-21.9	6.1	1.5-20.4	4.3	1.5-20.1
Elevation (m)	267	184-558	289	220-558	282	20-546
Watershed Area (ha)	115	10-54,501	91	10-54,501	60	10-54,501
Watershed-to-Lake Area Ratio	10.2	2.4-1703.2	7.0	2.4-1703.2	7.0	2.4-1703.2
Secchi Depth (m)	1.5	0.4-7.6	2.1	0.8-7.6	2.2	0.8-7.6

The majority of lakes in Subregion 2B occur at moderate elevation; median values for the ELS-I target population, ELS-II target population, and lakes sampled in ELS-II were 267, 289, and 282 m, respectively (Table 5.1). Over 75% of the lakes in each group occur at elevations below 450 m. No significant correlation was found for either lake elevation to lake area or for lake elevation to lake depth ($p > 0.05$, Spearman's rank correlation) in the ELS-I data set for Subregion 2B.

Watershed area and the watershed-to-lake area ratio provide a first-order index of the water residence time (or flushing rate) for the lake. Median values for the watershed-to-lake area ratio were 10.2 in the ELS-I target population, and 7.0 in both the ELS-II target population and the ELS-II sample (Table 5.1).

Four lake types were defined for the ELS-I:

1. drainage lakes -- lakes with surface water outlets or with both inlets and outlets;
2. reservoirs — artificial lakes as indicated by a dam at the lake outlet;
3. seepage lakes -- lakes with no permanent surface water inlets or outlets; and
4. closed lakes — lakes with a surface water inlet but no surface water outlet.

The majority of lakes in Subregion 2B (51% of the ELS-I target population) are drainage lakes. Seepage lakes are also quite common, however, comprising an estimated 37.7% of the ELS-I target population and 39.8% of the ELS-II target population. Twenty-nine of the 49 lakes sampled during the ELS-II (59.2%) were seepage lakes. Comparisons of the physical characteristics (lake area, depth, and elevation) of seepage versus nonseepage lakes for the 49 ELS-II lakes using non-parametric Wilcoxon rank sum and Kolmogorov-Smirnov tests (Hollander and Wolfe 1973) indicate no significant differences ($p > 0.05$) between the two lake groups.

During the ELS-II, in situ measurements of temperature and DO were taken at 1.5 m below the lake surface and at 1.5 m above the lake bottom. If the temperature difference between these two depths exceeded 4 °C, the lake was considered thermally stratified and additional profile data on temperature and DO were collected (Section 3.4). Lakes in the ELS-II were sampled over a three-month period from early June through the end of August. Thus, changes in the temperature and DO profile over this sampling period may hinder among-lake comparisons.

Of the 49 lakes sampled during ELS-II, 24 (49.0%) were classified as thermally stratified. Forty-one percent (n=20) of the lakes sampled had DO levels < 4 mg/L at one or more depths in the water column. Thermally stratified lakes had significantly ($p \leq 0.05$) lower minimum values for DO and a higher percentage of the water column with DO < 4 mg/L (based on Wilcoxon rank sum and Kolmogorov-Smirnov tests). In addition, thermally stratified lakes were generally deeper ($p \leq 0.05$) than nonstratified lakes.

Measures of Secchi depth, an index of lake transparency, were taken during both ELS-I (in fall 1984) and ELS-II (in summer 1987). The ELS-I and ELS-II values for Secchi depth are significantly correlated (r=0.80), although some divergence between the two samples is evident (Figure 5-1). Twelve of the ELS-II lakes had a Secchi depth exceeding the lake depth (i.e., the Secchi disk was visible on the lake bottom) and are not included in Figure 5-1.

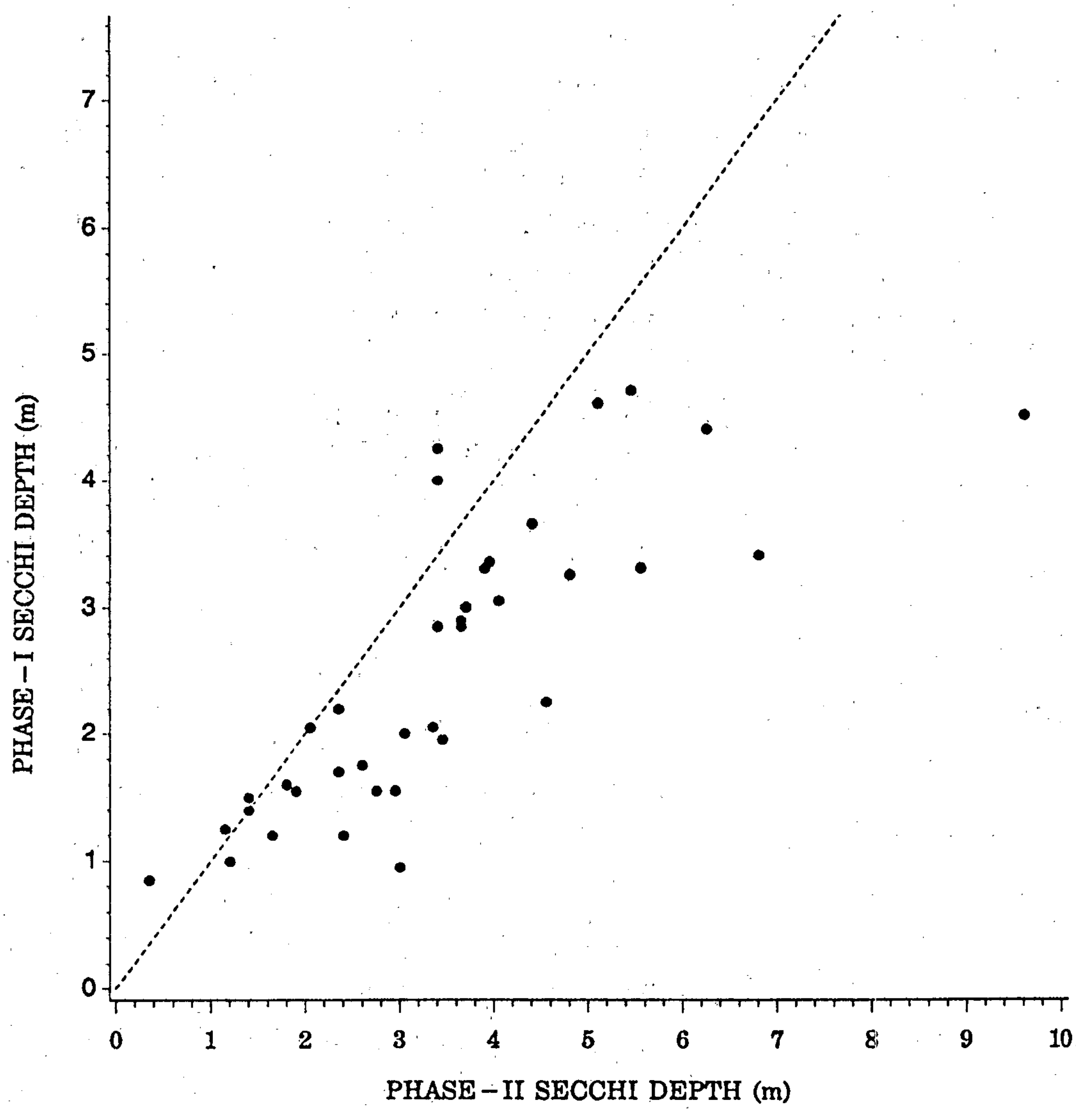


Figure 5-1. Comparison of ELS-I and ELS-II values for Secchi depth (m).

6. LAKE CHEMICAL CHARACTERISTICS

The primary objective of the ELS-I was to characterize the population of lakes expected to have low ANC in selected areas of the eastern United States. During the design phase of the ELS-I, it was recognized that the effects of both temporal and spatial variability in lake chemistry could compromise the survey results. The within-lake variability had to be minimized in order to observe differences among lakes. An attempt was made to overcome the effects of temporal and spatial variability through the use of the "index" concept. The index concept rests on two major assumptions: (1) that the chemical characteristics of a lake can be related to other lakes by sampling at a time when within-lake variability is minimized and (2) that the index sample is representative of within-lake chemistry and can be related to chemical conditions in the lake in other locations and at other times of the year.

During the ELS-I, a single water sample was collected at 1.5 m depth over the deepest part of the lake during fall overturn (i.e., the fall period when lakes were well mixed). A review of sampling seasons indicated that the fall mixing period would provide the most appropriate index period for sampling because of the low temporal and spatial variability in lake chemistry (Landers et al. 1988). It is obvious that one sample, at one location in the lake, at one time on one day, and at a specific season of a particular year is incapable of characterizing the complex chemical or biological dynamics of the sample lake. However, the purpose of the survey was to characterize geographical areas, not the dynamics of individual lakes. With this in mind, the chemical analysis for the fall 1984 sample provides a representative index of the lake chemistry that can be compared with the chemistry of other lakes sampled to detect regional patterns.

For the most part, the ELS-II data on fish communities in Subregion 2B that are reported in this document are interpreted relative to the ELS-I index of lake chemistry collected in fall 1984. Relatively few measurements of water chemistry were collected coincident with the ELS-II fish surveys in summer 1987, largely because of the high variability in lake chemistry expected to occur over the three-month sampling period (8 June to 30 August 1987). Since fish grow and live through a number of years, fish community status in 1987 would likely reflect both past and present-day physical and chemical conditions in the lake. Thus, the 1984 ELS-I measure of lake chemistry was selected as the best available index of the chemical conditions to which fish populations had been exposed. It is recognized that the ELS-I data are not direct measures of chemical conditions during those specific times and locales critical to fish population response, but it is assumed that the ELS-I index chemistry is at least correlated with these water quality values of interest.

6.1 ELS-I FALL INDEX SAMPLE

The chemical characteristics of the ELS-I and ELS-II target populations and the 49 lakes sampled during ELS-II in Subregion 2B, based on the ELS-I index sample, are summarized in Table 6.1. Lake-specific data for each of the 49 lakes sampled are presented in Appendix B.

Table 6.1. Chemical Characteristics of Lakes in Subregion 2B, for the ELS-I Target Population ($\hat{N}$=1050), ELS-II Target Population ($\hat{N}$=597), and the 49 Lakes Sampled During ELS-II

	ELS-I Target Population		ELS-II Target Population		Lakes Sampled in ELS-II	
Variable	Median	Range	Median	Range	Median	Range
ANC (µeq/L)	284	-49-2726	164	-48-2726	25	-48-2726
pH	7.10	4.43-8.58	6.93	4.43-8.25	5.75	4.43-8.25
Ca (µeq/L)	246	13-1826	179	22-1826	51	22-1826
Mg (µeq/L)	148	11-984	95	13-984	32	13-984
Na (µeq/L)	29	3-245	25	3-171	12	3-171
K (µeq/L	13	3-30	14	5-30	12	5-30
Sum Base Cations (µeq/L)	468	54-2966	282	54-2966	119	54-2966
Ext. Al (µg/L)	3	0-213	5	0-213	11	0-213
DOC (mg/L)	6.8	0.2-28.8	9	0.2-15.0	4.7	0.2-13.9
Color (PCU)	31	5-345	28	5-125	25	5-125
SO_4 (µeq/L)	78	16-281	77	16-161	67	17-161
SiO_2 (mg/L)	2.3	0.0-17.6	2.1	0.0-12.3	0.3	0.0-9.6
Total P (µg/L)	13	0-146	12	0-39	12	0-39

In ELS-I, Subregion 2B was estimated to have the highest percentage of acidic (11.3%) and low-pH lakes (9.4% with pH $\leq$ 5.0) in the Upper Midwest region (see Table 1.1). In addition, lakes selected for sampling for the ELS-II were specifically weighted to favor systems with low pH (Section 2.2.2). Forty-one percent (40.8%) of the lakes sampled were acidic, with ANC $\leq$ 0 µeq/L, and 24.5% had pH $\leq$ 5.0. Thus, the proportion of low ANC and low pH lakes among the 49 ELS-II lakes is distinctly higher than for either the ELS-I target population or the ELS-II target population (Figures 6-1a and b). As noted in Section 2.2.2, pH and Ca levels in lakes in the subregion are highly correlated (r=0.77, based on Spearman's rank correlation, p=0.0001). As a result, lakes sampled in the ELS-II also had generally lower Ca levels than either the ELS-I or ELS-II target populations (Figure 6-1c). Calcium concentrations for the 49 ELS-II lakes ranged between 22 and 1826 µeq/L (Table 6.1); 49.0% of the lakes had levels < 50 µeq/L (1.0 mg/L).

Subregion 2B also contains a relatively large population of high-ANC, high-pH lakes. Median values for the subregion (ELS-I target population) for ANC (284 µeq/L) and pH (7.10) are high relative to other subregions in the Upper Midwest (Linthurst et al. 1986). This heterogeneity in lake chemistry can be explained largely by the diversity of bedrock types and geology in the area (Rapp et al. 1987, Eilers et al. 1988). Five of the 49 lakes sampled in the ELS-II (10.2%) had ANC > 1000 µeq/L; nine (18.4%) had ANC > 500 µeq/L.

Acidic lakes in Subregion 2B are generally clear water, with a median color value of 22 PCU (ELS-I target population). Fifteen of the 20 acidic lakes sampled (75%) had color $\leq$ 25 PCU; 65% had DOC $\leq$ 4 mg/L. Higher pH lakes tend to have higher DOC (r=0.45 for the 49 ELS-II lakes; p=0.0011, Spearman's rank correlation analysis), although a high degree of scatter is evident in the relationship (Figure 2-3). Reflecting the weighted selection of low-pH lakes and the deletion of very shallow lakes (many of which had quite high DOC), the ELS-II sample and target population had a higher proportion of low DOC lakes relative to the ELS-I target population (Figure 6-1d).

As noted in Section 5, a high proportion of the lakes in Subregion 2B are seepage lakes (37.7% of the ELS-I target population, 39.8% of the ELS-II target population, and 59.2% of the lakes sampled in ELS-II). The chemical characteristics of seepage and nonseepage lakes are contrasted in Table 6.2 for the 49 ELS-II lakes. Levels of ANC, Ca, Mg, Na, sum of base cations, color, and SiO_2 were significantly lower (at α=0.05, adjusted for 14 tests, p $\leq$ 0.0036) in seepage lakes than in nonseepage lakes; differences in pH, K, DOC, and SO_4 occurred at 0.0036 < p $\leq$ 0.05. Sixteen of the 20 acidic lakes

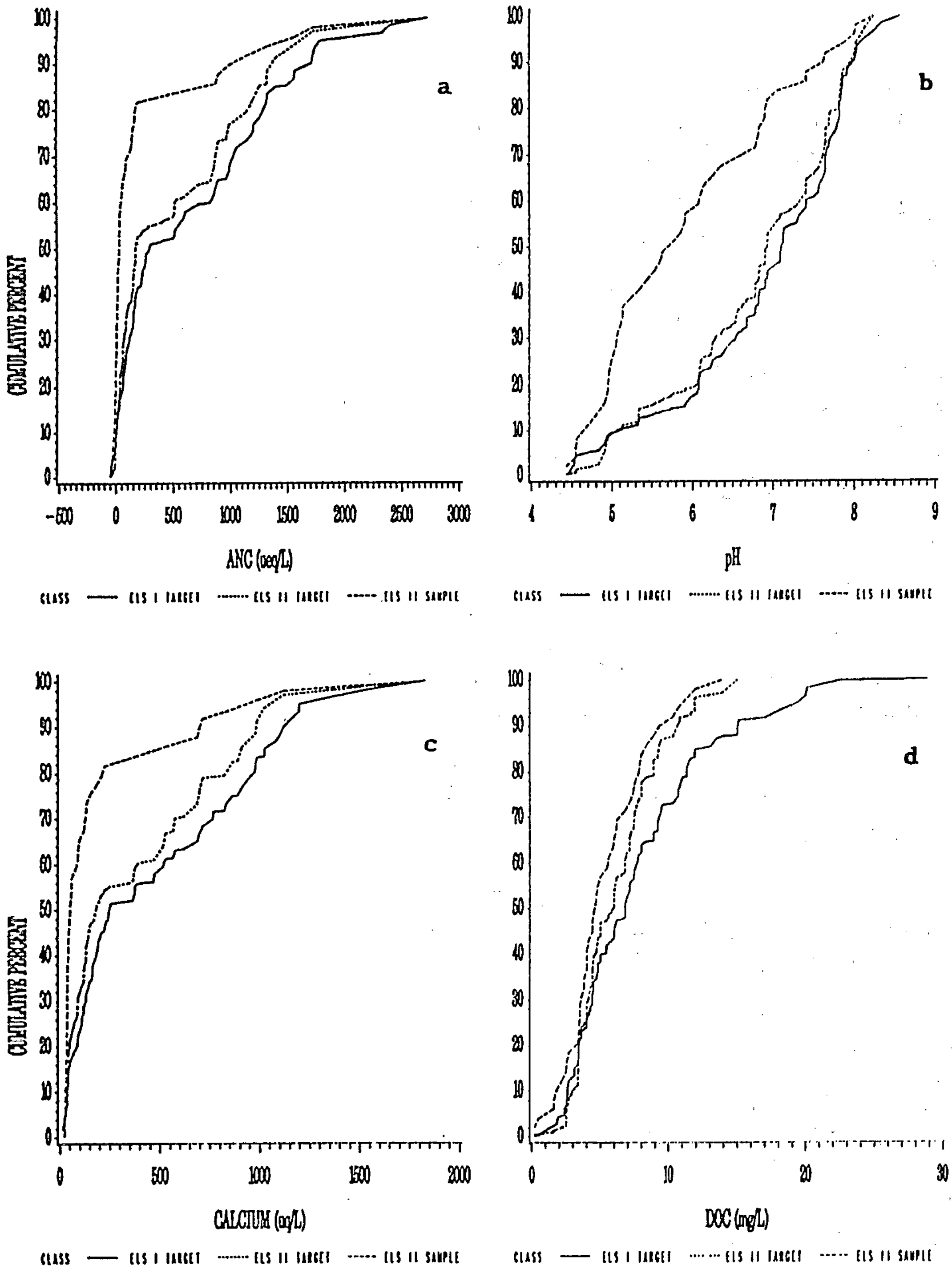


Figure 6-1. Cumulative frequency distributions for the ELS-I target population, the ELS-II target population, and the 49 lakes sampled for (a) ANC, (b) pH, (c) Ca, and (d) DOC.

Table 6.2. **Comparison of Lake Chemistry by Lake Type: Seepage Lakes versus Other Lake Types (Drainage, Reservoir, Closed) for the 49 Lakes Sampled During ELS-II**

Variable	Seepage Lakes		Other Lake Types		Test Statistics[a]	
	Median	Range	Median	Range	Wilcox.	K-S
pH	5.23	4.43-8.25	6.79	4.74-8.03	0.0052	0.0128
ANC (µeq/L)	-1	-46-1665	134	-20-2699	0.0014*	0.0227*
Inorg. Al (µg/L)	9	0-192	12	0-39	>0.05	>0.05
Ext. Al (µg/L)	11	0-213	10	0-120	>0.05	>0.05
Ca (µeq/L)	38	22-860	131	35-1826	0.0004*	0.0007*
Mg (µeq/L)	26	13-766	83	16-984	0.0005*	0.0004*
Na (µeq/L)	10	3-34	25	6-171	0.0002*	0.0004*
K (µeq/L)	10	5-21	14	5-30	0.0050	0.0074
Sum Base Cations (µeq/L)	88	50-1680	254	68-2960	0.0004*	0.0007*
DOC (mg/L)	4.0	0.2-10.3	6.5	2.5-13.9	0.0070	0.0264
Color (PCU)	21	5-80	37	10-125	0.0017*	0.0237
SO_4 (µeq/L)	60	17-144	85	48-161	0.0101	>0.05
SiO_2 (mg/L)	0.1	0-3.2	2.2	0.2-9.6	0.0001*	0.0001*
Total P (µg/L)	11	0-39	13	1-35	>0.05	>0.05

a Calculated p values for non-parametric comparisons of seepage lakes versus other lake types using the Wilcoxon rank sum (Wilcox.) and Kolmogorov-Smirnov (K-S) tests. Asterisks indicate statistical significance at α=0.05 adjusted for 14 tests, i.e., $p \leq 0.0036$.

sampled (80%) were seepage lakes. The high proportion of seepage lakes in the ELS-II sample is evident in the distinctly lower median value for SiO_2 in the 49 sample lakes than in either the ELS-I or ELS-II target populations (Table 6.1).

Concentrations of extractable (total monomeric) Al measured in ELS-I were generally quite low. An estimated 80% of the ELS-I target population had ≤ 12 µg/L (Eilers et al. 1988). Values for the 49 ELS-II lakes ranged between 0 and 213 µg/L (Table 6.1), although 85.7% of the lakes sampled had extractable Al levels ≤ 50 µg/L.

Sulfate levels in Subregion 2B (median value 78 µeq/L for the ELS-I target population) were slightly higher than for other subregions in the Upper Midwest (regional median 57 µeq/L), although lower than levels in lakes in the northeastern United States (regional median 115 µeq/L) (Linthurst et al. 1986, Eilers et al. 1988). Concentrations for the 49 ELS-II lakes ranged between 17 and 161 µeq/L, with a median value of 67. Sulfate concentrations in the 49 lakes sampled were similar to, although slightly lower than, values for the ELS-I and ELS-II target populations (Table 6.1).

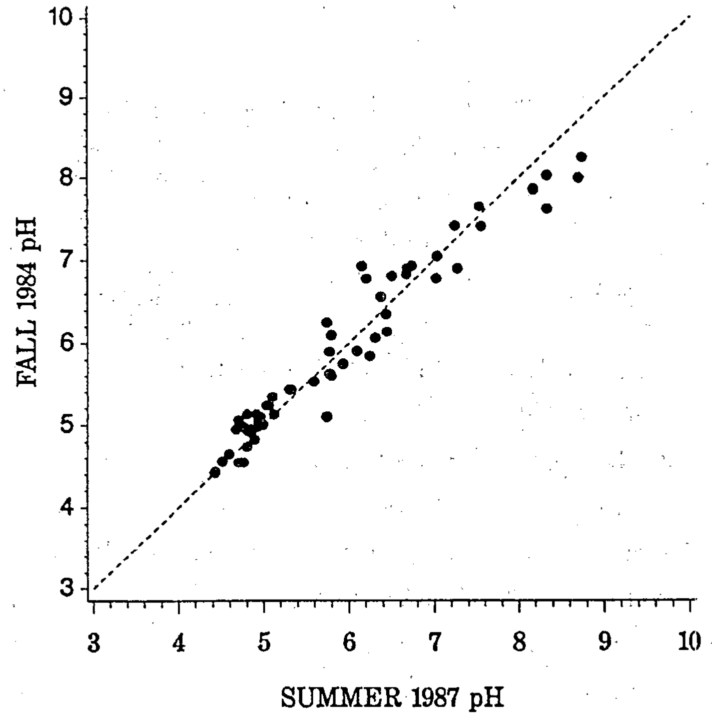
6.2 COMPARISON OF 1984 FALL INDEX WITH 1987 SUMMER CHEMISTRY

Water samples collected during the ELS-II surveys of fish communities in summer 1987 were analyzed for pH, total pyrocatechol violet (PCV) reactive Al, organic PCV reactive Al, and total F (Sections 3.5 and 4.1). In addition, pH, conductivity, temperature, and DO were measured in situ (Section 3.4). Lake-specific data for each of the 49 ELS-II lakes are presented in Appendix B. Other samples were also collected to assess concentrations of mercury and other trace metals in water and sediment; these data are discussed in a separate report evaluating mercury bioaccumulation (EPA, in prep.).

Measured values of pH and conductivity for fall 1984 (ELS-I) and summer 1987 (ELS-II) for the 49 ELS-II lakes in Subregion 2B are compared in Figure 6-2. Results for the two sampling periods were similar, with no dramatic differences for either variable between the sampling dates. Of the variables measured in both 1984 and 1987 (pH, conductivity, fluoride, and temperature), only temperature differed markedly between the two samples. As expected, temperatures measured at 1.5-m depth during summer (1987) were 5 °C to 22 °C warmer than values measured in fall (1984). None of the 49 ELS-II lakes were thermally stratified during the fall 1984 sampling, while 24 of the 49 lakes were stratified when sampled in summer 1987.

As part of EPA's Long-Term Monitoring Program, chemical conditions in 25 lakes in the Upper Peninsula of Michigan and northcentral Wisconsin have been monitored seasonally (spring, summer, and fall) since fall 1983 (Newell et al. 1987). Data on ANC, pH, and Ca for these lakes collected between 30 October 1984 and 4 November 1987 are summarized in Table 6.3 to illustrate the approximate magnitude of within-lake seasonal and year-to-year variations in water chemistry. Variations in ANC of 30 to 50 µeq/L, pH of 0.2 to 0.6 pH units, and Ca of 30 to 60 µeq/L are not atypical. However, only one lake, Lake Nevins, exhibited a detectable trend in lake chemistry (decreasing ANC, pH, and Ca) over the three-year period.

a



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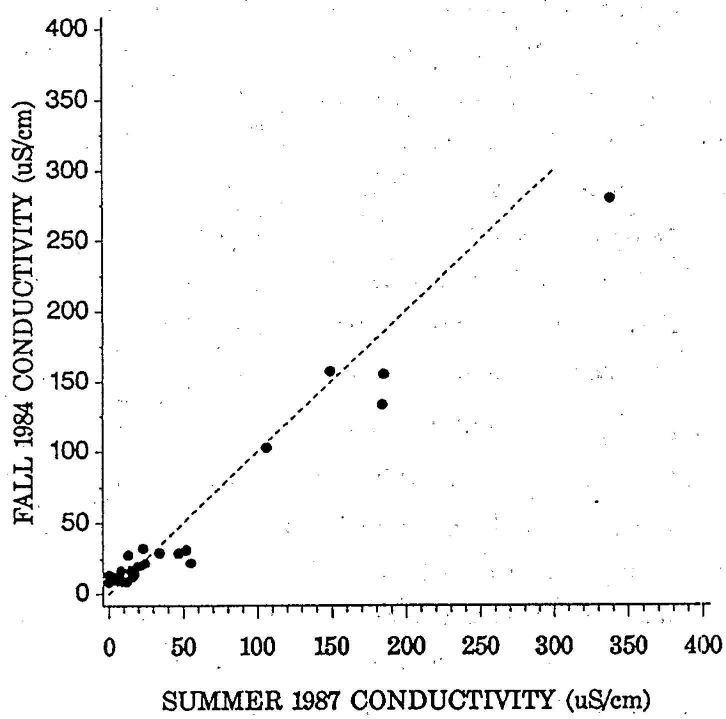

Figure 6-2. Comparison of chemical values measured in fall 1984 versus summer 1987 for the 49 ELS-II lakes in Subregion 2B, for (a) pH and (b) conductivity.

Table 6.3. **Summary of Long-Term Monitoring Data for Acid Neutralizing Capacity (ANC), Calcium (Ca), and pH from Lakes Located in the Upper Peninsula of Michigan and North Central Wisconsin**

		ANC (μeq/L)		Ca (μeq/L)		pH	
Lake Name	N	Median	Range	Median	Range	Median	Range
Johnson	9	-18	30	58	25	4.7	0.4
McNearney	9	-35	46	61	39	4.4	0.2
Bass	9	103	54	109	44	6.7	0.7
Murray	9	24	54	37	28	5.8	0.4
Buckeye	8	160	34	156	72	6.9	0.7
Stuart	8	-13	73	26	19	4.8	0.1
Cusino	8	-2	60	55	27	5.2	0.3
Nevins	9	98	111	126	63	6.7	0.5
Monocle	10	209	49	202	125	7.0	0.6
Amdrus	8	15	21	66	35	5.5	0.8
Kelly	9	-5	43	49	22	5.1	0.2
Chris Brown	10	204	63	148	93	7.0	0.6
McGrath	8	3	56	46	32	5.3	0.5
Sunset	9	23	35	67	44	6.1	0.3
Vandercook	8	13	29	60	37	6.0	0.7
Greater Bass	8	6	36	61	41	5.4	0.5
Sand	11	-2	47	79	47	5.1	0.5
Nichols	10	24	28	62	52	5.8	0.6
Little Rock	14	10	45	43	43	5.9	1.2
Long	8	16	36	53	30	5.9	0.5
Clear	8	-6	20	40	29	4.9	0.4
Camp Twelve	9	-8	66	40	37	5.2	0.6
Lake Clara	9	39	30	84	44	6.4	0.9
Luna	9	7	42	61	43	5.7	0.9
Sugar Camp	8	-7	45	77	51	5.2	0.2

6.3 ALUMINUM CHEMISTRY

Inorganic (labile monomeric) Al has been identified as a potentially important toxicant in acidic waters in at least some regions (Driscoll et al. 1980, Wright et al. 1980, LaZerte 1984). Levels of inorganic Al were not measured during ELS-I. Thus, to supplement the ELS-I data base, measurements of Al chemistry were conducted in summer 1987 (Sections 3.5 and 4.1). The results indicate quite low levels (< 60 µg/L) of inorganic Al in all but one ELS-II lake in Subregion 2B (Lake 2B1-048, McNearney Lake, with 192 µg/L and pH 4.43) (Figure 6-3). Given that the values for pH measured in fall 1984 and summer 1987 were similar (Figure 6-2), levels of inorganic Al measured in summer 1987 are used directly with ELS-I chemistry values (for all other chemical variables) in assessing the association between fish communities and lake chemistry (see Section 8).

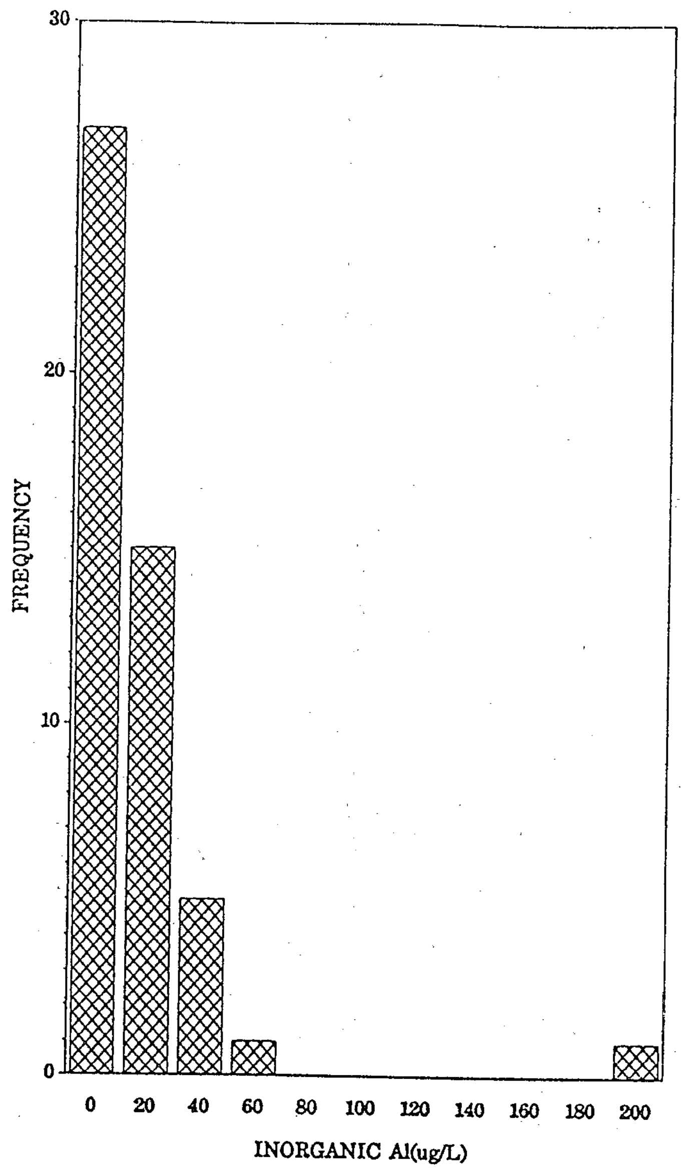

Figure 6-3. Distribution of inorganic aluminum in ELS-II lakes in Subregion 2B.

7. FISH COMMUNITY STATUS

Unless otherwise noted, the data and analyses presented in this section are based on a single sample per lake, collected between 8 June and 30 August 1987. Results from the duplicate surveys on 10 lakes, conducted between 31 August to 12 September 1987, are discussed and analyzed in Section 4.2. Measures of species richness and fish species presence/absence are discussed in Section 7.1; numbers of fish caught (indices of relative abundance) in Section 7.2; and information on fish size and condition factors in Section 7.3. The survey data for each lake are summarized in Appendix B.

7.1 FISH SPECIES DISTRIBUTION

Thirty-one fish species were caught in surveys of 49 lakes in Subregion 2B (Table 7.1).[1] Yellow perch was the most common species, collected in 31 lakes. Seven other species occurred in more than 10 lakes, in decreasing order of frequency: largemouth bass, bluegill sunfish (Lepomis macrochirus), pumpkinseed sunfish (Lepomis gibbosus), white sucker, brown bullhead (Ictalurus nebulosus), golden shiner (Notemigonus crysoleucas), and northern pike. The remaining 23 species were caught in less than 10 lakes, although some of these species were collected in large numbers in individual lakes (see Section 7.2). The types of fish caught in this survey are similar to those reported for lakes in other areas of the Upper Midwest (Wiener and Eilers 1987).

The number of fish species caught per lake varied between 0 and 13, with a median of 3 (Table 7.2). Two lakes (No Name, 2B1-038, and McNearney Lake, 2B1-048) had no fish caught. A third lake (Bohmier Lake, 2B2-078) had one fish species (brook stickleback, Culaea inconstans) caught during the initial survey but no fish caught during the duplicate QA/QC survey in September (Section 4.2). Six lakes (12.2%) had only yellow perch caught. Game fish, as defined in Section 3.6.2, were collected in 36 of the 49 lakes (73.5%).

In 11 lakes, beach seines could not be used because of the lack of suitable littoral area for seining (i.e., with relatively smooth substrate and free of obstructions and aquatic vegetation). In 16 of the 38 lakes in which beach seines were used (42%), beach

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1 Includes a bluegill-pumpkinseed sunfish hybrid as a separate species. In no lakes were all three caught: bluegill sunfish, pumpkinseed sunfish, and the hybrid sunfish. Fish caught in lake 2B3-031 identified as brook trout were later determined to be splake (a hybrid cross between brook trout and lake trout) based on stocking records from the Michigan Department of Natural Resources, but are treated as brook trout in these analyses.

Table 7.1. Fish Species Caught and Frequency of Occurrence

Family and Species	Common Name	No. of Lakes in Which Species Caught: All Gear Types	Gill Net, Trap Net, & Angling	Gill Net & Trap Net
Salmonidae				
Salvelinus fontinalis	brook trout	4	4	4
Salvelinus namaycush	lake trout	1	1	1
Osmeridae				
Osmerus mordax	rainbow smelt	1	1	1
Umbridae				
Umbri limi	central mudminnow	6	5	5
Esocidae				
Esox lucius	northern pike	11	11	11
Cyprinidae				
Semotilus atromaculatus	creek chub	5	4	4
Notemigonus crysoleucas	golden shiner	12	12	12
Notropis cornutus	common shiner	7	7	7
Notropis atherinoides	emerald shiner	1	0	0
Notropis emiliae	pugnose minnow	1	0	0
Pimephales promelas	fathead minnow	3	2	2
Pimephales notatus	bluntnose minnow	7	2	2
Hybognathus hankinsoni	brassy minnow	1	0	0
Chrosomus neogaeus	finescale dace	6	5	5
Catostomidae				
Catostous commersoni	white sucker	14	14	14
Ictaluridae				
Ictalurus nebulosus	brown bullhead	13	13	13
Cyprinodontidae				
Fundulus diaphanus	banded killifish	1	0	0
Gasterosteidae				
Culaea inconstans	brook stickleback	3	3	3
Centrarchidae				
Ambloplites rupestris	rock bass	4	4	4
Micropterus dolomieui	smallmouth bass	5	4	4
Micropterus salmoides	largemouth bass	17	16	13
Lepomis gibbosus	pumpkinseed sunfish	15	15	15
Lepomis macrochirus	bluegill sunfish	16	13	13
Lepomis spp.	sunfish hydrid	3	3	3
Pomoxis nigromaculatus	black crappie	3	3	2
Percidae				
Perca flavescens	yellow perch	31	31	31
Stizostedion vitreum	walleye	2	2	2
Percina caprodes	logperch	1	0	0
Etheostoma nigrum	johnny darter	3	0	0
Etheostoma exile	Iowa darter	7	1	1
Cottidae				
Cottus bairdi	mottled sculpin	1	1	1

Table 7.2. Species Richness, by Lake, for the 49 Lakes Sampled in Subregion 2B

Lake ID	Species Richness: All Gear Types	Gill Net, Trap Net & Angling	Gill Net & Trap Net
2B1-016	-	2	1
2B1-022	-	4	4
2B1-035	1	1	1
2B1-038	0	0	0
2B1-039	-	2	2
2B1-040	-	2	2
2B1-041	6	5	5
2B1-042	1	1	1
2B1-047	2	2	2
2B1-048	0	0	0
2B1-052	1	1	1
2B1-061	3	3	3
2B1-064	1	1	1
2B1-066	1	1	1
2B2-004	-	3	3
2B2-007	4	3	3
2B2-024	7	6	6
2B2-038	8	5	5
2B2-044	3	3	3
2B2-049	-	1	1
2B2-055	1	1	1
2B2-061	6	5	5
2B2-074	3	3	3
2B2-075	-	4	4
2B2-078	1	1	1
2B2-079	1	1	1
2B2-082	4a	-	3
2B2-090	2	2	2
2B2-098	-	4b	3b
2B2-100	1c	1c	1c
2B3-007	4	3	3
2B3-008	-	4	4
2B3-009	12	10	10
2B3-012	8	6	6
3B3-013	3	3	3

(continued)

Table 7.2. Continued

Lake ID	Species Richness: All Gear Types	Species Richness: Gill Net, Trap Net & Angling	Species Richness: Gill Net & Trap Net
2B3-020	-	7	7
2B3-023	9	9	9
2B3-027	4	2	2
2B3-028	7	6	5
2B3-030	4	4	4
2B3-031	13	9	9
2B3-034	9	7	7
2B3-037	11	9	9
2B3-051	1	1	1
2B3-055	11	8	8
2B3-056	2	2	2
2B3-057	-	7	6
2B3-058	1	1	1
2B3-071	9	8	8

a Lake not sampled by angling.
b Only one gill net fished.
c Only two (rather than three) trap nets fished.

seines collected additional species not caught with the other three gear types (Table 7.2). Small fish, particularly cyprinid (minnow) and darter species, were frequently collected only with beach seines (Table 7.1). Given that beach seines were not used in a relatively high percentage (22.4%) of lakes and that beach seines often collected fish species not caught with other gear types, species richness is calculated based on the catch from gill nets, trap nets, and angling, unless otherwise noted. Results from the beach seines are used only for comparisons among the 38 lakes in which beach seines were used. Species richness (based on fish caught with gill nets, trap nets, and angling) ranged between 0 and 9 species per lake, with a median of 3 (Table 7.2, Figure 7-1).

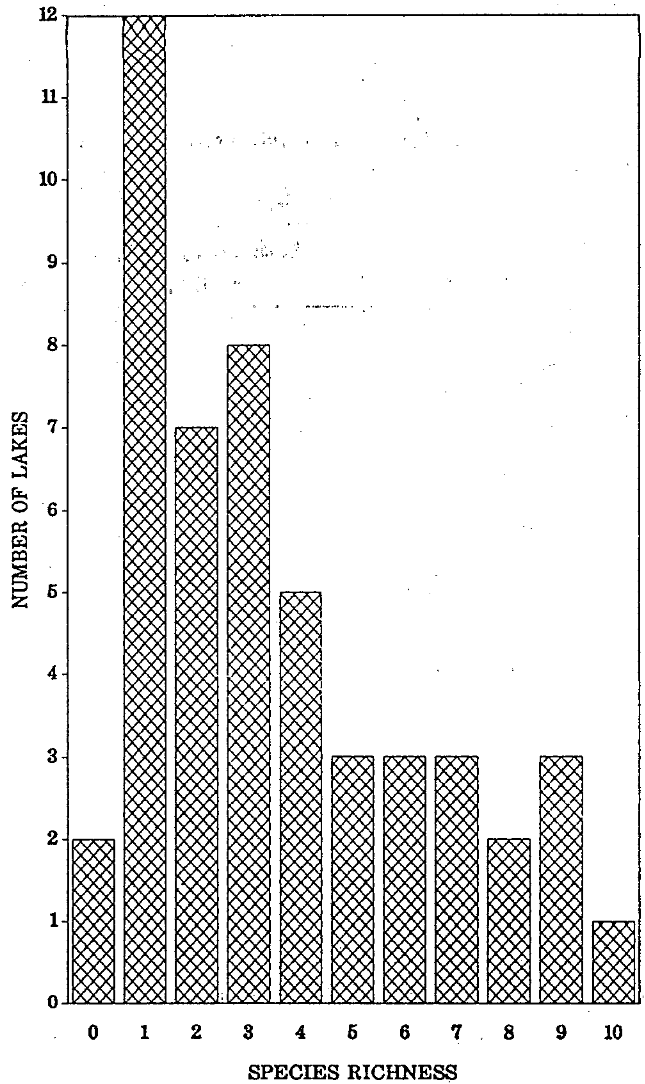


Figure 7-1. Distribution of species richness values among the 49 ELS-II lakes.

The effectiveness of each gear type in detecting fish presence varied somewhat among fish species (Tables 7.1 and 7.3). Salmonids (brook trout and lake trout) and largemouth and smallmouth bass were caught more frequently in gill nets than in trap nets, while the pumpkinseed sunfish, black crappie, and several minnow species were caught more often in trap nets than in gill nets. As noted above, beach seines were generally more effective at collecting cyprinids and darters than were other gear types. Angling was the least effective gear overall for detecting fish species presence, although the limited effort (total 2 man-hours) and time of day fished may have decreased angling efficiency. In a few lakes, largemouth bass (n=3 lakes) and black crappie (n=1 lake) were collected only with angling (Table 7.1).

Table 7.3. **Relative Gear Efficiency for Each Species, Calculated as the Percent of Lakes for Which the Gear Detected Each Species Out of the Total Number of Lakes in Which the Species Was Caught Regardless of the Gear Used**

Species	Relative Gear Efficiency (%)			
	Gill Net	Trap Net	Angling	Beach Seine[a]
Brook Trout	100	0	0	0
Lake Trout	100	0	0	0
Rainbow Smelt	100	0	0	0
Central Minnow	17	83	0	67
Northern Pike	82	55	36	0
Creek Chub	60	60	20	40
Golden Shiner	75	75	0	25
Common Shiner	57	43	0	29
Emerald Shiner	0	0	0	100
Pugnose Minnow	0	0	0	100
Fathead Minnow	0	67	0	33
Bluntnose Minnow	14	29	0	100
Brassy Minnow	0	0	0	100
Finescale Dace	17	67	0	67
White Sucker	93	79	0	0
Brown Bullhead	77	92	0	8
Banded Killifish	0	0	0	100
Brook Stickleback	0	100	0	100
Rock Bass	100	75	25	25
Smallmouth Bass	60	20	0	40
Largemouth Bass	71	24	29	24
Pumpkinseed Sunfish	33	100	0	27
Bluegill Sunfish	62	81	12	44
Sunfish Hybrid	33	67	0	0
Black Crappie	33	67	33	0
Yellow Perch	97	90	19	29
Walleye	50	50	0	0
Logperch	0	0	0	100
Johnny Darter	0	0	0	100
Iowa Darter	0	14	0	86
Mottled Sculpin	100	0	0	0

a Only 38 of the 49 lakes were sampled with beach seines.

7.2 TOTAL CATCH AND CATCH PER UNIT EFFORT

The numbers of fish caught per lake and the CPUE potentially may serve as indices of fish abundance, as discussed in Section 4.2. Catch rates from angling and beach seines tend to be highly variable. Thus, only fish caught in gill nets and traps nets are included in calculations of total catch and CPUE. Catch per unit effort is computed as the number of fish caught per hour per net, averaged over all the nets per lake for a given gear type (gill net or trap net).

Values for total catch and CPUE, summed across all fish species, are provided in Table 7.4 for each lake. Total catch ranged between 0 and 3000 fish, with a median of 210. Gill-net CPUE ranged between 0 and 16.2 fish/h/net, with a median of 0.83; trap-net CPUE from 0 to 67.2 fish/h/net, with a median of 1.33. For each of these variables, the distribution of values among the 49 lakes is highly skewed and non-normal ($p=0.0001$, Shapiro-Wilk test statistics, Conover 1980) (Figure 7-2).

Table 7.4. Total Catch and Catch Per Unit Effort (CPUE) by Lake, All Fish Species Combined

Lake ID	Total Catch	CPUE (fish/h/net)	
		Gill Net	Trap Net
2B1-016	6	0.03	0.06
2B1-022	28	0.13	0.27
2B1-035	407	2.45	3.40
2B1-038	0	0.00	0.00
2B1-039	378	3.53	1.76
2B1-040	138	1.35	0.74
2B1-041	218	1.12	1.52
2B1-042	1	0.00	0.01
2B1-047	748	3.03	9.67
2B1-048	0	0.00	0.00
2B1-052	1082	6.39	9.52
2B1-061	29	0.43	0.03
2B1-064	312	1.22	3.30
2B1-066	1	0.00	0.02
2B2-004	1058	0.60	21.17
2B2-007	210	0.82	2.30
2B2-024	344	0.23	5.24
2B2-038	364	1.33	5.02

(continued)

Table 7.4. Continued

Lake ID	Total Catch	CPUE (fish/h/net) Gill Net	Trap Net
2B2-044	260	3.27	0.55
2B2-049	792	10.45	1.26
2B2-055	25	0.00	0.44
2B2-061	686	3.58	3.70
2B2-074	3000	0.50	67.23
2B2-075	129	0.83	1.12
2B2-078	1	0.00	0.01
2B2-079	386	5.21	1.82
2B2-082	33	0.36	0.14
2B2-090	1540	16.19	11.38
2B2-098	51	1.02	0.31
2B2-100	204	2.47	1.49
2B3-007	52	0.48	0.42
2B3-008	266	0.11	3.92
2B3-009	187	1.01	0.18
2B3-012	86	0.02	1.23
2B3-013	630	6.44	3.62
2B3-020	456	3.91	2.75
2B3-023	262	2.70	0.42
2B3-027	32	0.41	0.02
2B3-028	118	0.73	0.19
2B3-012	86	0.02	1.23
2B3-013	630	6.44	6.62
2B3-020	456	3.91	2.76
2B3-023	262	2.70	0.42
2B3-027	32	0.41	0.03
2B3-028	118	0.73	0.19
2B3-030	502	0.75	6.51
2B3-031	373	1.32	1.84
2B3-034	53	0.60	0.33
2B3-037	238	1.28	2.27
2B3-051	3	0.00	0.05
2B3-055	232	0.89	2.53
2B3-056	153	0.00	2.32
2B3-057	97	0.37	1.33
2B3-058	2403	4.91	27.52
2B3-071	163	1.46	0.67

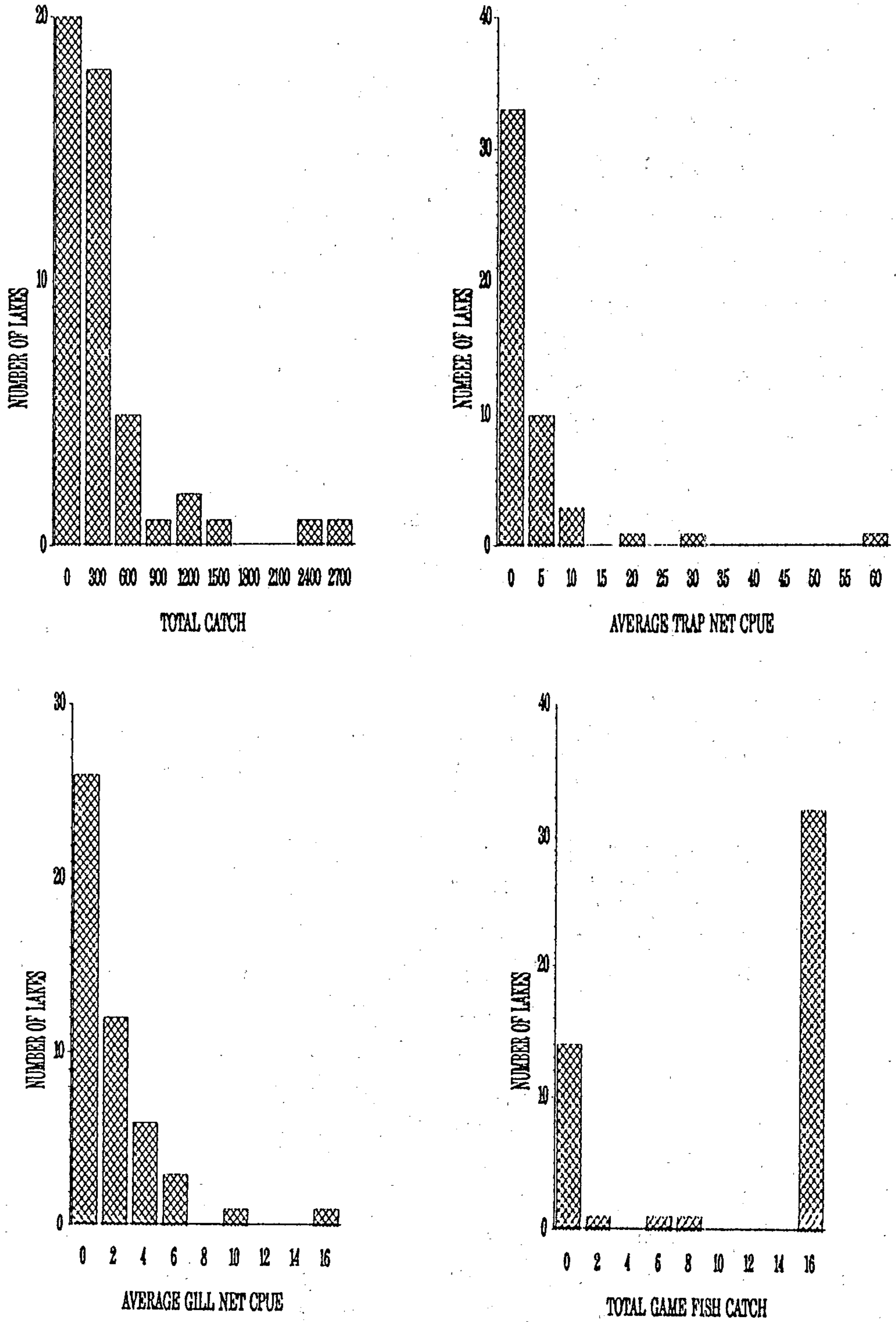


Figure 7-2. **Distribution of total catch, gill-net CPUE, and trap-net CPUE for all species, and total catch for game species for the 49 ELS-II lakes.**

Values for total catch and CPUE by fish species are summarized in Table 7.5, for those lakes in which each species was caught. Seven species had over 100 fish caught (in gill nets and trap nets) in at least one lake: golden shiner (maximum number caught per lake, 2318), brown bullhead (maximum 2403), yellow perch (maximum 1538), common shiner (maximum 1013), finescale dace (maximum 671), bluegill sunfish (maximum 458), and white sucker (maximum 229). In addition, creek chub and bluntnose minnow were caught in large numbers in beach seines in some lakes (maximum number caught per lake in all four gear types combined: creek chub 340; bluntnose minnow 279). For the 35 lakes with game fish caught in gill nets and trap nets, total catch ranged between 3 and 1538; gill-net and trap-net CPUE from 0.02 to 16.2 and 0.01 to 11.4 fish/h/net, respectively.

A Wilcoxon signed rank test was conducted to compare fish CPUE in gill nets versus trap nets (for all fish species combined, for game fish, and for each of the fish species caught in more than 10 lakes). No differences between gill nets and trap nets were detected ($p > 0.05$) for yellow perch, white sucker, golden shiner, and all species combined. Gill-net CPUE exceeded trap-net CPUE ($p \leq 0.05$) for largemouth bass, northern pike, and game fish as a group, while trap-net CPUE exceeded gill-net CPUE for brown bullhead, bluegill sunfish, and pumpkinseed sunfish.

7.3 FISH SIZE AND CONDITION FACTORS

Length-frequency histograms, by species, combined across all lakes and all gear types (including duplicate samples where available), are presented in Figure 7-3 for the six target and index species with >10 fish caught (brook trout, northern pike, white sucker, smallmouth bass, largemouth bass, and yellow perch). Data for individual lakes, by species, are summarized in Appendix B. Fish age estimates and associated analyses of fish growth rates are discussed in the report on fish mercury bioaccumulation (EPA, in prep.).

Fish condition factors reflect the relationship between fish weight and fish length. The larger the condition factor, the heavier the fish for a given length, and presumably the healthier the fish. The condition factor, K, is often calculated as follows, assuming isometric growth (Anderson and Gutreuter 1983):

$$K = \frac{(weight * 10^5)}{(total\, length)^3}$$

Table 7.5. **Summary of Total Catch and Catch Per Unit Effort (CPUE) for Selected Species, for Lakes where the Fish Species Was Caught with Gill Nets or Trap Nets**

				CPUE (fish/h/net)			
		Total Catch		Gill Nets		Trap Nets	
Species/Group	No. Lakes	Median	Range	Median	Range	Median	Range
Game Fish	35	93	3-1538	0.98	0-16.17	0.30	0-11.37
Cyprinids	17	39	4-2989	0.08	0-1.48	0.42	0-66.99
Brook Trout	4	8	3-28	0.09	0.04-0.50	0	0-0
Lake Trout	1	2	2-2	0.01	0.01-0.01	0	0-0
Rainbow Smelt	1	41	41-41	0.25	0.25-0.25	0	0-0
Central Mudminnow	5	9	1-25	0	0-0.13	0.05	0.02-0.44
Northern Pike	11	7	1-43	0.06	0-0.52	0.01	0-0.03
Creek Chub	4	4.5	1-20	0.03	0-0.07	0.04	0-0.22
Golden Shiner	12	36	1-2318	0.14	0-1.41	0.34	0-51.73
Common Shiner	7	4	1-1013	0.02	0-0.26	0	0-20.92
Fathead Minnow	2	7	4-10	0	0-0	0.13	0.06-0.21
Bluntnose Minnow	2	12.5	10-15	0.01	0-0.02	0.20	0.18-0.22
Finescale Dace	5	14	1-671	0	0-0.03	0.25	0-15.26
White Sucker	14	30	2-229	0.20	0-1.54	0.06	0-2.68
Brown Bullhead	13	29	1-2403	0.06	0-4.91	0.27	0-27.52
Brook Stickleback	3	1	1-1	0	0-0	0.01	0.01-0.02
Rock Bass	4	21	11-25	0.08	0.04-0.14	0.09	0-0.27
Smallmouth Bass	4	1.5	1-17	0.01	0-0.02	0	0-0.10
Largemouth Bass	13	3	1-29	0.04	0-0.42	0	0-0.06
Pumpkinseed	15	8	1-63	0	0-0.59	0.08	0.01-0.73
Bluegill	13	52	2-458	0.08	0-0.70	0.27	0.02-6.45
Sunfish Hybrid	3	2	2-38	0	0-0.03	0.04	0-0.60
Black Crappie	2	6	1-11	0.09	0-0.18	0.02	0.01-0.02
Yellow Perch	31	116	2-1538	0.98	0-16.17	0.47	0-11.37
Walleye	2	4.5	1-8	0.05	0-0.10	0.01	0.01-0.01
Iowa Darter	1	1	1-1	0	0-0	0.01	0.01-0.01
Mottled Sculpin	1	1	1-1	0.01	0.01-0.01	0	0-0

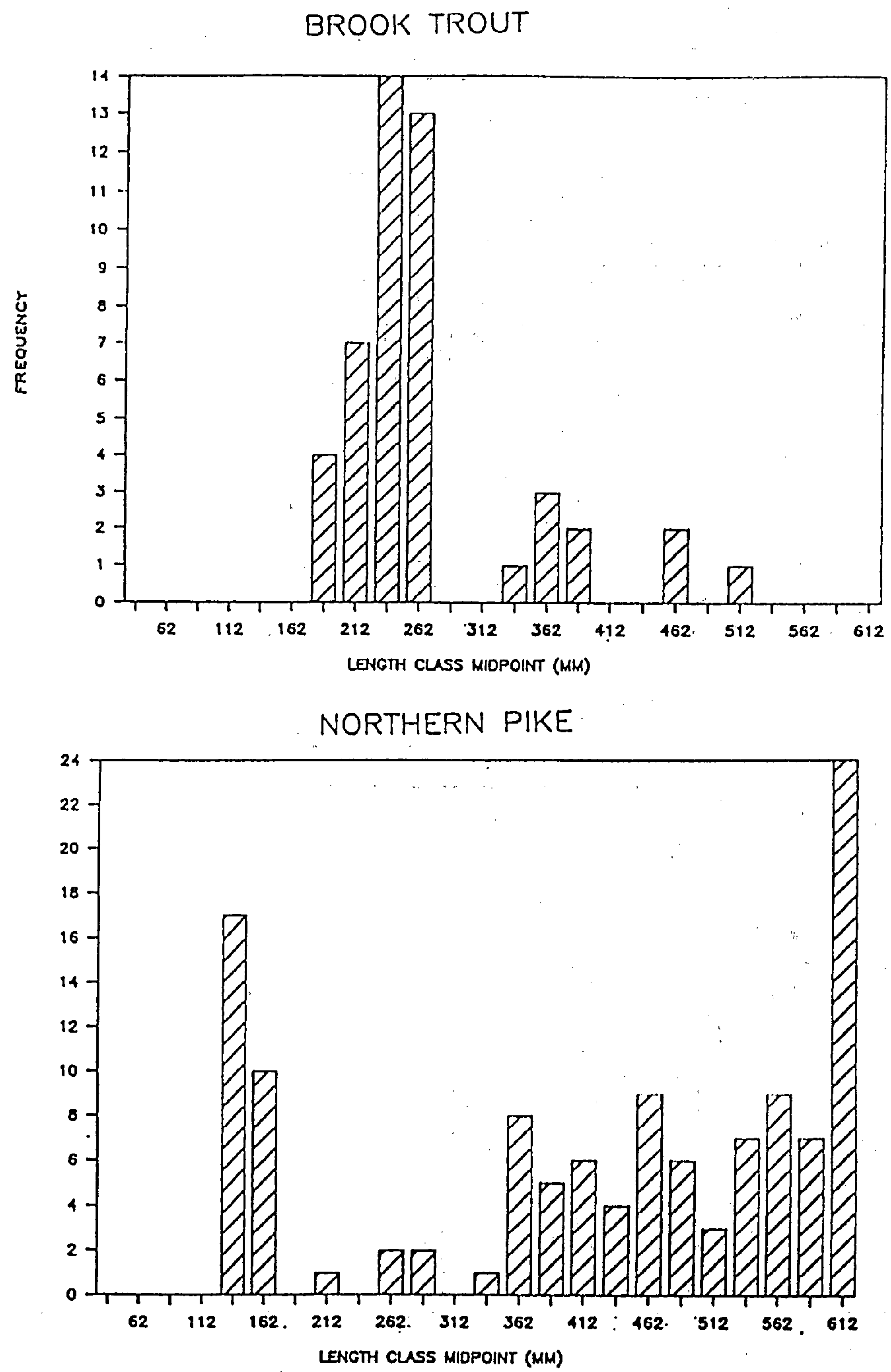
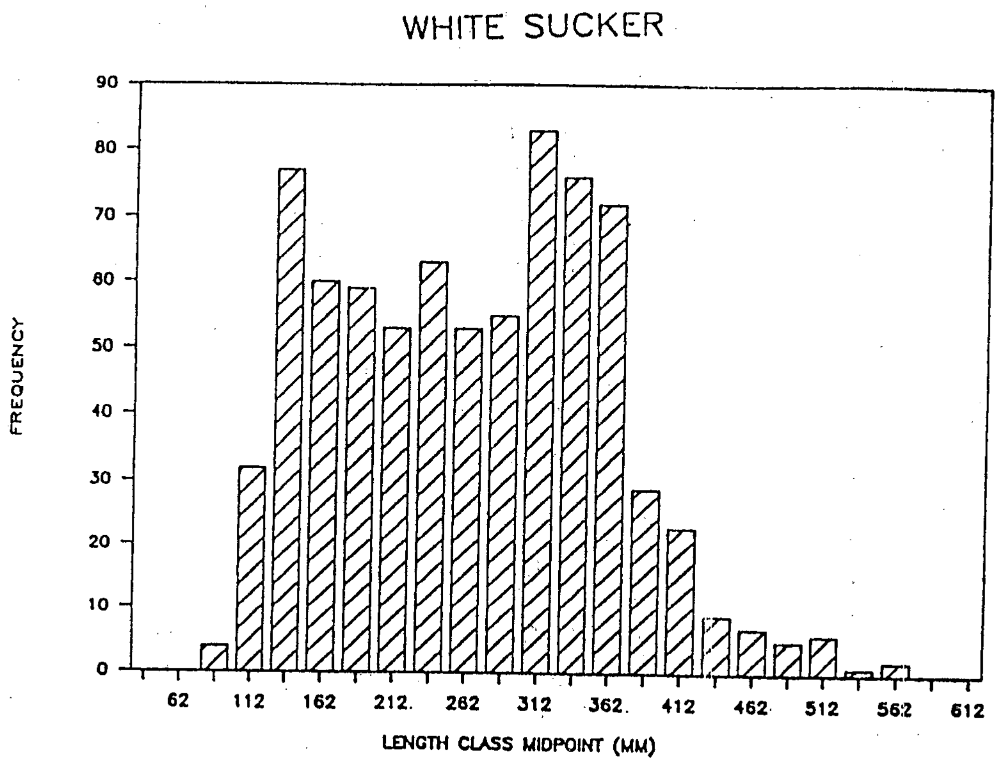


Figure 7-3. Length-frequency histograms, by species, for all fish caught in all gear types in all lakes.



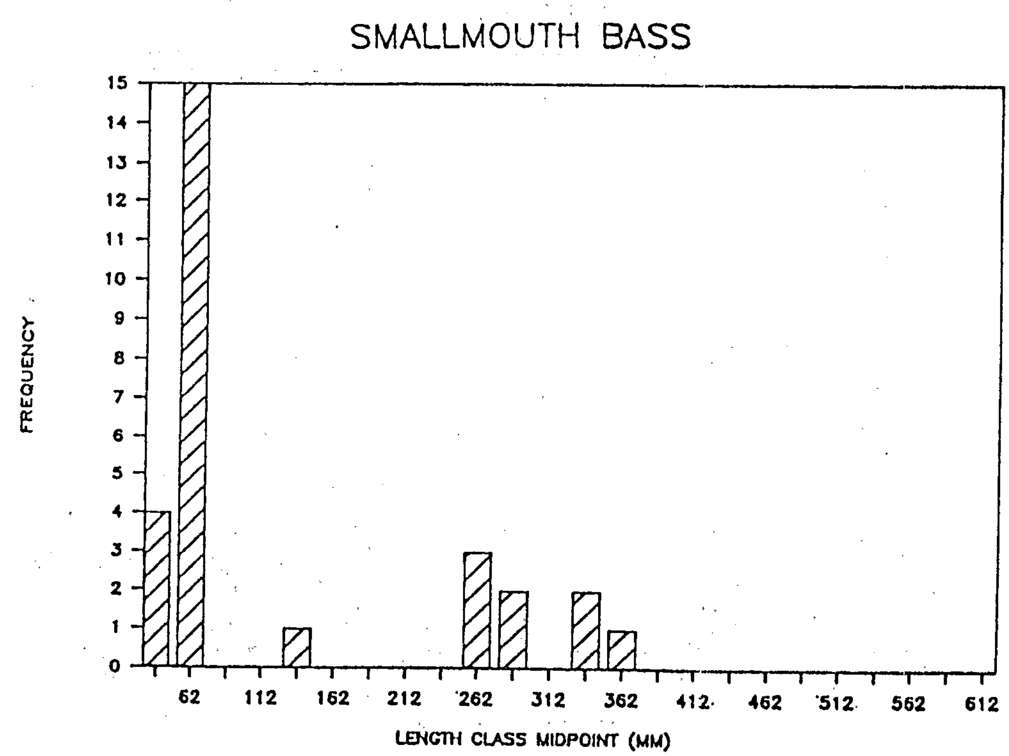
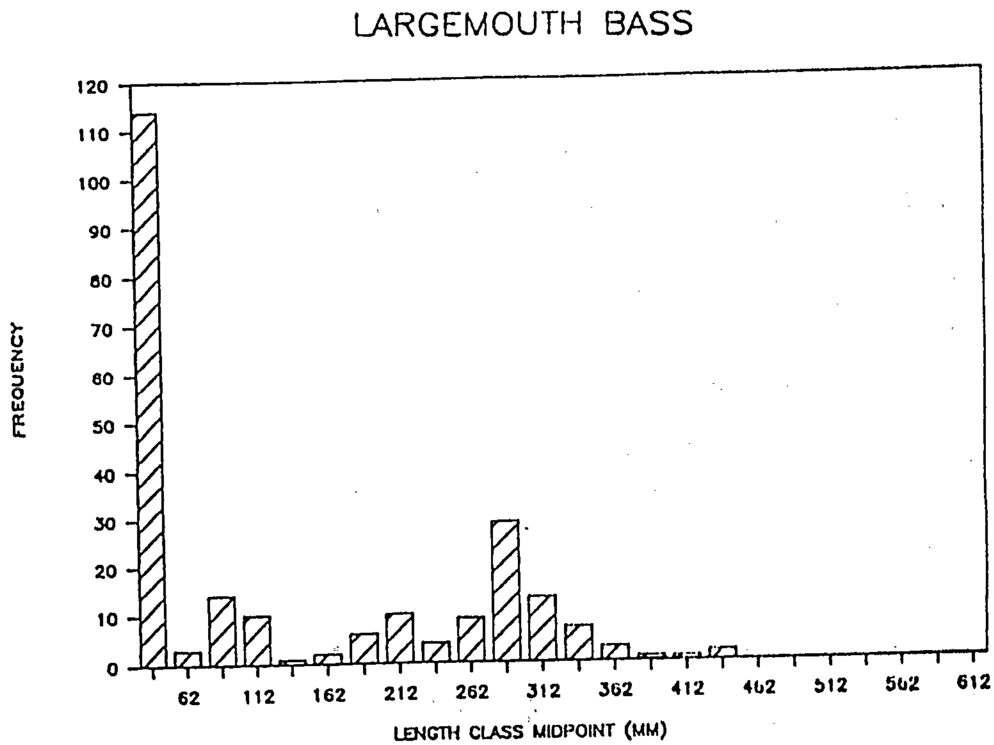


Figure 7-3. Continued



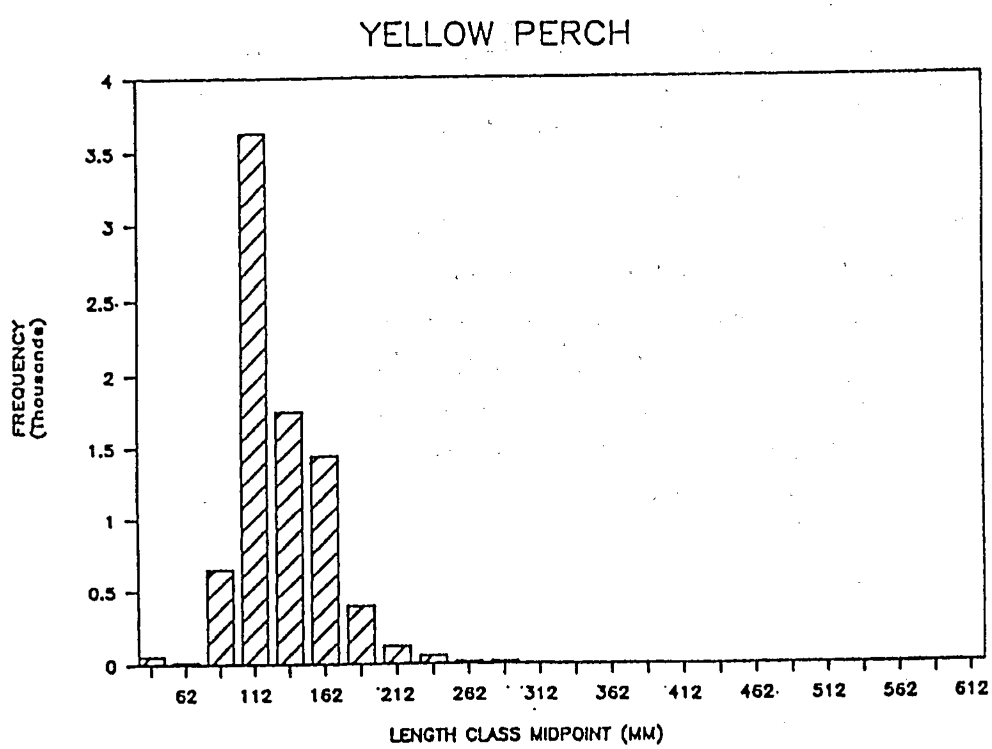
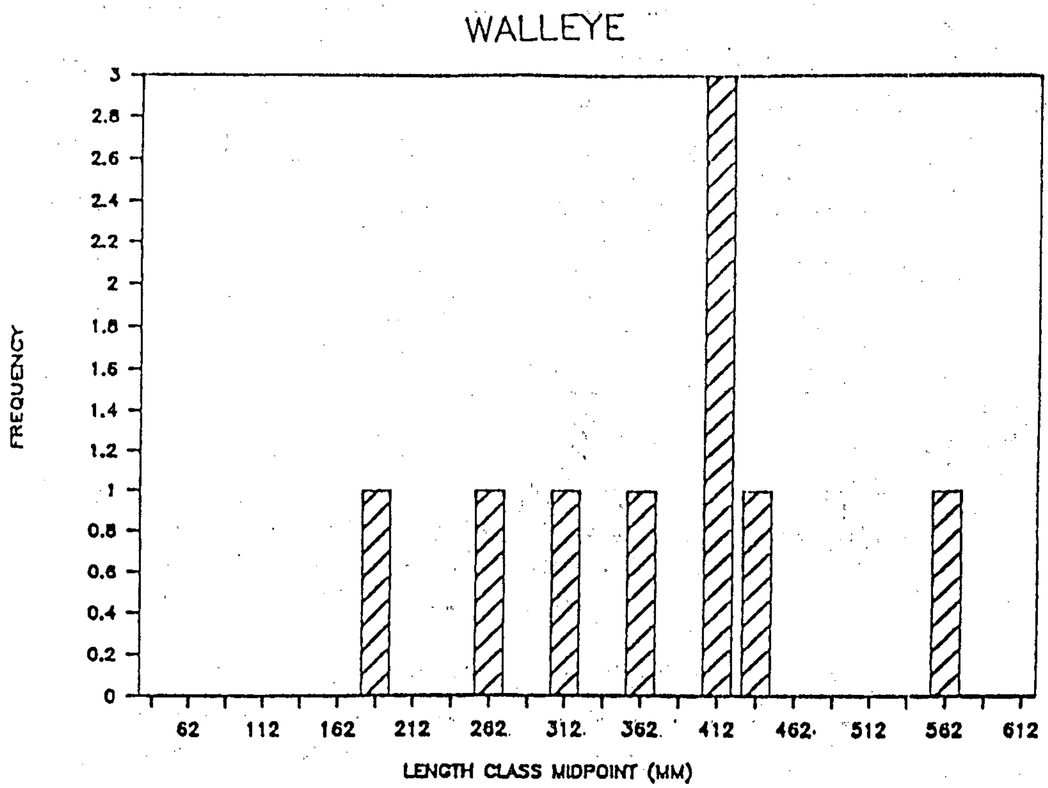


Figure 7-3. Continued



Condition factors for the 10 species measured for length and weight pooled across all lakes and all fish caught (including duplicate samples) are summarized in Table 7.6. Values tend to be species-specific, reflecting differences in fish shape. Fish condition factors also vary with season of the year, sex, stage of maturity, and size of the fish (Everhart et al. 1975). For the three species for which statewide average condition factors could be calculated (northern pike, largemouth bass, and yellow perch), values for the ELS-II tended to be similar to or slightly lower than the statewide averages.

Table 7.6. Fish Condition Factors, by Species, Pooled Across All Lakes and All Ages

Species	N	Condition Factor			
		Range	Std. Dev.	Mean	Statewide Average[a]
Brook Trout	27	0.78-1.70	0.24	1.13	-
Northern Pike	91	0.31-0.75	0.08	0.55	0.54-0.65
White Sucker	288	0.38-1.50	0.15	1.00	-
Rock Bass	14	1.42-2.23	0.19	1.87	-
Smallmouth Bass	6	1.15-1.55	0.16	1.32	-
Largemouth Bass	106	0.89-2.51	0.22	1.32	1.19-1.50
Pumpkinseed Sunfish	27	1.52-2.42	0.23	2.01	-
Bluefill Sunfish	46	0.97-2.00	0.20	1.51	-
Yellow Perch	1178	0.22-1.77	0.16	1.00	1.06-1.25
Walleye	8	0.79-0.99	0.06	0.85	-

[a] Statewide average values calculated by age class based on data presented in Merna et al. (1981); ranges for ages 0 to 9 for northern pike, 0 to 10 for largemouth bass, and 1 to 11 for yellow perch. Generally, younger, smaller fish have lower condition factors.

8. ASSOCIATION BETWEEN FISH COMMUNITY STATUS AND LAKE CHARACTERISTICS

The ELS-II data for Subregion 2B may be used to develop and examine hypotheses regarding the role of selected environmental factors in determining fish population success and fish community characteristics in lakes in the Upper Peninsula of Michigan and northeastern Wisconsin. Survey data alone, however, cannot establish causality. Caution must be exercised not to assume that observed spatial associations imply a direct cause-and-effect relationship. Many factors influence fish community status, and most of these factors are themselves interrelated and correlated.

A wide range of alternative predictor variables were examined that may directly or indirectly influence fish community characteristics:

- Lake type -- It is expected that seepage lakes, without inlets and outlets, would have reduced rates of colonization and thus naturally lower numbers of species and perhaps lower fish abundance. Drainage lakes, reservoirs, and closed lakes, on the other hand, have connecting lakes and streams that may serve both as potential refuges during severe conditions and as source areas for potential immigrants (Tonn and Magnuson 1982). For analyses of fish community status, lake type is defined as a binary variable, seepage versus nonseepage lakes.

- Lake area -- Many investigators have reported a positive association between lake area and species richness (Magnuson 1976, Harvey 1979, Rago and Wiener 1986). Larger lakes generally provide greater habitat complexity and also are more likely to include refuge areas during adverse environmental conditions.

- Lake depth (based on the ELS-I site depth) -- Shallower lakes are less likely to be thermally stratified, and thus are less likely to support fish species intolerant of relatively warm water temperatures. It should be noted that the ELS-I site depth is only a rough approximation of lake maximum depth (Linthurst et al. 1986). Unpublished data for lakes in the northeastern United States indicate relatively poor agreement between the ELS-I site depth and the true maximum depth in some lakes.

- Elevation -- Lakes at higher elevations tend to be cooler, favoring fish species less tolerant of higher water temperatures. In addition, lakes at higher elevations may experience longer periods of ice cover and as a result may be more susceptible to oxygen depletion during the winter.

- Dissolved oxygen -- Fish require adequate levels of DO to survive, although minimum tolerance levels vary among fish species. Variations in DO concentrations over the three-month sampling period may limit, however, the utility of the ELS-II measurements for among-lake comparisons. Two indices are computed from the ELS-II measurements: the minimum measured level of DO and the proportion of the water column with DO levels below 4 mg/L.

- Thermal stratification — The optimum temperature for fish survival and growth varies among fish species. Thus, water temperatures play a major role in determining fish community composition in surface waters. ELS-II water temperature measurements were collected over a three-month period and are not considered suitable for direct among-lake comparisons. Analyses of fish community status, therefore, include only a binary index of thermal stratification, as defined in Section 5.

- Secchi depth — Secchi depth is a measure of light transparency and penetration, which in turn affects the lake thermal regime and light availability for primary production. In addition, some fish species (e.g., fish that rely heavily on visual prey selection) are relatively intolerant of turbid waters.

- Lake pH — Low levels of pH may be toxic to fish (Altshuller and Linthurst 1984). Low pH levels may result from naturally acidic conditions, from acidic deposition, or from other sources of acidity. Specific causes for low pH waters in Subregion 2B are not examined in this document (see Eilers et al. 1988).

- Inorganic aluminum — High levels of inorganic Al may be toxic to fish. Aluminum and pH (or the hydrogen ion concentration) are the principal toxic agents for fish in acidic waters (Schofield and Trojnar 1980, Driscoll et al. 1980).

- Calcium — Higher levels of Ca may mitigate the potential toxic effects of low pH and elevated levels of inorganic Al. Fish tolerate lower pH levels and higher Al concentrations in waters with higher Ca concentrations (Brown 1983, Ingersoll 1986).

- Dissolved organic carbon — High levels of DOC may complex Al and other metals thereby decreasing metal toxicity (Driscoll et al. 1980, Parkhurst 1987). High levels of DOC (and water color, discussed below) are in some cases indicative of lakes with high levels of organic acids and/or extensive bog development. Lakes with high levels of DOC tend to have higher water temperatures (due to the effect of dissolved organics on light adsorption in water). Lakes with extensive bog development may be subject to periodic oxygen depletion. The occurrence of bog development was not directly assessed in either the ELS-I or ELS-II.

- Color — Levels of DOC and water color are generally highly correlated. However, neither is an exact measure of the availability of organics for metal complexation or of organic acidity. Thus, both variables are included as potential predictor variables of fish community status.

- Acid neutralizing capacity — Acidification is defined as the loss of ANC. Acidic waters are defined by ANC ≤ 0 µeq/L. While ANC, by itself, may have no direct effects on fish survival, variations in the relationship between ANC and pH may reflect the varying importance of weak acids (including Al and organic acids), which in turn may influence fish survival and fish community composition.

- Sum of the base cations -- Studies have demonstrated that Na, Mg, and K may also influence the toxicity of acidic waters to fish, although to a lesser degree than does Ca (Altshuller and Linthurst 1984).

- Extractable Al -- Procedures for the fractionation and speciation of Al are still fairly controversial. Thus, in addition to inclusion of the estimated inorganic Al, noted above, measured values for extractable Al (i.e., total monomeric Al) from ELS-I are also considered.

- Total phosphorus (P) -- Phosphorous is the key nutrient controlling primary productivity in most temperate, inland lakes (Schindler 1975). Levels of total P are often positively correlated with levels of algal standing crop (Nicholls and Dillon 1978, Schindler 1975), and may in turn influence fish abundance.

- Sulfate -- Levels of SO_4 measured during ELS-I are included as a potential index of the influence of SO_4 deposition on lake chemistry. However, in-lake SO_4 reduction, especially in seepage lakes, may alter markedly regional patterns in lake SO_4. Sulfate in lakes in Subregion 2B likely has no direct measurable effects on fish.

- Silica -- Seepage lakes tend to have lower levels of SiO_2 than do drainage lakes, reservoirs, or closed systems (Linthurst et al. 1986). In addition, varying levels of SiO_2 among seepage lakes may be indicative of the varying importance of groundwater inflow to lake-ion budgets. Silica has no direct effects on fish, but may serve as an independent index of lake type and of the importance of watershed processes to lake chemistry.

The analyses in this document are considered exploratory. In order not to limit data analyses to factors considered most important a priori, a large number of statistical tests have been conducted involving all of the above parameters. Of primary interest is the pattern of results and the consistency of these results with proposed mechanisms of effects, rather than any one test per se. While some adjustment is made for the number of tests conducted, individual spurious results may still occur.

Relationships between fish community characteristics and lake physical and chemical attributes were evaluated using nonparametric statistics and regression analyses. As part of each regression analysis, appropriate model diagnostics were examined, including residual plots, normal plots, Cook's D influence statistic, and the condition index (Belsley et al. 1980, Myers 1986). These tools were used to assess model adequacy, to inspect for homogeneity of variance and collinearity problems, to detect outliers and influential data points, and to test for normality.

The sample of 49 ELS-II lakes was assumed to be a sample from an infinite population. Therefore, all analyses in this section are unweighted and do not include the ELS-II weighting factors defined during lake selection (Section 2.2.2). The objective is to better understand processes and factors that influence fish community status and fish distribution. Use of the ELS-II weighting factors to extrapolate from the sample of 49 lakes to the ELS-II target population is presented in Section 9.

Consistent with the basic format used in other sections, among-lake patterns in fish community characteristics are discussed for each measured response variable in the following order: species richness (Section 8.2), fish species presence/absence (Section 8.3), total catch and CPUE (Section 8.4), and fish size and condition factors (Section 8.5). Section 8.1 contains an evaluation of multicollinearity among the 19 predictor variables of interest (i.e., the lake physical and chemical attributes described above). As in Section 7, unless otherwise noted, the data and analyses presented are based on a single sample per lake, collected between 8 June and 30 August 1987. Results from duplicate surveys on 10 lakes, conducted 31 August to 12 September, are discussed and analyzed in Section 4.2.

8.1 MULTICOLLINEARITY AMONG PREDICTOR VARIABLES

Many of the predictor variables considered are themselves highly correlated (Table 8.1), causing problems with both model interpretation and inflated variance terms for regression parameter estimates. Among-lake variations in lake pH, for example, were significantly correlated (α=0.05, adjusted for 16 tests per variable, $p \leq 0.0031$) with ANC (r=0.99, Spearman's rank correlation), the sum of base cations (r=0.81), Ca (r=0.77), extractable Al (r=-0.68), SiO_2 (r=0.63), and DOC (r=0.45), and to a lesser degree ($0.0031 < p \leq 0.05$) with inorganic Al (r=-0.41) and lake area (r=0.39). Seepage lakes had significantly lower levels of ANC, Ca, sum of base cations, color, and SiO_2 than did nonseepage lakes (Section 6.1, Table 6.2). These strong associations among key predictor variables of interest make it difficult to determine the relative importance of individual lake characteristics as factors influencing observed among-lake variations in fish communities.

To quantify these patterns and associations among predictor variables, a principal component analysis (Pielou 1984) was conducted on the full set of 19 chemical and physical variables. Both nontransformed and log-transformed data were evaluated and yielded similar results. The final data set consisted of a combination of nontransformed and log-transformed variables, selected after examining the relationship between individual predictor variables and the fish response data (see Sections 8.2 and 8.3). A constant (100 µeq/L) was added to ANC prior to the logarithmic (base e) transformation, to adjust for ANC values ≤ 0. Concentrations of extractable Al, inorganic Al, SiO_2, and total P ≤ 0 were converted to the lowest recorded positive value for the variable in

Table 8.1. Correlation Matrix for the 17 Continuous Predictor Variables[a]

	Area	Depth	Elev.	Min. DO	% DO < 4 mg/L	Secchi Depth	pH	ANC	Inorg. Al	Ext. Al	Ca	Sum Base Cations	DOC	Color	SO_4	SiO_2	Total P
Area	1.0	ns	ns	.31	ns	ns	.39	.35	ns	ns	.51*	.51*	ns	ns	.40	ns	ns
Depth		1.0	ns	-.61*	.65*	.47*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Elevation			1.0	ns	ns	ns	ns	ns	ns	.28	ns	ns	ns	.32	ns	ns	ns
Min. DO				1.0	-.84*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
% DO < 4					1.0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Secchi Depth						1.0	ns	ns	ns	ns	ns	ns	-.61*	-.77*	ns	-.42*	-.39
pH							1.0	.99*	-.41	-.68*	.77*	.81*	.45*	ns	ns	.63*	ns
ANC								1.0	-.40	-.66*	.80*	.83*	.50*	.29	ns	.69*	ns
Inorg. Al									1.0	.59*	ns	ns	ns	ns	.45*	ns	ns
Ext. Al										1.0	-.38	-.37	ns	ns	ns	-.30	ns
Ca											1.0	.98*	.40	.30	.43*	.71*	ns
Base Cations												1.0	.43*	.34	.40	.70*	ns
DOC													1.0	.75*	ns	.55*	.34
Color														1.0	ns	.55*	.39
SO_4															1.0	ns	ns
SiO_2																1.0	ns
Total P																	1.0

a Analyses based on Spearman's rank correlation. Numbers in matrix indicate correlation coefficients for comparisons with $p \leq 0.05$. Asterisks indicate significance at α=0.05, adjusted for 16 tests per variable ($p < 0.0031$). Comparisons nonsignificant with $p > 0.05$ are identified as ns.

the ELS-II data set (1 µg/L, 0.1 µg/L, 0.02 mg/L, and 0.5 µg/L, respectively) for log-transformation. In each instance, these lowest recorded values were below the minimum system detection limit defined in Linthurst et al. (1986).

Separate principal component analyses were conducted for the full set of 49 ELS-II lakes in Subregion 2B and for the 38 lakes sampled with beach seines. Coefficients for the first five principal components accounted for 82.8% and 85.2% of the total variation in the 49-lake and 38-lake data sets, respectively; the first two principal components accounted for 49.5% and 53.9% of the variation in the two data sets (Table 8.2). In both data sets, the first principal component was defined primarily by terms related to watershed weathering: Ca, the sum of base cations, lake pH, ANC, and SiO_2. The second principal component was determined largely by levels of DO, lake depth, and the occurrence of thermal stratification. The relationships between these principal components and fish response variables (species richness and fish species presence/absence) are assessed in Sections 8.2 and 8.3.

8.2 SPECIES RICHNESS

Initially, simple associations between species richness and each lake characteristic of interest were examined using nonparametric statistical tests: Spearman's rank correlations for continuous predictor variables (e.g., lake pH) and the Wilcoxon rank sum and Kolmogorov-Smirnov tests for binary predictor variables (i.e., lake type and the occurrence of thermal stratification). The results were similar for the 49-lake data set (with species richness defined by catch from gill nets, trap nets, and angling) and the 38-lake data set (using the number of species caught in all four gear types, see Section 7.1). Species richness was significantly correlated (α=0.05, adjusted for 19 tests per data set, $p \leq 0.0026$) with eight lake attributes: lake type, pH (r=0.74 for the 49-lake data set), ANC (r=0.74), sum of base cations (r=0.65), Ca (r=0.64), SiO_2 (r=0.60), extractable Al (r=-0.45), and DOC (r=0.42) (Table 8.3; Figures 8-1 and 8-2). Additional correlations with $0.0026 < p \leq 0.05$ include lake area, minimum DO, the occurrence of thermal stratification, depth, and SO_4.

Multivariate models of species richness as a function of lake physical and chemical characteristics were developed and explored using ordinary least-squares (OLS) regression analysis (Myers 1986). As a first-step in OLS regression, single-variable models and bivariate plots were examined for each variable to evaluate the need for data transformations and to detect outliers and influential data points. For lake area, depth, elevation, Ca, sum base cations, ANC, color, extractable Al, and total P, the log-

Table 8.2. **Results from Principal Components Analysis on 19 Physical and Chemical Variables**

Variable	Principal Component 1		Principal Component 2		Principal Component 3	
	49 Lakes	38 Lakes	49 Lakes	38 Lakes	49 Lakes	38 Lakes
pH	0.369	0.363	-0.043	-0.011	0.066	0.048
ln (Ca)	0.379	0.370	-0.055	-0.028	0.135	0.151
DOC	0.211	0.216	-0.106	-0.195	-0.360	-0.299
ln (Inorg.Al)	-0.029	-0.022	0.047	0.032	0.035	0.104
ln (Sum Base Cations)	0.385	0.374	-0.060	-0.038	0.121	0.140
ln (ANC)	0.383	0.375	-0.037	-0.013	0.110	0.098
ln (Color)	0.150	0.142	-0.125	-0.240	-0.465	-0.417
ln (Ext Al)	-0.207	-0.217	-0.003	-0.069	-0.173	-0.055
SO_4	0.156	0.155	0.073	0.090	0.271	0.328
SiO_2	0.366	0.362	-0.029	-0.029	0.033	0.040
ln (Total P)	0.075	0.113	-0.103	-0.162	-0.250	-0.220
ln (Area)	0.208	0.218	-0.132	-0.048	0.198	0.261
ln (Depth)	0.092	0.110	-0.478	0.454	0.097	-0.016
ln (Elevation)	0.014	-0.019	-0.085	-0.061	-0.221	-0.214
ln (Secchi Depth)	-0.107	-0.095	0.208	0.358	0.457	0.362
Lake Type[a]	-0.263	-0.283	-0.088	-0.014	0.169	0.175
Minimum DO	-0.076	-0.062	0.478	-0.432	0.184	0.295
% O_2 < 4 mg/L	0.090	0.077	0.425	0.367	-0.237	-0.325
Thermal Strat.[a]	0.066	0.099	0.480	0.446	-0.109	-0.206
Eigenvalue	6.091	6.432	3.309	3.811	2.968	2.409
Proportion of Total Variance	0.321	0.339	0.174	0.201	0.156	0.127
Cumulative Variance Explained	0.321	0.339	0.495	0.539	0.651	0.666

(continued)

Table 8.2. Continued

Variance	Principal Component 4		Principal Component 5	
	49 Lakes	38 Lakes	49 Lakes	38 Lakes
pH	-0.172	-0.130	0.135	-0.172
ln (Ca)	0.004	-0.018	-0.001	-0.057
DOC	0.061	0.182	0.104	-0.016
ln (Inorg. Al)	0.566	0.512	-0.253	0.306
ln (Sum Base Cations)	0.002	-0.018	0.010	-0.074
ln (ANC)	-0.109	-0.115	0.001	-0.090
ln (Color)	0.140	0.205	0.025	0.022
ln (Ext. Al)	0.489	0.484	-0.060	0.130
SO_4	0.446	0.387	0.000	0.058
SiO_2	0.075	0.035	-0.077	0.040
ln (Total P)	0.148	-0.207	-0.608	0.603
ln (Area)	0.276	0.282	0.079	0.073
ln (Depth)	0.022	0.045	-0.023	0.052
ln (Elevation)	0.178	0.312	0.677	-0.653
ln (Secchi Depth)	0.038	0.019	0.037	0.029
Lake Type[a]	-0.183	-0.131	0.214	-0.192
Minimum DO	0.054	-0.001	-0.090	0.001
% O_2 < 4mg/L	0.017	0.082	0.067	0.001
Thermal Strat.[a]	-0.046	0.006	-0.030	0.033
Eigenvalue	2.139	2.365	1.226	1.163
Proportion of Total Variance	0.113	0.124	0.065	0.061
Cumulative Variance Explained	0.764	0.790	0.828	0.852

a Lake type and thermal stratification are coded as binary variables. Lake type = 1 for seepage lakes and 0 for nonseepage lakes. Thermal stratification = 1 for lakes thermally stratified at the time of sampling and 0 for nonstratified lakes.

transformation (base e) resulted in a higher model coefficient of determination, an improved residual plot (improved homogeneity of variance), and/or fewer outliers with less influence on the regression (based on Cook's D statistic) relative to the nontransformed data. For minimum DO, percent of the water column with DO < 4 mg/L, DOC, and SiO_2, the nontransformed data resulted in a better OLS model

Table 8.3. Association Between Species Richness, Total Catch, and Catch Per Unit Effort (CPUE, Averaged Over Gill Nets and Trap Nets) and Lake Physical and Chemical Characteristics

Variables	Species Richness		Total Catch	CPUE
	49 Lakes	38 Lakes		
Lake Type	*	*	ns	ns
Area	0.39	0.38	ns	ns
Depth	ns	0.38	ns	-0.30
Elevation	ns	ns	ns	ns
Min. DO	-0.31	-0.36	ns	ns
% DO < 4 mg/L	ns	ns	ns	ns
Therm. Strat.	x	x	ns	ns
Secchi Depth	ns	ns	-0.38	-0.40
pH	0.74*	0.79*	ns	ns
Inorg. Al	ns	ns	ns	-0.29
Ca	0.64*	0.68*	ns	ns
DOC	0.42*	0.45	ns	ns
Sum Base Cations	0.65*	0.68*	ns	ns
ANC	0.74*	0.79*	ns	ns
Color	ns	ns	ns	ns
Ext. Al	-0.45*	-0.48*	ns	ns
SO_4	0.31	ns	ns	ns
SiO_2	0.60*	0.68*	ns	ns
Total P	ns	ns	ns	ns

a Analyses based on Spearman's rank correlation for continuous variables and Wilcoxon rank sum and Kolmogorov-Smirnov tests for binary variables (lake type and thermal stratification). Tests with $p > 0.05$ noted as ns (not significant). Numbers indicate correlation coefficients for comparisons with $p \le 0.05$. Asterisks indicate tests significant at $\alpha = 0.05$, adjusted for 19 tests per variable ($p \le 0.0026$). Results for binary variables with $0.0026 < p \le 0.05$ noted by an x.

with species richness. Analyses for Secchi depth, inorganic Al, and SO_4, were inconclusive; therefore, for consistency with other similar variables in the data set and with the logistic models of fish presence/absence (Section 8.3), log-transformed data were used for Secchi depth and inorganic Al and nontransformed data for SO_4.

Transformation of the dependent variable, species richness, was also considered. A Box-Cox analysis (Box and Cox 1964) for linear models of species richness fit to pH

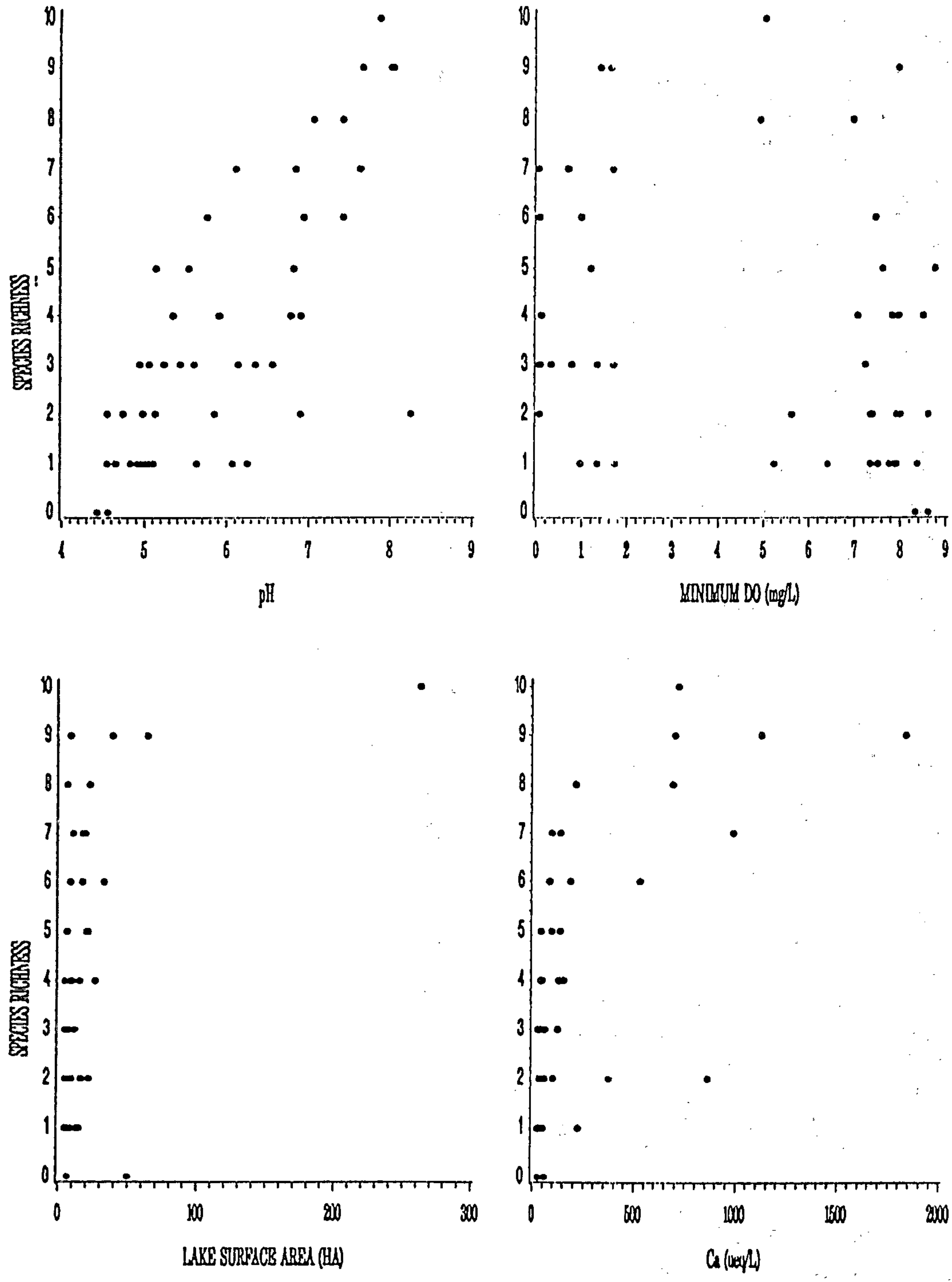


Figure 8-1. **Bivariate plots of species richness and lake characteristics, for those continuous physical and chemical variables associated with species richness at $p \leq 0.05$ (see Table 8.3).**

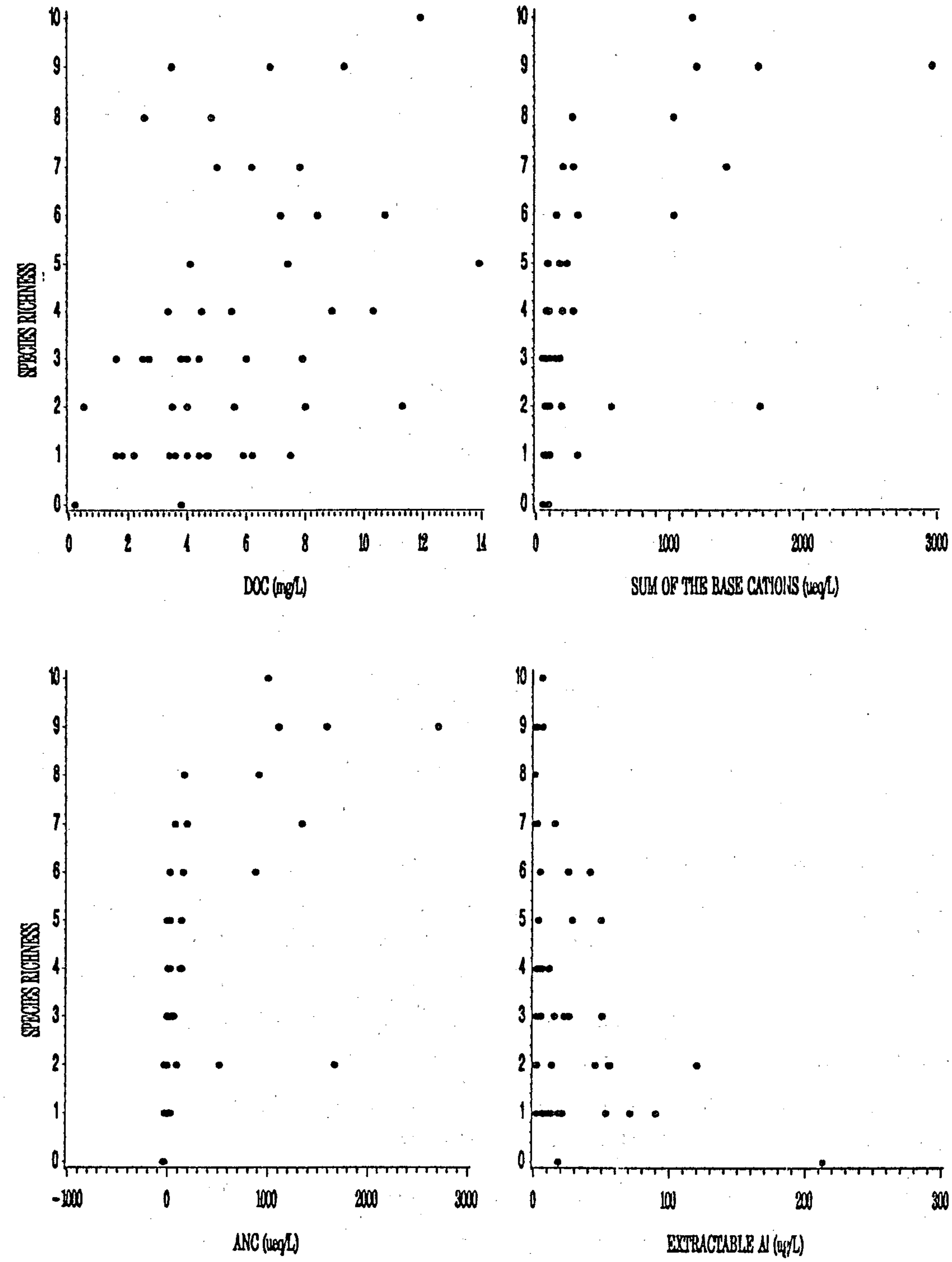


Figure 8-1. Continued.

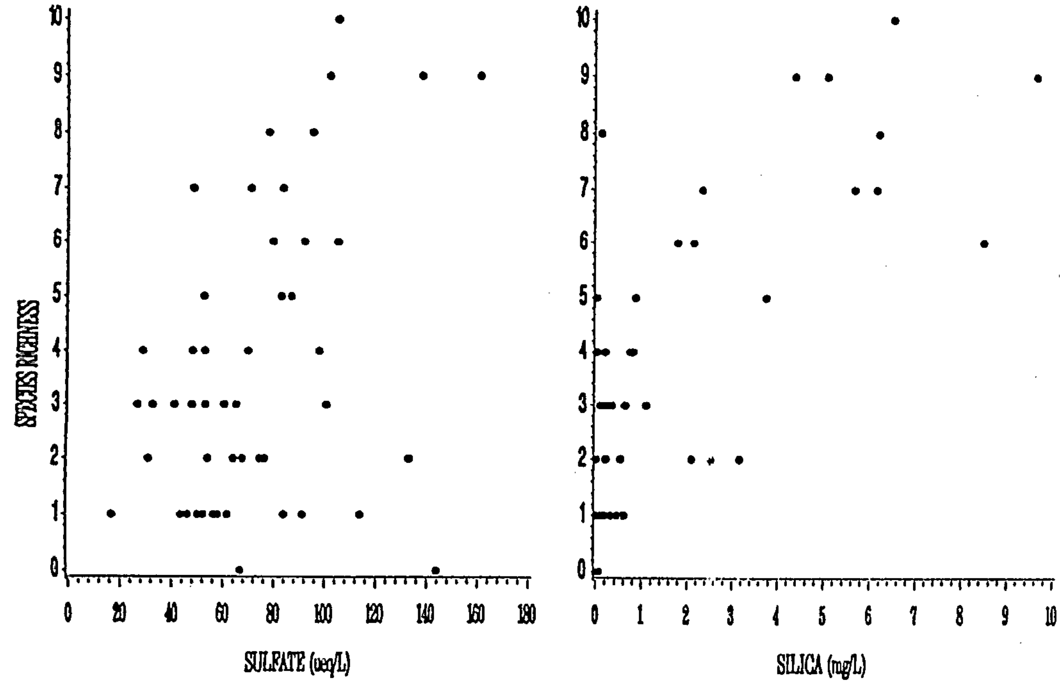


Figure 8-1. Continued.

and Ca indicated no need for transformation. Thus, in the analyses that follow, species richness was used directly without transformation.

For several predictor variables of interest, examination of the residual plots for the single-variable OLS models indicated one or two outliers and/or influential data points. Typically, these outliers/influential data points represented lakes with values at the high end of the range for the 49 ELS-II lakes. The specific lake identified varied, however, among predictor variables. In addition, there was no indication that errors in data collection or recording could account for these outliers. Thus, no data points were discarded from subsequent analyses, although the effects of outliers on model results were continually examined as part of model development.

Three approaches – stepwise forward and backward and maximum r^2 OLS regressions – were conducted to examine the relationship between species richness and multiple lake attributes. For the 49-lake data set, all three approaches identified the same model, predicting species richness as a function of three variables (Table 8.4): lake pH, SiO_2, and the occurrence of thermal stratification (model r^2=0.69). On the other hand, for the 38-lake data set (including species collected with beach seines), each

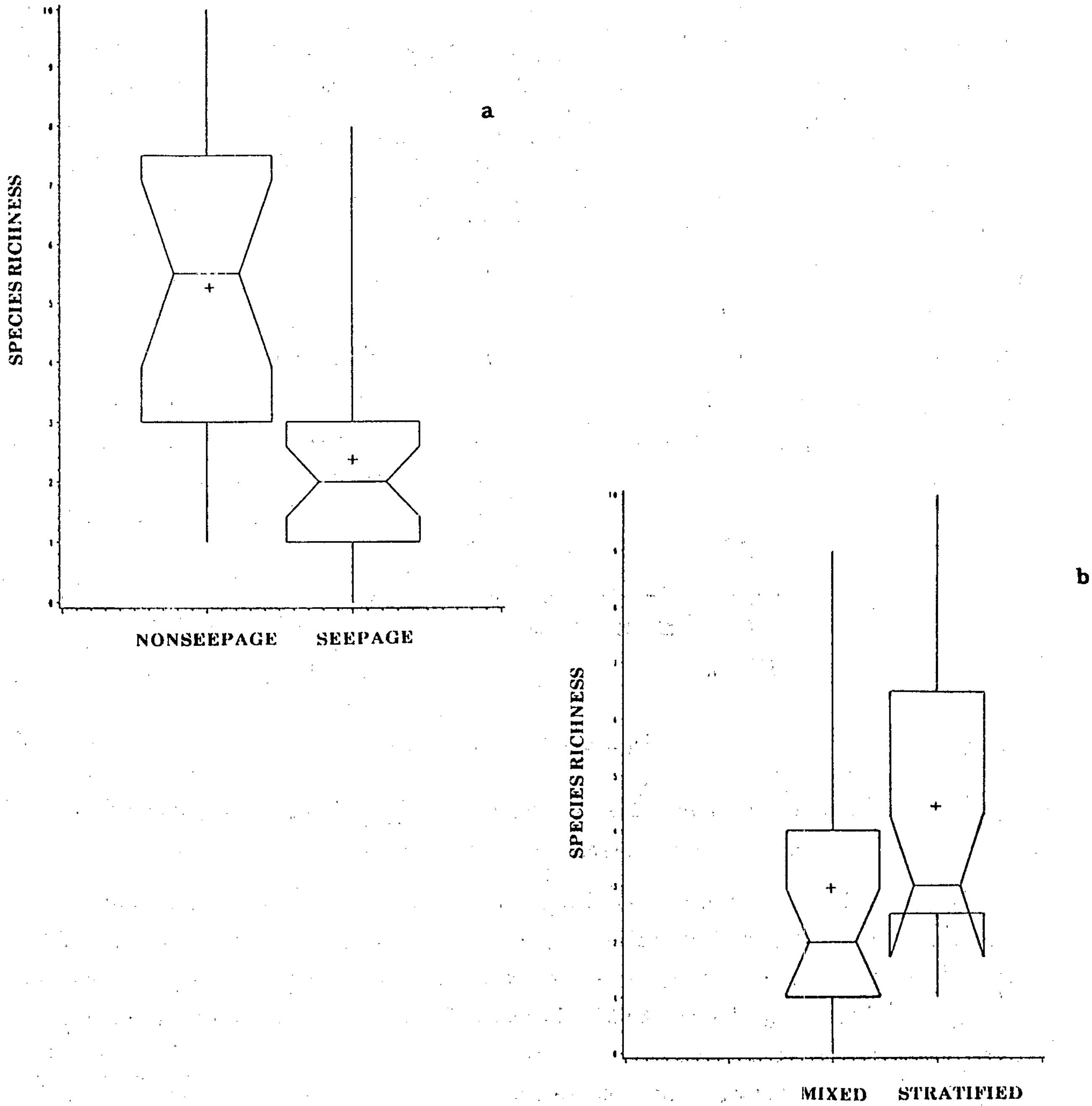


Figure 8-2. **Box-and-whisker plots comparing species richness in (a) seepage versus nonseepage lakes and (b) thermally stratified versus mixed lakes. The vertical bar represents the data range; the upper and lower boundaries of the box, the 75% and 25% quartiles; the notch, the 90% confidence limits around the median; the center of the box, the median; and the cross-mark, the mean.**

approach selected a slightly different model, perhaps reflecting the model instability typically associated with a high level of collinearity among predictor variables. Four variables were included in the final model by stepwise forward OLS: pH, lake type, the occurrence of thermal stratification, and SO_4 (model r^2=0.79). Stepwise backward OLS identified a five-variable model including inorganic Al, DOC, the sum of the base cations, SO_4, and the occurrence of thermal stratification (model r^2=0.82). Results from the maximum r^2 approach were consistent with results for the 49-lake data set, selecting lake pH, SiO_2, and the occurrence of thermal stratification as the best three-variable model (model r^2=0.78)(Table 8.4). In both data sets, species richness was positively associated with all three variables; i.e., all other factors being equal, lakes with more species tended to have higher pH and SiO_2 and were more likely to be thermally stratified. Silica in the model may serve as a surrogate for lake type. Nonseepage lakes had significantly higher levels of SiO_2 (Table 6.2) and higher numbers of species (Table 8.3) than did seepage lakes.

Table 8.4. Multivariate Regression Models for Species Richness

		Regression Coefficient				
Data Set	Variable	Estimate	Std. Error	p-Value	Model r^2	Condition Index
49 lakes	Intercept	-4.02	1.65	0.0187	0.69	16.0
	Lake pH	1.06	0.30	0.0010		
	SiO_2	0.46	0.14	0.0014		
	Thermal Strat.[a]	1.22	0.45	0.0095		
38 lakes	Intercept	-5.48	2.14	0.0152	0.78	17.7
	Lake pH	1.33	0.40	0.0021		
	SiO_2	0.60	0.18	0.0020		
	Thermal Strat.[a]	2.04	0.62	0.0023		

a Thermal stratification coded as a binary variable = 1 for lakes thermally stratified at the time of sampling and 0 for nonstratified lakes.

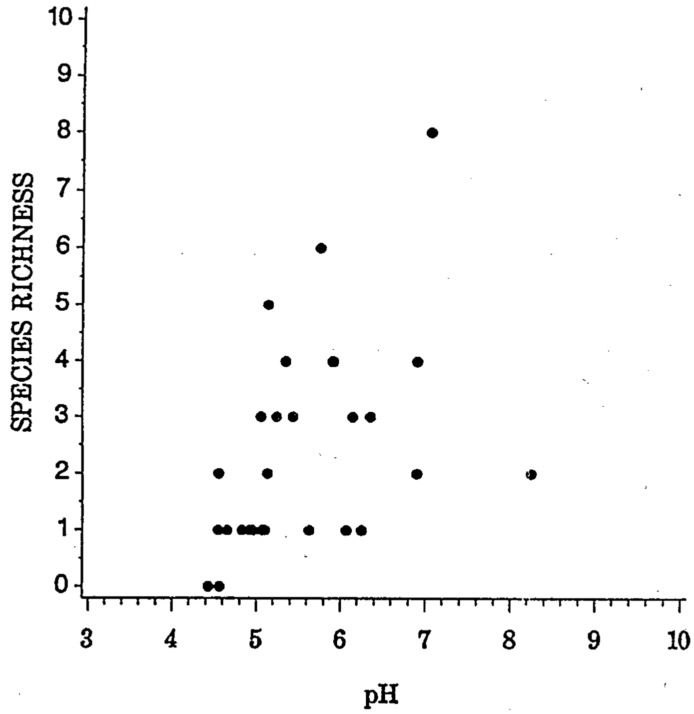
Interactions among predictor variables may also be important. For example, the relationship between species richness and lake pH differs significantly ($p \leq 0.05$) between seepage and nonseepage lakes (Table 8.5, analysis of covariance, Snedecor and Cochran 1967). While species richness and lake pH are highly correlated in nonseepage lakes (r=0.92, Spearman's rank correlation), the relationship is somewhat less consistent in seepage lakes (r=0.60)(Figure 8-3). Inclusion of interaction terms in the above multivariate regression analyses would further aggravate problems with multicollinearity, and thus was not pursued.

Table 8.5. Analysis of Covariance: Variations in the Relationship Between Species Richness and Lake pH, by Lake Type

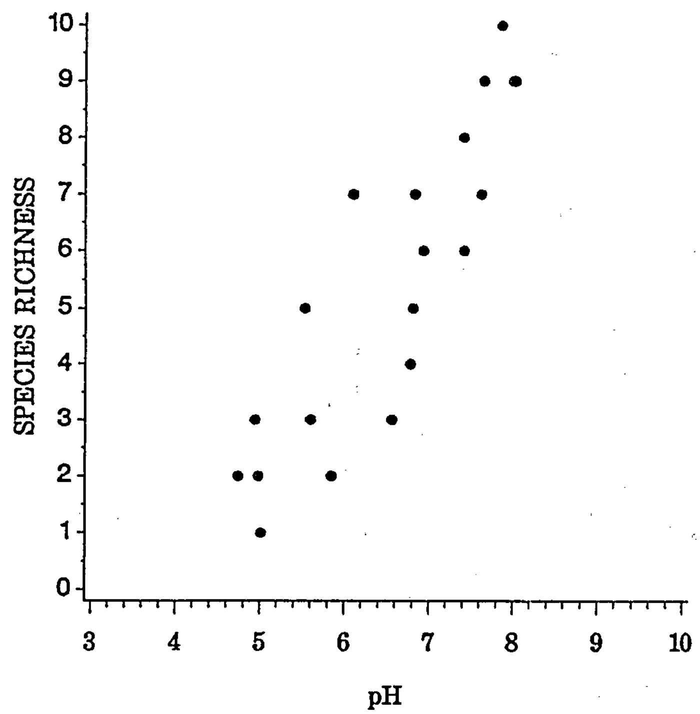
Source	Degrees of Freedom	Type I Sum of Squares	f-Value	p-Value
49 LAKES				
Model				
Lake Type	1	108.0	43.0	0.0001
pH	1	113.3	45.2	0.0001
pH*Lake Type	1	19.4	7.7	0.0079
Error	45	112.9		
Corrected Total	48	353.6		
38 LAKES				
Model				
Lake Type	1	231.2	64.4	0.0001
pH	1	136.8	38.1	0.0001
pH*Lake Type	1	28.6	8.0	0.0079
Error	34	122.0		
Corrected Total	37	518.6		

The relationship between species richness and each of the physical/chemical principal components described in Section 8.1 was also examined. Only the first principal component (determined largely by Ca, base cations, pH, ANC, and SiO_2) was significantly ($p \leq 0.05$) associated with species richness: model r^2=0.67 for the 49-lake data set and 0.76 for the 38-lake data set.

Clearly, species richness is influenced by a number of lake attributes including, but not limited to, factors related to lake acidity. Important variables include, at a minimum, lake pH, lake type (or SiO_2 concentrations), and the occurrence of thermal stratification. The observed relationships between species richness and each of these variables are consistent with the expected patterns and hypotheses discussed at the beginning of Section 8. The high degree of correlation among lake characteristics complicates, however, interpretation of these results. The relative importance of



a



b

Figure 8-3. Species richness as a function of lake pH for (a) seepage and (b) nonseepage lakes.

acidity-related factors cannot be quantified with certainty, nor can the potential role of other lake characteristics, not specifically identified in these analyses, be dismissed with confidence.

8.3 FISH SPECIES PRESENCE/ABSENCE

Differences in the physical and chemical characteristics of lakes with fish caught versus those without fish caught were examined for (1) individual fish species (for species caught in at least three lakes), (2) cyprinid and darter species as a group (see Table 7.1), (3) game fish as a group (defined in Section 3.6.2), and (4) all fish species combined. As noted in Section 7.1, several fish species, especially cyprinid and darter species, were caught most effectively with beach seines, but beach seines were used in only 38 of the 49 lakes. For those fish species, and for cyprinids and darters examined as a group, analyses of lake characteristics were restricted to the 38 lakes sampled with beach seines. For all other analyses, the full data set of 49 lakes was used.

Comparisons of the characteristics of lakes with and without fish were based on the Wilcoxon rank sum and Kolmogorov-Smirnov tests for continuous variables and the Fisher exact test for binary variables. The Fisher exact test requires that fewer than 25% of the cells have expected counts less than five observations to calculate a valid chi-square. Thus, the tests for lake type and occurrence of thermal stratification could be run for only some species.

Of the 20 species tested, statistically significant differences in lake characteristics ($\alpha=0.05$, adjusted for 19 tests per species, $p \leq 0.0026$) were detected only for four species: white sucker, golden shiner, northern pike, and smallmouth bass (Tables 8.6 and 8.7). All species except four (brook trout, central mudminnow, brook stickleback, and yellow perch), however, had at least one physical or chemical variable with $p \leq 0.05$. All four of these species have been reported in prior studies to be tolerant of acidity (Althshuller and Linthurst 1984, Rahel and Magnuson 1983, Schofield and Driscoll 1986) and other extreme environmental conditions (e.g., Tonn and Magnuson [1982] observed that central mudminnows are common in northern Wisconsin lakes that experience near zero DO levels under ice cover).

Of the 19 variables examined, significant differences ($p \leq 0.0026$) between lakes with and without individual fish species were found for eight variables: lake pH (for 4 of 20 species), Ca (3 species), ANC (3 species), sum of base cations (2 species), lake area (2 species), SiO_2 (2 species), SO_4 (1 species), and lake type (1 species out of 8 with sufficient numbers of lakes in each cell for a valid test). For those species for which

Table 8.6. Comparison of Lake Physical Characteristics for Lakes With (P) and Without (A) Fish Caught[a]

Fish Species/ Group	No. of Lakes with Fish		Lake Type	Area	Site Depth	Elevation	Min. DO	% DO < 4 mg/L	Therm. Strat.	Secchi Depth
	P	A								
All Fish	47	2	–	ns	ns	ns	x	ns	–	ns
Game Fish	36	13	x	ns	ns	ns	ns	ns	ns	ns
Cyprinids	16	22	x	x	ns	ns	ns	ns	–	ns
Darters	9	29	–	ns	ns	x	ns	ns	–	ns
Brook Trout	4	45	–	ns	ns	ns	ns	ns	–	ns
Central Mudminnow	5	44	–	ns	ns	ns	ns	ns	–	ns
Northern Pike	11	38	ns	*	ns	ns	ns	ns	ns	ns
Creek Chub	4	45	–	ns	ns	ns	ns	ns	–	ns
Golden Shiner	12	37	x	ns	ns	ns	ns	ns	ns	ns
Common Shiner	7	42	–	ns	ns	ns	ns	ns	–	ns
Bluntnose Minnow	7	31	–	ns	x	ns	ns	ns	–	ns
Finescale Dace	5	44	–	ns	ns	ns	ns	ns	–	ns
White Sucker	14	35	*	x	ns	ns	x	x	ns	ns
Brown Bullhead	13	36	x	ns	ns	x	ns	ns	ns	ns
Brook Stickleback	3	46	–	ns	ns	ns	ns	ns	–	ns
Rock Bass	4	45	–	x	x	x	ns	ns	–	ns
Smallmouth Bass	5	33	–	*	x	x	ns	ns	–	ns
Largemouth Bass	16	33	ns	x	ns	ns	ns	ns	ns	ns
Pumpkinseed	15	34	x	ns	ns	ns	x	x	ns	ns
Bluegill Sunfish	13	36	ns	ns	ns	ns	ns	ns	ns	ns
Black Crappie	3	46	–	ns	ns	ns	ns	ns	–	ns
Yellow Perch	31	18	ns	ns	ns	ns	ns	ns	ns	ns
Johnny Darter	3	35	–	ns	ns	x	ns	ns	–	ns
Iowa Darter	6	32	–	ns	ns	ns	ns	ns	–	ns

[a] Statistical comparisons for continuous variables are based on the Wilcoxon rank sum and Kolmogorov-Smirnov tests. Statistical comparisons for binary variables (lake type and thermal stratification) are based on the Fisher exact test. Asterisks indicate tests considered statistically significant at $\alpha=0.05$ adjusted for 19 tests per species (including both chemical and physical variables), i.e., $p \leq 0.0026$. x's indicate tests with $p \leq 0.05$; dashes indicate variables and species for which statistical comparisons could not be conducted; and ns indicates variables that were not significant, $p > 0.05$.

Table 8.7. Comparison of Lake Chemical Characteristics for Lakes With (P) and Without (A) Fish Caught[a]

Fish Species/ Group	No. of Lakes with Fish P	No. of Lakes with Fish A	pH	Inorg. Al	Ca	DOC	Base Cations	ANC	Color	Ext. Al	SO_4	SiO_2	Total P
All Fish	47	2	x	ns	ns	ns	ns	x	ns	ns	ns	ns	ns
Game Fish	36	13	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cyprinids	16	22	*	ns	*	*	*	*	ns	x	x	*	ns
Darters	9	29	*	ns	*	ns	*	*	ns	x	ns	*	ns
Brook Trout	4	45	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Central Mudminnow	5	44	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Northern Pike	11	38	*	ns	*	x	ns	*	ns	x	ns	x	ns
Creek Chub	4	45	ns	ns	ns	ns	ns	ns	ns	ns	ns	x	ns
Golden Shiner	12	37	*	ns	*	x	*	*	x	ns	*	*	ns
Common Shiner	7	42	x	ns	x	x	x	x	ns	ns	ns	ns	ns
Bluntnose Minnow	7	31	x	ns	x	ns	x	x	ns	ns	ns	x	ns
Finescale Dace	5	44	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	x
White Sucker	14	35	*	ns	*	x	*	*	x	ns	x	*	ns
Brown Bullhead	13	36	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Brook Stickleback	3	46	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Rock Bass	4	45	x	ns	x	ns	x	x	ns	x	ns	ns	ns
Smallmouth Bass	5	33	*	ns	x	x	x	x	ns	x	ns	x	ns
Largemouth Bass	16	33	x	ns	ns	ns	ns	x	ns	x	ns	ns	ns
Pumpkinseed	15	34	x	ns	x	ns	x	x	ns	ns	ns	x	ns
Bluegill Sunfish	13	36	x	ns	x	ns	x	x	ns	x	ns	ns	ns
Black Crappie	3	46	x	ns	x	ns	x	x	ns	x	ns	x	ns
Yellow Perch	31	18	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Johnny Darter	3	35	x	ns	x	ns	x	x	ns	x	ns	x	ns
Iowa Darter	6	32	x	ns	x	ns	x	x	ns	ns	ns	x	ns

a Statistical comparisons are based on the Wilcoxon rank sum and Kolmogorov-Smirnov tests. Asterisks indicate tests considered statistically significant at $\alpha=0.05$ adjusted for 19 tests per species (including both chemical and physical variables), i.e., $p \leq 0.0026$. x's indicate tests with $p \leq 0.05$; and ns indicates variables that were not significant, $p > 0.05$.

statistical differences were identified, lakes without fish caught had consistently lower pH, Ca, ANC, sum of base cations, SiO_2, and SO_4, had smaller lake area, and were more often seepage lakes than nonseepage lakes. All variables except thermal stratification, Secchi depth, and inorganic Al had a calculated p value ≤ 0.05 for at least one fish species. As an example, differences between lakes with and without white sucker are illustrated in Figure 8.4 for those physical and chemical variables with $p \leq 0.05$.

Of the 38 lakes surveyed with beach seines, cyprinid species (8 species; see Table 7.1) were caught in 16 lakes; darters (2 species) were collected in 9 lakes. In all lakes in which darters were caught, cyprinids were also collected. Statistical differences ($p \leq 0.0026$) between lakes with and without cyprinids occurred for six variables: lake pH, Ca, DOC, ANC, sum of the base cations, and SiO_2 (Tables 8.6 and 8.7). Lakes without cyprinids had significantly lower pH, Ca, DOC, ANC, sum of base cations, and SiO_2 concentrations. Similar results were found for darters, with statistical differences detected for the same set of chemical variables except DOC. Of the 38 lakes sampled with beach seines, 24 (63.2%) were seepage lakes. Cyprinids and darters were caught in only 6 of these seepage lakes (25% of the seepage lakes), but in 10 of the 14 nonseepage lakes (71.4%).

For game fish and all fish species combined, no statistical differences ($p > 0.0026$) were detected for any of the lake characteristics for lakes with and without fish caught (Tables 8.6 and 8.7).

The relationship between fish species presence/absence and lake characteristics [1] was quantified using maximum likelihood logistic regression (Harrell 1983):

$$\hat{P}_i = \frac{1}{1 + e^{-\left(b_0 + b_1 X_{i1} + b_2 X_{i2} + \ldots + b_k X_{ik}\right)}}$$

where:

$\hat{P}_i$ is the predicted probability of fish presence in lake i,

b_0 through b_k are the estimated regression coefficients, and

X_{i1} through X_{ik} represent the physical and chemical characteristics of lake i.

In general, logistic regression models should include no more than m/10 independent variables, where m is the number of observations for the least frequent category of the

[1] Logistic regression analyses were conducted for the 17 continuous predictor variables; models could not be developed for the two binary variables (lake type and thermal stratification).

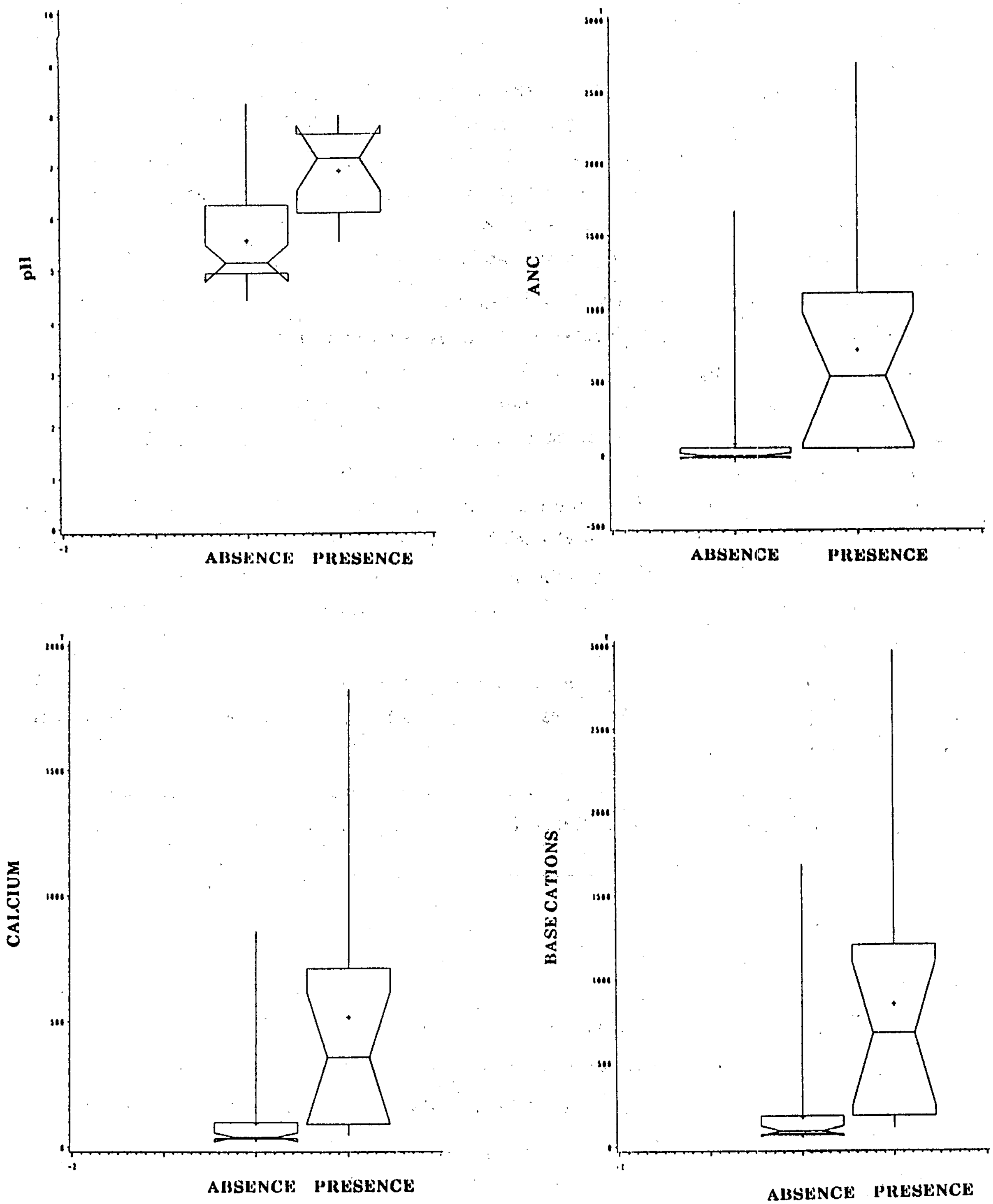


Figure 8-4. Box-and-whisker plots comparing lake characteristics with and without white sucker. The vertical bar represents the data range; the upper and lower boundaries of the box, the 75% and 25% quartiles; the notch, the 90% confidence limits around the median; the center of the box, the median; and the cross-mark, the mean.

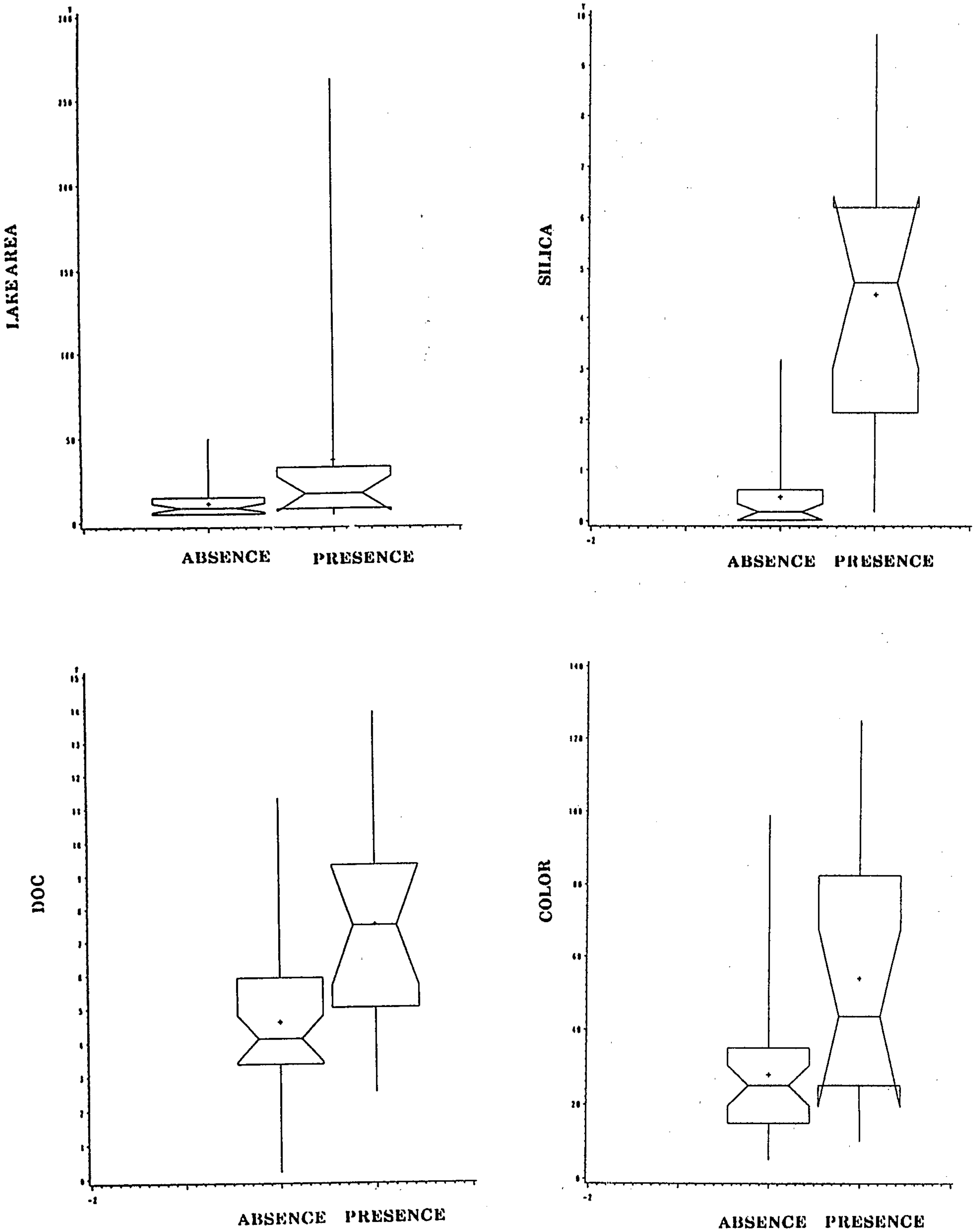


Figure 8-4. Continued.

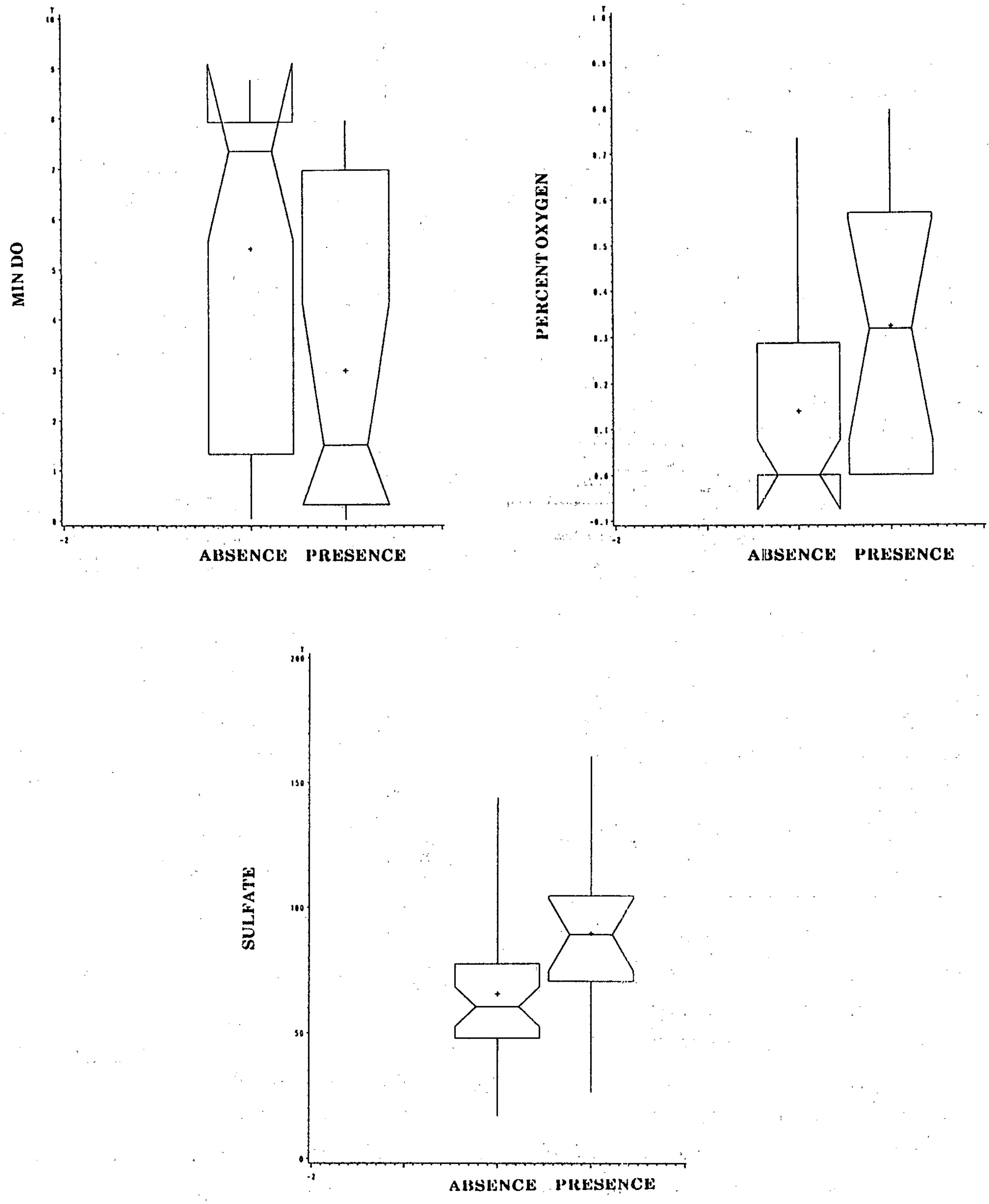


Figure 8-4. Continued.

binary response variable (i.e., the number of lakes with the fish species absent)(Harrell 1983). Thus, logistic regression models were developed only for the eight species and two groups of fish (game fish and cyprinids) caught in at least 10 lakes (see Table 8.6). For all of these species and groups, fish were caught in greater than 10 but fewer than 20 lakes (i.e., $10 < m < 20$); thus these analyses were limited to single-variable models.

For each variable of interest, models based on the nontransformed and log-transformed (base e) data were compared, using the likelihood ratio statistic (a goodness-of-fit test that compares the specified model with the unrestricted model; Statistical Analysis System [SAS] 1987). The results were generally similar to the model comparisons conducted for the OLS species richness models (Section 8.2). For lake area, elevation, Ca, sum of base cations, ANC, color, and extractable Al, for most fish species (for those models with $p \leq 0.05$ for the predictor variable) the log-transformed data resulted in a better goodness-of-fit (higher likelihood ratio) than did the nontransformed data. For SO_4, DOC, minimum DO, and proportion of the water column with DO < 4 mg/L, models based on the nontransformed data had a better goodness-of-fit. For SiO_2, lake depth, inorganic Al, and total P, results from the logistic regression analysis provided no definitive indication of the relative merits of the nontransformed and log-transformed data. For consistency with the species richness models, log-transformations were used for lake depth, inorganic Al, and total P, while values for SiO_2 were not transformed.

Estimates of the model coefficients for each of the single-variable logistic models with $p \leq 0.05$ are provided in Table 8.8. As expected, the pattern of results is quite similar to that for the nonparametric comparisons of lakes with and without fish. Five predictor variables resulted in models of fish species presence/absence significant at α=0.05, adjusted for 17 tests per species ($p \leq 0.0029$): lake pH, ln(Ca), ln(base cations), ln(ANC), and SiO_2. All other variables examined except ln(depth), ln(Secchi depth), ln(inorganic Al), and ln(total P) had $0.0029 < p \leq 0.05$ in at least one model (for 10 fish species or groups). The probability of fish presence was consistently higher in lakes with higher pH, Ca, DOC, base cations, ANC, color, SO_4, and SiO_2; lower levels of extractable Al and minimum DO; and a higher proportion of the water column with DO < 4 mg/L; and for larger lakes at lower elevations (Table 8.8).

Principal components, derived from the principal components analysis of lake physical and chemical variables described in Section 8.1 (Table 8.2), were also considered as predictor variables of fish presence/absence in single-variable logistic

Table 8.8. Model Coefficient Estimates for Those Single-Variable Logistic Regression Models with $p \le 0.05$ for the Predictor Variable

Fish Species/Group	Likelihood Ratio	Intercept			Predictor Variable		
		Estimate	Std. Error	p-Value	Estimate	Std. Error	p-Value
ln (Area)							
Cyprinids	0.12	-3.23	1.32	0.0142	1.20	0.53	0.0232
Northern Pike	0.57	-5.40	1.61	0.0008	1.63	0.59	0.0056
Golden Shiner	0.34	-3.43	1.18	0.0038	0.92	0.44	0.0360
White Sucker	0.24	-3.51	1.20	0.0034	1.05	0.46	0.0215
ln (Elevation)							
Brown Bullhead	0.55	17.34	8.97	0.0531	-3.22	1.58	0.0423
Minimum DO							
White Sucker	0.17	0.01	0.50	0.9897	-0.22	0.10	0.0284
Proportion of water column with DO < 4mg/L							
White Sucker	0.10	-1.48	0.45	0.0009	2.51	1.20	0.0359
pH							
Cyprinids	0.92	-12.78	3.62	0.0004	2.08	0.61	0.0006
Northern Pike	0.89	-10.79	3.09	0.0005	1.50	0.46	0.0011
Golden Shiner	0.55	-7.38	2.34	0.0016	1.01	0.36	0.0050
White Sucker	0.55	-9.35	2.61	0.0003	1.36	0.40	0.0008
Largemouth Bass	0.26	-5.32	1.93	0.0060	0.76	0.31	0.0142
Pumpkinseed	0.24	-5.67	1.99	0.0045	0.79	0.31	0.0118
Bluegill	0.30	-5.43	2.03	0.0075	0.72	0.32	0.0238

(continued)

Table 8.8. Continued

Fish Species/Group	Likelihood Ratio	Intercept			Predictor Variable		
		Estimate	Std. Error	p-Value	Estimate	Std. Error	p-value
ln (Ca)							
Cyprinids	0.66	-8.11	2.39	0.0007	1.73	0.54	0.0014
Northern Pike	0.60	-5.60	1.60	0.0005	0.91	0.31	0.0033
Golden Shiner	0.47	-5.22	1.52	0.0006	0.86	0.30	0.0040
White Sucker	0.51	-6.72	1.75	0.0001	1.23	0.36	0.0006
Largemouth Bass	0.09	-3.18	1.25	0.0112	0.54	0.26	0.0398
Pumpkinseed	0.42	-4.47	1.39	0.0013	0.79	0.29	0.0059
Bluegill	0.28	-3.50	1.32	0.0079	0.53	0.27	0.0453
DOC							
Cyprinids	0.49	-3.26	1.08	0.0026	0.59	0.21	0.0046
Northern Pike	0.21	-2.60	0.82	0.0016	0.23	0.12	0.0500
Golden Shiner	0.29	-3.27	0.93	0.0004	0.35	0.13	0.0069
White Sucker	0.30	-3.01	0.87	0.0006	0.35	0.13	0.0059
ln (Base Cations)							
Cyprinids	0.79	-10.59	3.31	0.0014	2.02	0.67	0.0025
Northern Pike	0.68	-6.58	1.92	0.0006	0.99	0.34	0.0033
Golden Shiner	0.60	-6.43	1.88	0.0006	0.99	0.33	0.0031
White Sucker	0.77	-8.59	2.27	0.0002	1.44	0.42	0.0005
Largemouth Bass	0.14	-3.84	1.55	0.0130	0.60	0.29	0.0374
Pumpkinseed	0.29	-5.23	1.69	0.0020	0.84	0.31	0.0072
Bluegill	0.28	-4.19	1.61	0.0093	0.60	0.29	0.0396

(continued)

Table 8.8. Continued

Fish Species/Group	Likelihood Ratio	Intercept			Predictor Variable		
		Estimate	Std. Error	p-Value	Estimate	Std. Error	p-Value
ln (ANC)							
Cyprinids	0.72	-11.30	3.99	0.0046	2.16	0.82	0.0084
Northern Pike	0.70	-7.05	2.02	0.0005	1.07	0.36	0.0026
Golden Shiner	0.51	-6.09	1.88	0.0012	0.92	0.34	0.0060
White Sucker	0.70	-8.56	2.30	0.0002	1.43	0.43	0.0008
Largemouth Bass	0.18	-4.73	1.72	0.0060	0.76	0.32	0.0172
Pumpkinseed	0.29	-5.60	1.81	0.0020	0.90	0.33	0.0070
Bluegill	0.30	-4.65	1.73	0.0071	0.68	0.31	0.0291
ln (Color)							
Golden Shiner	0.22	-4.89	1.87	0.0090	1.10	0.52	0.0342
White Sucker	0.17	-5.95	1.97	0.0026	1.46	0.55	0.0076
ln (Ext. Al)							
Cyprinids	0.09	0.88	0.65	0.18	-0.056	0.26	0.0300
Northern Pike	0.74	0.36	0.61	0.5607	-0.87	0.33	0.0076
Largemouth Bass	0.44	0.55	0.58	0.3365	-0.62	0.25	0.0144
Bluegill	0.59	0.25	0.58	0.6623	-0.64	0.27	0.0183
SO_4							
Golden Shiner	0.46	-3.28	1.03	0.0015	0.03	0.01	0.0192
White Sucker	0.29	-2.89	0.96	0.0026	0.03	0.01	0.0229

(continued)

Table 8.8. Continued

Fish Species/Group	Likelihood Ratio	Intercept			Predictor Variable		
		Estimate	Std. Error	p-Value	Estimate	Std. Error	p-Value
SiO_2							
Cyprinids	0.25	-1.23	0.47	0.0086	0.61	0.24	0.0110
Northern Pike	0.42	-2.03	0.50	0.0001	0.38	0.14	0.0083
Golden Shiner	0.37	-1.94	0.49	0.0001	0.41	0.15	0.0061
White Sucker	0.96	-2.97	0.73	0.0000	1.25	0.39	0.0013
Pumpkinseed	0.26	-1.40	0.42	0.0008	0.32	0.14	0.0195
Principal Component 1							
Cyprinids	0.87	-0.08	0.54	0.8850	1.01	0.33	0.0019
Northern Pike	0.79	-1.61	0.45	0.0004	0.53	0.17	0.0018
Golden Shiner	0.71	-1.44	0.43	0.0007	0.53	0.17	0.0016
White Sucker	0.97	-1.44	0.51	0.0046	0.94	0.26	0.0003
Largemouth Bass	0.16	-0.79	0.33	0.0159	0.29	0.13	0.0273
Pumpkinseed	0.34	-0.95	0.36	0.0073	0.42	0.15	0.0043
Principal Component 5							
Brown Bullhead	0.50	-1.42	0.45	0.0016	-1.27	0.49	0.0088
Cyprinids	0.11	-0.30	0.35	0.3969	1.58	0.77	0.0398
Principal Component 8							
Game fish	0.29	1.16	0.36	0.0014	-1.24	0.64	0.0500
Principal Component 14							
Yellow Perch	0.11	0.61	0.32	0.0543	2.18	1.05	0.0385

regression models. For 4 of the 10 species/groups, the first principal component (defined primarily by Ca, sum of the base cations, pH, ANC, and SiO_2) was significantly associated with fish presence/absence at $\alpha=0.05$, adjusted for 19 tests per species/group ($p \leq 0.0026$); two additional species had $0.0026 < p \leq 0.05$ for principal component 1 (Table 8.8). Brown bullhead and cyprinid presence/absence were associated at $0.0026 < p \leq 0.05$ with principal component 5 (defined primarily by lake elevation and total P). Game fish and yellow perch were marginally associated ($0.0026 < p \leq 0.05$) with higher-order principal components, 8 and 14, respectively. All other comparisons between fish presence/absence and the lake physical/chemical principal components were nonsignificant with $p > 0.05$.

Given that many of the above predictor variables (e.g., pH, Ca, ANC, sum of base cations, SiO_2, lake type, and lake area; Section 8.1) are themselves highly collinear, it is not possible to determine definitively which lake attributes are actually most important in controlling patterns of fish species distribution among the ELS-II lakes. Individual predictor variables resulting in the highest likelihood ratio (goodness-of-fit) for each species in the single-variable logistic regression models were as follows: white sucker, SiO_2 (0.96)(also principal component 1, 0.97); cyprinids and northern pike, pH (0.92 and 0.89, respectively); golden shiner, ln(sum of base cations) (0.60)(also principal component 1, 0.71); bluegill sunfish and largemouth bass, ln(extractable Al) (0.59 and 0.44, respectively); brown bullhead, ln(elevation)(0.55); and pumpkinseed sunfish, ln(Ca) (0.42). In contrast, for yellow perch and game fish (which includes yellow perch), presence/absence was not significantly associated with any of the lake physical or chemical attributes considered.

The pH range of occurrence for each species caught in at least five ELS-II lakes is illustrated in Figure 8-5. Consistent with the above results, yellow perch, central mudminnow, and brown bullhead appear quite tolerant of acidic conditions, occurring at pH levels as low as 4.55-4.74. Bluegill sunfish were also caught in lakes with very low pH (4.55). Pumpkinseed sunfish, largemouth bass, and golden shiner occurred at pH levels down to 4.9-5.1, while cyprinid and darter species were generally restricted to lakes with pH > 5.7. A two-way analysis of variance (lake pH as a function of lake type and fish presence/absence, for each species caught in at least 10 lakes) indicated no significant differences ($p > 0.05$) in the pH levels associated with fish presence/absence in seepage as opposed to nonseepage lakes.

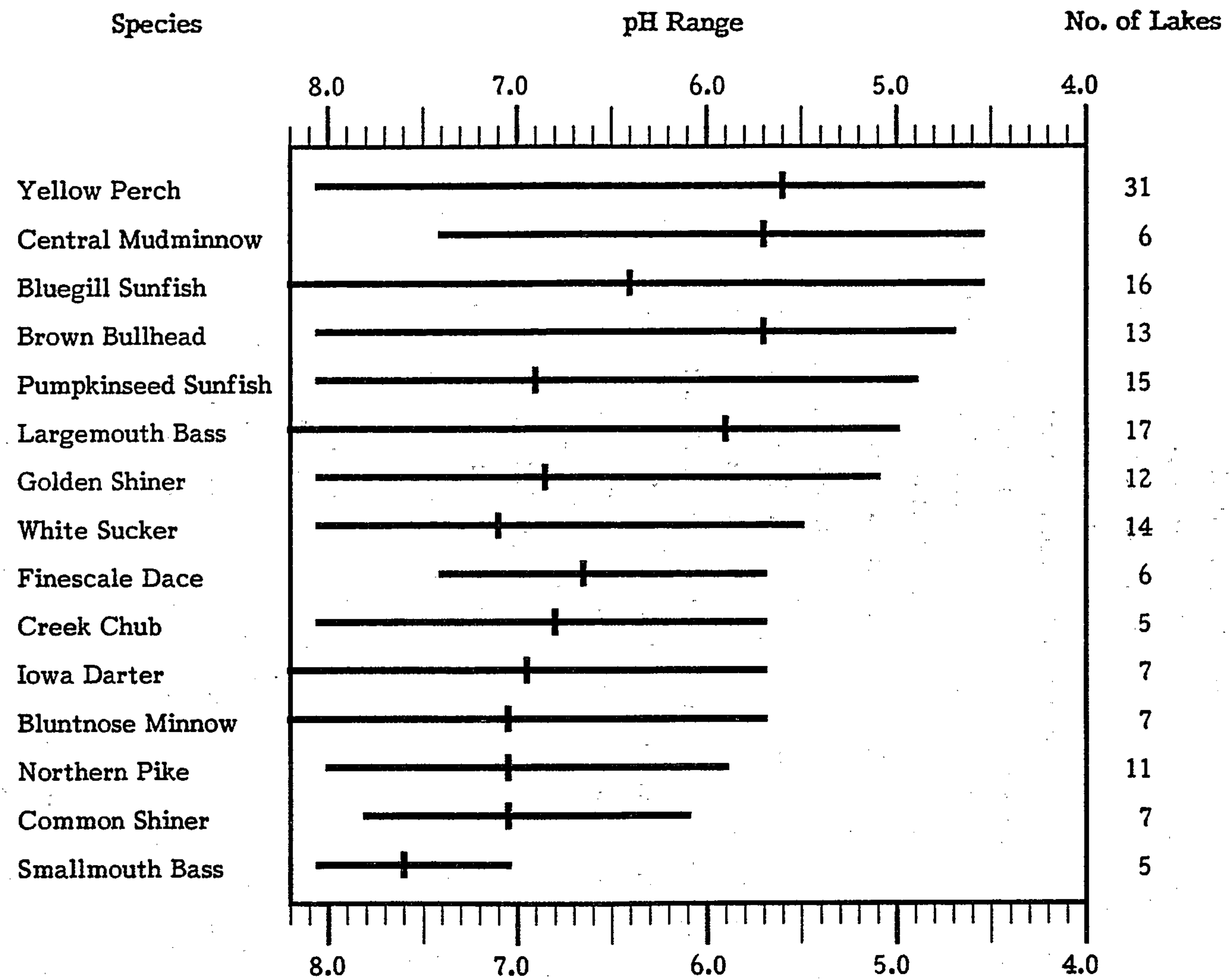


Figure 8-5. The distribution of fish species in relation to pH for the 49 ELS-II lakes. Maximum, median, and minimum pH of occurrence noted.

8.4 TOTAL CATCH AND CATCH PER UNIT EFFORT

In contrast to the large number of variables associated with species richness and fish presence/absence, nonparametric comparisons between total catch (and CPUE; all fish species combined) and the 19 physical and chemical variables of interest indicated no correlations significant at $\alpha=0.05$ (adjusted for 19 tests per fish response variable, $p \leq 0.0026$) and only three physical/chemical variables with $0.0026 < p \leq 0.05$ (depth, Secchi depth, and inorganic Al)(Table 8.3). Ordinary least-squares regression with ln(catch) (for the 47 lakes with fish caught) produced similar results. Stepwise forward OLS regression identified only ln(depth) as significant at $p \leq 0.05$. Total catch and lake depth were inversely related with a very low model r^2 (0.11). Likewise, regression of the physical/chemical principal components (Table 8.2) on ln(catch) and ln(CPUE) indicated no significant associations (all principal components had $p > 0.05$).

Among-lake patterns in catch and CPUE were also examined for the 8 individual fish species caught with gill nets and trap nets in 10 or more lakes. Only for yellow perch were any significant associations (at $\alpha=0.05$, adjusted for 19 tests per response variable per species, $p \leq 0.0026$) identified between fish catch or CPUE and lake physical and chemical characteristics (Table 8.9). Numbers of yellow perch caught and yellow-perch CPUE (for both gill nets and trap nets) were higher in lakes with lower pH ($r=-0.68$ to -0.72, Spearman's rank correlation), ANC ($r=-0.68$ to -0.71), Ca ($r=-0.56$ to -0.61), sum of base cations ($r=-0.55$ to -0.60), and SiO_2 ($r=-0.48$ to -0.56), and higher concentrations of extractable Al ($r=0.55$ for trap-net CPUE). Thus, yellow perch appear not only tolerant of acidic conditions, but actually more abundant in acidic waters with low Ca, base cations, and SiO_2.

The high variability in catch rates, discussed in Section 4.2.2, limits the utility of catch and CPUE as indices of relative fish abundance. The lack of any clear correlations between lake characteristics and fish catch for most species may result largely from this high variability in catch efficiency. Definitive conclusions regarding the relationship between lake characteristics and fish abundance are not possible based solely on the ELS-II survey data.

8.5 FISH CONDITION FACTORS

Only four fish species had adequate numbers of fish caught and measured (at least five fish per lake, including fish caught in the duplicate surveys, Section 4.2.2) in a sufficient number of lakes (at least five) for evaluation of among-lake patterns in fish condition factors: largemouth bass (7 lakes), northern pike (7), white sucker (11), and

Table 8.9. Association Between Total Catch and Catch Per Unit Effort and Lake Physical and Chemical Characteristics for Selected Fish Species[a]

	Yellow Perch			Northern Pike			Largemouth Bass		
	Total Catch	Gill-Net CPUE	Trap-Net CPUE	Total Catch	Gill-Net CPUE	Trap-Net CPUE	Total Catch	Gill-Net CPUE	Trap-Net CPUE
No. of Lakes	31	31	31	11	11	11	13	13	13
VARIABLE									
Lake Type	-	x	x	-	ns	x	-	ns	ns
Area	-0.41	-0.47	-0.37	ns	ns	ns	ns	ns	-0.60
Depth	ns	ns	-0.42	ns	ns	ns	ns	ns	ns
Elevation	ns	ns	ns	ns	ns	ns	ns	ns	ns
Minimum DO	ns	ns	ns	ns	ns	ns	ns	ns	ns
%DO < 4mg/L	ns	ns	ns	ns	ns	ns	ns	ns	ns
Thermal Stratif.	ns	ns	ns	ns	ns	ns	ns	ns	ns
Secchi Depth	ns	ns	ns	ns	ns	ns	ns	ns	ns
pH	-0.71*	-0.68*	-0.72*	0.62	ns	ns	ns	ns	ns
Inorg. Al	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ca	-0.61*	-0.60*	-0.56*	0.62	ns	ns	ns	ns	ns
DOC	-0.38	-0.41	-.036	ns	ns	ns	ns	ns	ns
Sum Base Cations	-0.60*	-0.60*	-0.55*	0.64	ns	ns	ns	ns	ns
ANC	-0.71*	-0.68*	-0.71*	0.61	ns	ns	ns	ns	ns
Color	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ext. Al	0.46	0.38	0.55*	ns	ns	ns	ns	ns	ns
SO_4	ns	ns	ns	ns	ns	ns	ns	ns	ns
SiO_2	-0.55*	-0.56*	-0.48*	ns	ns	0.70	ns	ns	ns
Total P	ns	ns	ns	ns	ns	ns	ns	ns	ns

(continued)

Table 8.9. Continued

	Pumpkinseed			Brown Bullead			Golden Shiner		
	Total Catch	Gill-Net CPUE	Trap-Net CPUE	Total Catch	Gill-Net CPUE	Trap-Net CPUE	Total Catch	Gill-Net CPUE	Trap-Net CPUE
No. of Lakes	15	15	15	13	13	13	12	12	12
VARIABLE									
Lake Type	-	ns	ns	-	x	ns	-	ns	ns
Area	ns	ns	ns	-0.68	ns	-0.66	ns	ns	ns
Depth	ns	ns	ns	ns	ns	ns	ns	ns	ns
Elevation	ns	ns	ns	ns	ns	ns	ns	ns	ns
Minimum DO	ns	ns	ns	ns	ns	ns	ns	ns	ns
%DO < 4mg/L	ns	ns	ns	ns	ns	ns	ns	ns	ns
Thermal Stratif.	ns	ns	ns	ns	ns	ns	ns	ns	ns
Secchi Depth	ns	ns	ns	ns	ns	-0.60	ns	ns	ns
pH	ns	ns	ns	ns	ns	ns	ns	ns	ns
Inorg. Al	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ca	ns	ns	ns	ns	ns	ns	ns	ns	ns
DOC	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sum Base Cations	ns	ns	ns	ns	ns	ns	ns	ns	ns
ANC	ns	ns	ns	ns	ns	ns	ns	ns	ns
Color	ns	ns	ns	ns	ns	ns	0.61	ns	ns
Ext. Al	ns	ns	ns	ns	ns	ns	ns	ns	ns
SO_4	ns	0.56	ns	ns	ns	ns	ns	ns	ns
SiO_2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Total P	ns	ns	ns	ns	ns	ns	ns	ns	ns

[a] Analyses restricted to those lakes in which the species was caught. For continuous variables, values reported are the Spearman's rank correlation coefficient. For binary variables (lake type and thermal stratification, comparisons are based on Wilcoxon rank sum and Kolmogorov-Smirnov (K-S) tests. Asterisks indicate correlations significant at $\alpha=0.05$, adjusted for 19 tests per response variable per species ($p \leq 0.0026$). For the Wilcoxon and K-S tests, x's indicate $p \leq 0.05$. For two fish species, white sucker and bluegill sunfish, all comparisons were non-significant with $p > 0.05$ (ns); therefore, no results for these species are included in the table.

yellow perch (29). Variations in fish condition factors were analyzed as a function of fish length and each of the 19 physical/chemical lake characteristics of interest, in separate two-variable OLS regression models (Table 8.10). Three-variable models with fish condition as a function of fish length, the number of fish caught per lake, and each lake attribute were also evaluated and provided similar results.

For each of the four species, fish condition factors were significantly associated (α=0.05, adjusted for 19 tests per species, $p \leq 0.0026$) with at least one lake characteristic. For white sucker, higher condition factors (heavier fish for a given length) occurred in lakes at lower elevation; with higher transparency (Secchi depth), pH, ANC, Ca, sum of base cations, SiO_2, and total P; and lower levels of DOC, color, and extractable Al. Yellow perch condition factors were significantly ($p \leq 0.0026$) higher in shallower lakes; lakes with higher ANC, color, and SiO_2; lower transparency; a smaller percentage of the water column with DO < 4 mg/L; and higher minimum DO values; and in lakes not thermally stratified. In contrast, condition factors for northern pike and largemouth bass were significantly correlated ($p \leq 0.0026$) with relatively few lake characteristics. Northern pike tended to have higher condition factors in larger lakes with higher levels of DO. Variations in largemouth bass condition factors were significantly associated only with variations in total P: heavier fish (adjusted for fish length) occurred in lakes with lower levels of total P.

Given the large number of factors that influence fish growth and condition, and also expected variations in condition factors across the three-month sampling period, the above results must be interpreted with caution. Specific factors responsible for variations in fish condition among lakes cannot be determined from the ELS-II survey data.

Table 8.10 Summary of Results from Ordinary Least Squares Regression of Fish Condition Factors as a Function of Fish Length and Lake Physical and Chemical Characteristics[a]

	Northern Pike	White Sucker	Largemouth Bass	Yellow Perch
No. of Fish	88	282	89	1174
Lake Type	x	ns	ns	ns
ln (Area)	*	ns	ns	ns
ln (Depth)	ns	x	ns	*
ln (Elevation)	ns	*	x	ns
Min.DO	x	ns	ns	*
%DO< 4mg/L	*	ns	ns	*
Thermal Strat.	ns	ns	ns	*
ln (Secchi Depth)	ns	*	ns	*
pH	ns	*	ns	ns
ln (Inorg. Al)	ns	x	ns	ns
ln (Ca)	ns	*	ns	ns
DOC	x	*	x	ns
ln (Base Cations)	ns	*	ns	x
ln (ANC)	ns	*	ns	*
ln (Color)	ns	*	ns	*
ln (Ext. Al)	ns	*	x	ns
SO_4	ns	ns	ns	x
SiO_2	ns	*	ns	*
ln (Total P)	ns	*	*	ns

[a] In most cases, the relationship between fish condition and fish length was significant ($p \leq 0.0029$). Asterisks in the table indicate significant relationships between fish condition factors and lake characteristics, adjusted for fish length [model: fish condition=f (fish length, lake attribute)] at $\alpha=0.05$, adjusted for 19 tests per species ($p \leq 0.0026$); x's indicate models with $p \leq 0.05$; ns indicates $p > 0.05$. Analyses include only lakes with at least five fish of the species caught.

9. REGIONAL POPULATION ESTIMATES

Based on the probability sampling frame for the ELS-I and ELS-II surveys (Section 2), data collected on fish community status for the 49 ELS-II lakes can be extrapolated to estimate fish community characteristics for Subregion 2B as a whole. In this section, regional estimates are provided for (1) the numbers and area of lakes with selected fish species and groups of fish (e.g., game fish) and (2) species richness. No regional estimates are computed for fish catch, size, or condition factors.

Two methods of regional extrapolation were used to estimate the ELS-II target population descriptions. The first approach involved a direct estimate from the ELS-II sample using the ELS-II weighting factors described in Section 2.2.2 (Table 2.3). The second approach incorporated the additional information collected in ELS-I (i.e., the lake physical and chemical data). In this case, the observed relationships between fish community status and lake characteristics for the 49 lakes sampled during ELS-II (Section 8) were assumed to hold for all lakes in the ELS-II target population. Using these relationships and the lake physical and chemical data collected in ELS-I, values for the fish response variables (and associated estimates of standard error) can be predicted for each ELS-I lake in the ELS-II target population (n=105 lakes). The ELS-I weighting factors and algorithms for regional extrapolation were then applied to calculate population estimates. Model-based population estimates were calculated only for species richness. The specific procedures for computing population estimates and appropriate measures of variance for both approaches are described in Overton (in prep.), adapted from Overton (1987).

As discussed in Section 2.2, only 49 of the 50 lakes selected for ELS-II were sampled. The lake not sampled, 2B1-065, has a small weighting factor (2.72) and represents only 0.4% of the ELS-II target population (Table 2.3). As a result, the absence of data for Lake 2B1-065 has a relatively minor impact on the ELS-II population estimates (and variances). For example, the estimated number of lakes in the ELS-II target population based on the ELS-II weighting factors for the 49 lakes sampled is 639.5 (standard error = 148.3 lakes); as compared to 642.3 lakes (standard error = 100.4) calculated from the ELS-II weighting factors for all 50 lakes, and 596.7 lakes (standard error = 58.9) calculated using the ELS-I weighting factors for the 105 ELS-I lakes in the ELS-II target population (see Section 2.2). The population estimates that follow, therefore, were calculated from the 49-lake sample without any specific adjustment for the missing data for Lake 2B1-065.

Regional estimates of the number and area of lakes with fish present were calculated for (1) all fish species combined, (2) for game fish as a group (see Section 3.6.2), and (3) for the 17 fish species susceptible to the three gear types fished in all lakes (see Table 7.1), based on the ELS-II weighting factors and direct estimation from the 49 lakes sampled in ELS-II (Table 9.1). The estimated proportion of the fishery resource (i.e., lakes with the fish species present) occurring in lakes with low ANC (< 50 μeq/L) is also indicated in Table 9.1. Fish occurred in an estimated 99.4% of the lakes in Subregion 2B (ELS-II target population), 99.5% based on lake area. Game species (i.e., yellow perch, brook trout, lake trout, smallmouth bass, largemouth bass, northern pike, and walleye) occurred in an estimated 83.7% of the lakes, 95.7% based on lake area. Yellow perch was the most common species in Region 2B, occurring in an estimated 69.8% of the lakes, 88.6% based on lake area. White sucker and largemouth bass also occurred in over 50% of the lakes in the ELS-II target population (52.1% and 50.8%, respectively; 81.6% and 36.2% based on lake area). Of the estimated 535 lakes supporting game species, 16.6% had ANC ≤ 50 μeq/L (4.0% based on lake area). Of the estimated 73 acidic lakes in the ELS-II target population, 94.9% (69.5 lakes) support one or more species of fish; 14.8% support only yellow perch.

Population estimates for species richness in lakes in Subregion 2B were calculated in three manners:

1. a direct estimate from the ELS-II sample using the ELS-II weighting factors and with species richness defined as the number of species caught with gill nets, trap nets, and angling;

2. a model-based estimate based on the OLS regression model of species richness as a function of the first 10 principal components derived from the 15 physical and chemical lake characteristics measured during ELS-I and with species richness defined as the number of fish species caught with gill nets, trap nets, and angling; and

3. a model-based estimate as described above but with species richness defined as the number of species caught in all four gear types, using data for only those 38 lakes sampled with beach seines.

The estimated mean number of species per lake from the direct estimation procedure was 5.5 (median 5.4) as compared to 5.0 species per lake (median 5.3) from the model-based approach. Inclusion of the catch in beach seines increases the estimated mean number of species (using the model-based approach) to 6.3 (median 6.1). Cumulative frequency distributions for the three population estimates (and associated 95% upper confidence limits) are presented in Figures 9-1 and 9-2.

Table 9.1. Population Estimates (Subregion 2B) of Lakes With Fish, based on Direct Estimation from the Sample of 49 ELS-II Lakes[a]

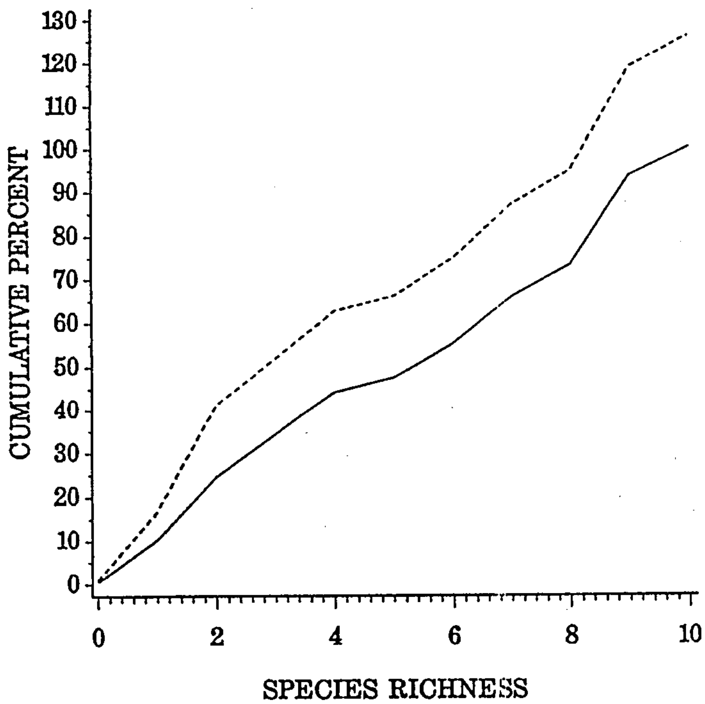
						Proportion of Lakes with Fish Present		Proportion of Lakes with Fish that have ANC ≤50 μeq/L	
	n	N̂	SE (N̂)	Â	SE (Â)	p	g	p	g
Lakes in ELS-II Target Population	49	639.5	148.3	21,995	10,934			0.233	0.066
All Fish Species	47	635.8	100.6	21,889	10,934	0.994	0.995	0.233	0.062
Game Fish	36	535.0	100.9	21,041	10,952	0.837	0.957	0.166	0.040
Brook Trout	4	95.4	56.7	2211	1837	0.149	0.100	0.020	0.006
Lake Trout	1	41.9	41.3	10,978	10,846	0.065	0.499	0.000	0.000
Rainbow Smelt	1	41.9	41.3	10,978	10,846	0.065	0.499	0.000	0.000
Northern Pike	11	267.4	80.5	16,561	10,935	0.418	0.753	0.042	0.006
Golden Shiner	12	269.8	85.1	16,323	11,016	0.422	0.742	0.038	0.009
Common Shiner	7	165.7	63.7	14,259	10,964	0.259	0.648	0.045	0.004
White Sucker	14	332.9	90.7	17,949	10,998	0.521	0.816	0.059	0.010
Brown Bullhead	13	220.2	76.6	3279	1872	0.344	0.149	0.291	0.204
Brook Stickleback	3	7.8	3.9	61	27	0.012	0.003	1.000	1.000
Rock Bass	4	143.7	70.7	13,815	10,915	0.225	0.628	0.000	0.000
Largemouth Bass	17	325.0	94.7	7961	3003	0.508	0.362	0.133	0.065
Pumpkinseed Sunfish	15	307.2	85.5	6464	2804	0.480	0.294	0.093	0.035
Sunfish Hybrid	3	27.5	17.9	405	314	0.043	0.018	0.374	0.213
Black Crappie	3	92.3	55.6	1573	981	0.144	0.072	0.000	0.000
Yellow Perch	31	446.3	91.8	19,484	10,967	0.698	0.886	0.182	0.040
Walleye	2	62.3	43.0	3083	2303	0.097	0.140	0.000	0.000
Mottled Sculpin	1	41.8	41.3	10,978	10,846	0.065	0.499	0.000	0.000

n = Number of lakes sampled with the fish species/group present.
N̂ = Estimated number of lakes with the species/group present in the ELS-II target population.
Â = Estimated lake area with fish present in the ELS-II target population.
p = Estimated proportion of lakes.

SE (N̂) = Standard error on N̂.
SE (Â) = Standard error on Â.
g = Estimated proportion of lake area.

a Estimates developed for those fish species reasonably susceptible to capture with gill nets, trap nets, and/or angling. Evaluation of fish presence/absence in the sample based on catch/no catch using all four gear types.

a



b

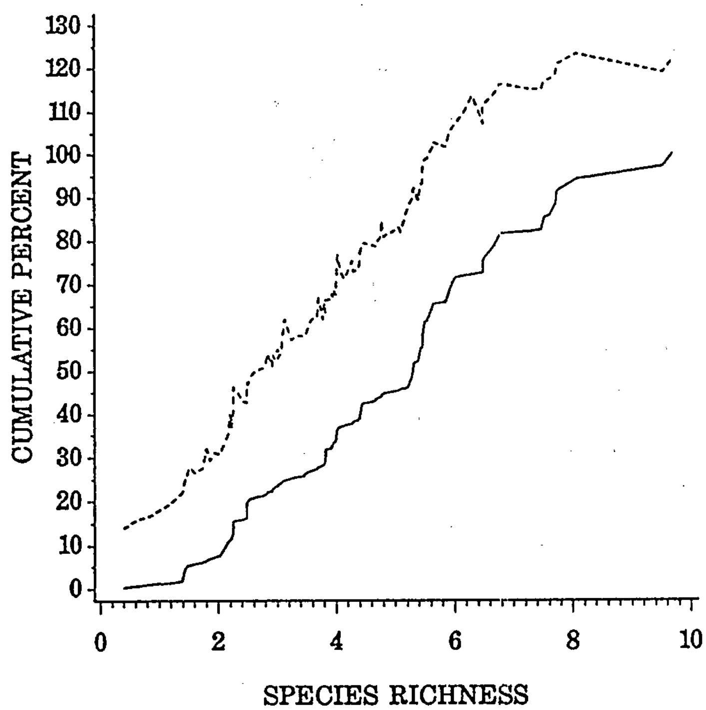


Figure 9-1. Cumulative frequency distributions of species richness (by number of lakes) for lakes in Subregion 2B, based on (a) the direct ELS-II estimate with 49 lakes and (b) the model-based approach, with species richness defined from catch with gill nets, trap nets, and angling. Dashed line indicates the 95% upper confidence limit.

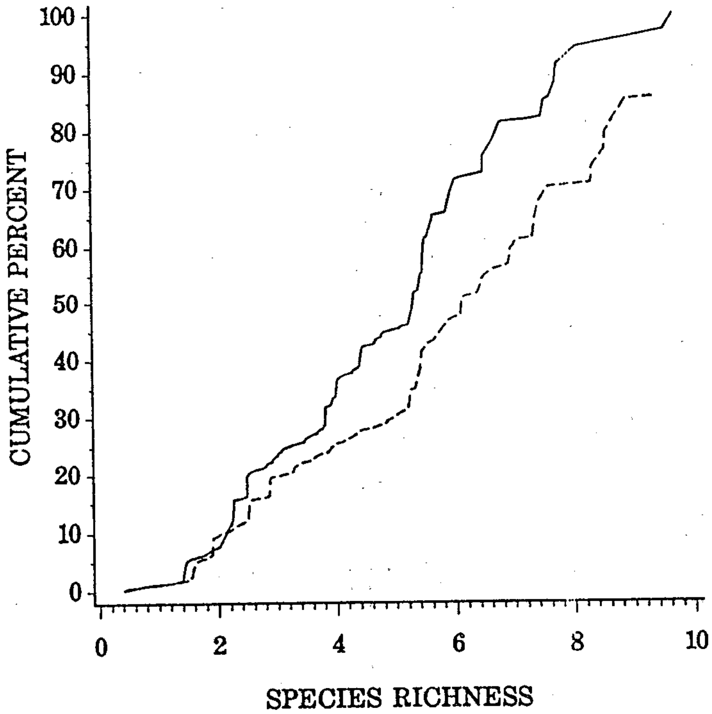


Figure 9-2. Cumulative frequency distributions of species richness (by number of lakes) for lakes in Subregion 2B, based on the model-based approach with species richness defined from catch with gill nets, trap nets, and angling (solid line) and with all four gear types (dashed line).

10. DISCUSSION AND SUMMARY

The fish species collected in the ELS-II were similar to those reported for lakes in other areas of the Upper Midwest (Wiener and Eilers 1987). Thirty-one fish species were collected in total. Yellow perch was the most common species, caught in 31 of the 49 lakes sampled and occurring in an estimated 69.8% of the lakes in the region (88.6% based on lake area). Largemouth bass and white sucker also occurred in over 50% of the lakes in the ELS-II target population.

Several of the fish species common in the region are quite tolerant of acidic conditions, as evidenced by their presence and reproduction in lakes with pH ≤ 5.0. Twelve of the 49 lakes surveyed had pH ≤ 5.0, with a minimum lake pH of 4.43. Six fish species occurred in at least one of these low-pH lakes: yellow perch (minimum pH of occurrence 4.55), central mudminnow (pH 4.55), bluegill sunfish (pH 4.55), brook stickleback (pH 4.65), brown bullhead (pH 4.74), and pumpkinseed sunfish (pH 4.94). Three additional fish species were caught in the 8 ELS-II lakes with pH 5.0 to 5.5: largemouth bass (pH 5.05), brook trout (pH 5.05), and golden shiner (pH 5.13). The apparent tolerance of these species to acidic conditions is supported by their occurrence in acidic waters in other surveys of lakes in the Upper Midwest (Rahel and Magnuson 1983, Wiener 1983, Rahel 1986, Wiener and Eilers 1987) and in the Adirondack region of New York State (Kretser et al. 1988) (Table 10.1).

While the presence of a reproducing population of fish in waters with low pH may confirm the tolerance of the species to acidic conditions, the absence of fish from such waters is not, by itself, sufficient evidence to conclude that the species is sensitive to acidity. Eight fish species occurred in at least 5 of the ELS-II lakes, but only in lakes with pH > 5.5: white sucker (n=14 lakes; minimum pH of occurrence 5.53), creek chub (n=5; pH 5.75), bluntnose minnow (n=7; pH 5.75), Iowa darter (n=7; pH 5.75), finescale dace (n=6; pH 5.75), northern pike (n=11; pH 5.90), common shiner (n=7; pH 6.10), and smallmouth bass (n=5; pH 7.05).

For some of these species, other information exists to support their classification as acid sensitive. For example, cyprinid species have been identified as particularly sensitive of low pH (pH 5.5-6.0) in laboratory and field bioassays (Johnson et al. 1987) and during the experimental acidification of Lake 223 (Mills et al. 1987, Mills and Schindler 1986), consistent with their absence at pH < 5.7 in the ELS-II. Rahel and Magnuson (1983) exposed 12 fish species from northern Wisconsin lakes to low pH levels in short-term laboratory bioassays. Cyprinids (e.g., bluntnose minnow and common

Table 10.1. Minimum pH Levels of Fish Species Occurrence in Synoptic Lake Surveys

Fish Species	Upper Peninsula of Michigan[a]	Northern Wisconsin[b]	Adirondacks, NY[c]
Acid-tolerant:			
Yellow Perch	4.5	4.4	4.5
Central Mudminnow	4.5	4.0	4.2
Bluegill Sunfish	4.5	4.5	-
Brook Stickleback	4.6	5.4	-
Brown Bullhead	4.7	-	4.5
Pumpkinseed Sunfish	4.9	4.9	4.6
Moderately Acid-tolerant			
Largemouth Bass	5.0	4.6	4.7
Brook Trout	5.0	-	4.6
Golden Shiner	5.1	5.2	4.5
Other Species			
White Sucker	5.5	4.9	4.6
Creek Chub	5.7	5.6	4.6
Bluntnose Minnow	5.7	6.2	6.6
Finescale Dace	5.7	-	-
Iowa Darter	5.7	6.2	-
Northern Pike	5.9	5.1	5.6
Common Shiner	6.1	6.2	4.9
Smallmouth Bass	7.0	5.2	5.6

a ELS-II data base, for those species caught in 5 or more lakes of the 49 surveyed.
b Wiener and Eilers (1987); species caught in 10 or more lakes of the 150 lakes surveyed.
c Kretser et al. (1988); species caught in 10 or more lakes of the 1123 surveyed.

shiner) were the most sensitive to low pH, while yellow perch, central mudminnows, and black bullhead were the most acid tolerant (Table 10.2). Schofield and Driscoll (1987) exposed seven species to acidic Adirondack stream water at pH 4.6. All common shiners and creek chub had died within 28 days, while 72% of the yellow perch and 100% of the central mudminnow survived. These results are consistent with the relative acid-sensitivity of the species inferred from the ELS-II survey (Table 10.2).

Table 10.2. Fish Survival Exposed to Continuously Declining pH in Laboratory Bioassays (Source: Rahel and Magnuson 1983), Compared to the Relative Sensitivity of Fish Species Inferred from the ELS-II Survey

					Sensitivity Rank Based on:	
	N	Median Survival Time (h)	pH at Median Survival Time	% Alive at Termination	Lab. Survival	ELS-II Field Distrib.
Blacknose Shiner	28	99	4.05	0	–	–
Bluntnose Minnow	15	105	4.00	0	1.5	3
Common Shiner	25	105	4.00	0	1.5	2
Northern Redbelly Dace	23	126	3.85	0	–	–
Smallmouth Bass	12	160	3.60	0	3	1
Mottled Sculpin	24	162	3.55	0	–	–
Golden Shiner (young)	24	174	3.45	0	–	–
Golden Shiner (adult)	18	176	3.45	0	4	4
Walleye	11	220	3.20	18	–	–
Rock Bass (adult)	21	223	3.15	14	–	–
Black Bullhead (young)	31	223	3.15	3	5	5
Rock Bass (young)	29	236	3.10	31	–	–
Black Bullhead (adult)	25	240	3.05	48	–	–
Central Mudminnow	17	240	3.05	41	6	6.5
Yellow Perch (young)	25	>240	<3.05	96	–	–
Yellow Perch (adult)	25	>240	<3.05	80	7	6.5

The absence of white sucker, northern pike, and smallmouth bass from ELS-II lakes with pH < 5.5-5.7, on the other hand, may result from factors other than low pH. In field surveys in northern Wisconsin (Rahel and Magnuson 1983) and New York (Schofield and Driscoll 1987, Kretser et al. 1988), white sucker were caught in lakes with pH levels as low as 4.6-4.9 (Table 10.1). During the experimental acidification of Lake 223, no adverse effects on white sucker populations were evident until pH levels reached 5.0-5.1 (Mills et al. 1987). Beamish et al. (1975) and Beggs et al. (1985) reported the extinction of white sucker populations from Ontario lakes at pH 4.8-5.2. Similar thresholds for the loss of northern pike and smallmouth bass in Ontario lakes were pH 4.7-6.2 (Beamish et al. 1975) and pH 5.2-5.4 (Harvey and Lee 1982), respectively. Northern pike and smallmouth bass have also been reported to occur at pH levels down to 5.1 to 5.2 in other areas of the Upper Midwest (Wiener and Eilers 1987) (Table 10.1). Rahel (1986) proposed that the absence of these two species from small, low-ANC lakes resulted from other habitat characteristics typical of these water bodies: the lack of vegetated littoral areas required by northern pike for spawning and the preference of smallmouth bass for wave-washed hard-bottomed substrates, generally rare in small, seepage lakes, as habitat and spawning sites.

Fish species distributions among lakes in the Upper Peninsula of Michigan, therefore, are influenced by a number of factors, not just acidity. In analyses of fish community structure in lakes in northern Wisconsin, Tonn and Magnuson (1982), Rahel and Magnuson (1983), Rahel (1986), and Rago and Wiener (1986) identified the importance of lake isolation (i.e., lake type and connectedness), lake area, winter anoxia, biological interactions, and lake pH and ANC as primary factors responsible for fish community composition and species richness. Results from the Upper Peninsula of Michigan were similar: fewer fish species occurred in seepage than in nonseepage lakes, in smaller lakes, and in lakes with lower levels of ANC, Ca, and base cations, and higher concentrations of extractable Al and DO.

Other than for yellow perch, no consistent relationship between fish catch, or CPUE, and lake characteristics was evident for the 49 ELS-II lakes in the Upper Peninsula of Michigan. Fish catch rates (capture efficiency) are often highly variable, making detection of patterns among lakes difficult (Ricker 1975, Bannernot and Austin 1983). Associations between CPUE and lake chemistry have been reported for some surveys (Kretser et al. 1988, Frenette et al. 1986), while other survey data sets suggest no consistent trends or relationships (Beggs et al. 1985, Haines et al. 1986). It is unclear whether the lack of a consistent pattern results from sampling variability or the absence of simple relationships between fish abundance and lake characteristics, detectable in synoptic surveys.

Likewise, fish condition factors tend to be highly variable, among seasons, among years, and among lakes, and influenced by a large number of environmental variables. In the ELS-II lakes, white sucker condition factors were significantly correlated with 11 of the 19 lake attributes evaluated; yellow perch with 8. Interpretation of these patterns to delineate effects related to acidity was not possible.

Studies in the Adirondack region of New York (Schofield and Trojnar 1980) and laboratory bioassays (Driscoll et al. 1980, Baker 1982, Ingersoll 1986) identified low pH and elevated levels of inorganic Al as the primary toxic agents in acidic waters. In the

ELS-II survey, however, relatively little of the among-lake variation in fish community status could be attributed to inorganic Al. Concentrations of Al are often low in seepage lakes (Eilers et al. 1988); sixteen of the 20 acidic lakes sampled were seepage lakes and all but one of the lakes sampled had levels of inorganic Al < 60 µg/L. As a result of these low concentrations, inorganic Al may play a relatively minor role in the effects of acidification on fish populations in the region.

Despite the relatively large numbers of acidic and low-pH lakes in the Upper Peninsula of Michigan, Subregion 2B, most lakes in the area (over 99% of the ELS-II target population by number and by lake area) support at least one fish species. Eighty-four percent of the lakes (96% of the lake area) support at least one game species (defined as yellow perch, walleye, largemouth and smallmouth bass, brook trout, and lake trout). Of the estimated 636 lakes that currently support fish in Subregion 2B (in the ELS-II target population), 23.3% have ANC ≤ 50 µeq/L and thus are potentially sensitive to future effects from acidic deposition; an estimated 16.6% of the lakes with game fish currently have ANC ≤ 50 µeq/L.

The ELS-II data base on fish communities in lakes in Subregion 2B provides a regional perspective on the current status of the fishery resource in the Upper Peninsula of Michigan and adjacent northeastern Wisconsin. It cannot be used, by itself, to determine whether aquatic resources in the region have been impacted by acidic deposition, nor to determine specific causes for observed among-lake patterns in fish communities. The ELS-II may, however, provide insight into processes of importance in controlling fish population responses to acidification and serve as a baseline for future analyses of trends in fish communities in the area.

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APPENDIX A

Quality Assurance and Quality Control Protocols for Measurement of Water Chemistry

APPENDIX A

A.1 INTRODUCTION

Basic information on quality assurance (QA) and quality control (QC) methods and results for Phase II of the Eastern Lake Survey (ELS-II) in the Upper Peninsula of Michigan were provided in Section 4 of Volume I of the project report. Further details on QA/QC procedures and protocols specifically for ELS-II measurements of water chemistry are described in the following sections: QA system audits (Section A.2), field measurements and sampling (Section A.3), laboratory measurements (Section A.4), and the overall QA procedures (Section A.5).

A.2 QUALITY ASSURANCE SYSTEM AUDITS

A system audit is a qualitative on-site evaluation of the field station and field operations, the sample processing laboratory, and the analytical laboratory. Facilities, equipment, and operations (e.g., record keeping, data reporting, and QC procedures) were reviewed during the system audits for this study of Fish Communities in Lakes in Subregion 2B (Upper Peninsula of Michigan) in Relation to Lake Acidity.

A.2.1 Field Operations On-Site Evaluation

During the course of field sampling, supervisory personnel from Michigan State University (W. Taylor, M. Fabrizio, and D. Hayes) performed four audits of field operations. In addition, periodic checks were made of completed data sheets for completeness and accuracy of data entry.

A.2.2 Laboratory On-Site Evaluation

An authorized representative of the U.S. Environmental Protection Agency (EPA) QA Manager conducted an in-depth evaluation of the analytical laboratory and the processing laboratory 19 June 1987. QA sample (audit, duplicate, and blank) data and QC data were reviewed, and methods for processing and analysis were observed. The auditor summarized all observations in the QA logbook for the project. All problems encountered were brought to the attention of the responsible laboratory manager for corrective action after the evaluation was completed.

A.3 FIELD MEASUREMENTS AND SAMPLING

In situ measurements consisted of four Hydrolab measurements (water temperature, DO, pH, and conductance), Secchi transparency, air temperature, and site depth, taken at the Eastern Lake Survey - Phase I (ELS-I) fall index site.

The Hydrolab was calibrated each morning prior to sampling. Calibrations for pH and conductivity were made with standards of low ionic strength applicable over a range of temperatures and barometric pressures; settings were checked using quality control check (QCC) solutions. The detailed calibration procedure is described in Hydrolab (1985) and in Hagley et al. (1987). Conductivity was standardized with a 0.001 N KCl solution (specific conductance = 147 µS/cm at 25 °C). National Bureau of Standards (NBS) traceable buffers (pH = 4.00 and pH = 7.00 at 25 °C) were used to standardize the pH electrode. Dissolved oxygen measurements were calibrated with water-saturated air.

Following acceptable calibration, the Hydrolab pH and conductivity calibrations were tested with the QCC solution. A table of theoretical values for various temperatures and barometric pressures was used to determine the accuracy of the calibrations (Hagley et al. 1987). If measurements of the QCC solution differed from theoretical values by more than 0.15 pH units or by more than 15 µS/cm, then the Hydrolab was recalibrated. If the recalibration failed, maintenance procedures were performed according to manufacturer recommendations. The Hydrolab temperature probe was also checked; the temperature reading of the QCC solution was required to be within $\pm$ 1 °C of the QCC solution temperature measured by an NBS-traceable thermometer.

A field QCC was performed on the Hydrolab after arrival at the lake. Sulfuric acid (0.0001 N, pH 4.03 at 25 °C) and KCl (0.001 N, 147 µS/cm at 25 °C) solutions were used for pH and conductivity checks, respectively.

Each afternoon, when sampling personnel returned to the base site, a QCC of each Hydrolab was performed using the QCC solution; daily maintenance was also completed. These procedures are described in detail in Hagley et al. (1987).

Secchi transparency was measured on the shaded side of the boat. The descending and the ascending Secchi depth readings were recorded. There are no QC checks for this measurement.

Air temperature was measured in the shade with a hand-held thermometer. There are no QC checks for this measurement.

Site depth was measured with an electronic depth (Ray Jefferson) recorder. The depth recorder was checked each day against a calibrated sounding line.

A.4 LABORATORY MEASUREMENTS

Sample analyses (including analyses for assessment of mercury bioaccumulation were performed by four laboratories (Table A.1) The methods for analysis, the

Table A.1. Laboratories Analyzing Water Chemistry Samples for the ELS-II in Subregion 2B

Laboratory	Sample Type	Analysis
Las Vegas Processing Laboratory	Water	pH Total reactive aluminum Nonlabile (organic)reactive aluminum
EMSL-Las Vegas	Water	Dissolved organic carbon Total dissolved fluoride
Battelle Northwest	Water Sediment	Dissolved mercury Total mercury Total mercury Particle size Organic carbon
Cornell University	Fish	Total mercury Total organic mercury

required detection limits and QA objectives were listed in Table 4.2 (Volume I). All analyses for each parameter were performed within the specified maximum allowable sample holding times [3 days for measurements of pH and aluminum (Al), 14 days for dissolved organic carbon (DOC), and 28 days for total dissolved fluoride (F)]. Table A.2 summarizes QC protocols for the processing laboratory in Las Vegas and the analytical laboratory at the EPA Environmental Monitoring Systems Laboratory (EMSL)-Las Vegas.

Table A.2. Summary of Quality Control Procedures for Water Chemistry Measurements for ELS-II in Subregion 2B

Parameter[a]	QC Check	Control Limits	Corrective Action[b]
pH	1. Electrode calibration Nernstian response (check)	1. Slope=1.00 ±0.05	1. Recalibrate or replace electrode
	2. pH QCCS 4 analyses	2. ±0.05 pH unit	2. Recalibrate
	3. Duplicate analysis	3. ±0.05 pH unit	3. Refine analytical technique; analyze another duplicate
Total dissolved F DOC Total monomeric Al Nonlabile monomeric Al	1. QCCS analysis (calibration and verification)	1. The lesser of the 99% confidence interval or value given in Table A.3.	1. Prepare new standards and recalibrate; reanalyze associated samples
	2. Detection limit determination (biweekly)	2. Required detection limits (RDL) given in Table 4.2 (Vol. I).	2. Refine instrumentation and technique
	3. Detection limit QCCS analysis	3. ±20%	3. Refine instrumentation and technique
	4. Calibration and reagent blank analyses	4. Blank value <2 x RDL.	4. Determine and eliminate contamination source; prepare fresh blank solution; reanalyze affected samples
	5. Duplicate analysis	5. Duplicate precision (% relative standard deviation) limits given in Table 4.2 (Vol I).	5. Investigate and eliminate source of imprecision; analyze another duplicate

a F and Al measured in mg/L.
b To be followed when QC check is outside of control limits.

The following documents and information were kept current and available to the analyst, supervisor, and QA representatives involved in the project:

- Standard operating procedures (SOP) - detailed instructions about the laboratory and the instrument operations.

- Laboratory QA plan - clearly defined laboratory protocols, including personnel responsibilities and use of QC protocols.

- Instrument performance study information - information on baseline noise, calibration standard response, precision as a function of concentration, and detection limits; used by the analyst and the supervisor to evaluate daily instrument performance.

- QC charts - the most recent QC charts with 99% warning limits and 95% control limits for all QCC samples and detection limit QCC samples, generated and updated for each batch of samples. The same QCC samples were used for all QC charts to ensure continuity. These QC charts were prepared specifically to ensure that the analysis remained in control. The actual control limits did not exceed the values given in Table A.3.

- Data sheet QC report - the laboratory manager's report reviewing the QC results for each parameter and flagging all results outside the statistically established QC limits for reanalysis before submitting the data to the Lockheed QA personnel.

Table A.3. Maximum Allowable Control Limits for Chemical Measurements for the ELS-II in Subregion 2B

Parameter	Detection Limit	QCCS
pH (pH units)	±0.05	N/A
DOC (mg/L)	±10%	±20%
F, total dissolved (mg/L)	±5%	±20%
Al, total monomeric (mg/L)	±10%	±20%
Al, nonlabile monomeric (mg/L)	±10%	±20%

An initial calibration was performed as required for each analytical method. Next, the linear dynamic range (LDR) was determined for the initial calibration. The concentrations of the calibration standards bracketed the expected sample concentrations. The low standard was ≤ 10 times the detection limit. If the concentration of a sample was above the LDR during the analysis, two options were considered: (1) dilute (maintaining a matrix similar to the sample matrix with respect to all preservatives) and reanalyze the sample or (2) calibrate a second concentration range, requiring analysis of a separate QC sample for each concentration range.

Immediately after standardization of the instrument, a QCC sample containing the analyte of interest at a concentration in the mid-calibration range was analyzed. The

QCC samples were obtained commercially or prepared by the analyst from a source independent of the calibration standards.

The calibration QC sample was analyzed to verify the calibration curve prior to any sample analysis and after the last sample. The observed value for the QC sample must not differ from the theoretical value by more than the limits given in Table A.3. When an unacceptable value for the calibration QC sample was obtained, the instrument was recalibrated and all samples analyzed since the last acceptable QC calibrations were reanalyzed.

Detection limit QCC samples were dilute (low-level) QC samples containing the analyte of interest at a concentration of two to three times the required detection limit. These QC samples were analyzed once per batch for total dissolved F, DOC, total monomeric Al, and nonlabile monomeric Al. The results were reported on the analytical data forms. The purpose of the detection limit QCC sample is to eliminate the necessity of formally determining the detection limit on a daily basis. The measured value of the analyte was required to be within 20% of the theoretical concentration to be considered acceptable. If it was not, the problem was identified and corrected, and an acceptable result or explanation was obtained prior to sample analysis.

A calibration blank was analyzed once per batch, immediately after the initial calibration, to check for baseline drift. The instrument was rezeroed if necessary. The calibration blank was defined as a "0" mg/L standard and contained only the matrix of the calibration standards. The observed concentration of the calibration blank was expected to be ≤ 2 X the required detection limit. If it was not, the instrument was rezeroed and the calibration rechecked.

A reagent blank was prepared and analyzed for each batch of samples for total monomeric Al, nonlabile monomeric Al, and F analyses. A reagent blank is defined as a deionized water sample plus all of the reagents (in the same quantities) used in preparing a routine sample for analysis. The reagent blank was carried through the same digestion/extraction procedure as a routine sample. The concentration of the reagent blank must be ≤ 2 X the required detection limit. If the concentration exceeded this limit, the source of contamination was investigated and corrective action implemented. A new reagent blank was then prepared and analyzed for any sample in which the high reagent blank value contributed significantly (>10%) to the value of the parameter in question. Reagent blank results were reported on the analytical data form but were not subtracted from sample results.

One sample per batch was prepared and analyzed in duplicate for each parameter to provide an estimate of analytical within-batch precision. The percent relative standard deviation (%RSD) between duplicate measurements was calculated as follows:

$$\%RSD = \frac{s}{\bar{X}} * 100$$

$$s = \left(\frac{\Sigma (\bar{X} - X)^2}{n-1} \right)^{\frac{1}{2}}$$

where: s is the standard deviation of the pair of measurements,

X is a datum (either the routine or the duplicate measurement),

$\bar{X}$ is the mean of the pair of measurements, and

n is the population size (2).

The %RSD of each duplicate pair was then plotted on a QC chart and the 99% and 95% confidence intervals established. Initial control limits were set at the precision levels given in Table 4.2 (Vol. I). If the precision of the laboratory duplicate values fell outside the control limits, a second, different sample was analyzed in duplicate. No further samples were analyzed until duplicate sample results were within the control limits.

After the last sample, a QC sample was analyzed to verify the calibration curve. If the measured value of the QC sample differed from the theoretical value by more than the limits given in Table A.2, the instrument was recalibrated and the affected samples reanalyzed.

Instrumental detection limits (IDLs) were determined and reported biweekly for each parameter except pH. For this study, the detection limit was defined as three times the standard deviation of eight nonconsecutive replicate reagent or calibration blank analyses for DOC and total dissolved F. For both Al analyses, detection limits were calculated using three times the standard deviation for the low-level audit sample. Calibration blanks were analyzed when a method did not require a reagent blank. Detection limits did not exceed the limits listed in Table 4.2 (Volume I).

A.5 OVERALL QUALITY ASSURANCE PROCEDURES

Field and laboratory audit samples, as well as field blanks and field replicates, were used as part of the QA activities for the ELS-II in Subregion 2B. The audit samples, field blanks, and field replicates were shipped to the analytical laboratory from the sample processing facility as though they were routine lake samples. Every attempt was made to ensure that the analytical laboratory did not recognize the audit samples as different from the routine lake samples. As a result, the audit samples were double blind to the analytical laboratory. That is, the laboratory neither recognized them as audit samples nor knew their compositions.

The purpose of field natural audit samples is to identify problems affecting data quality that may occur during sample processing, shipment, or analysis. When used in conjunction with laboratory audit samples, the analysis of these samples provides data that can be used to distinguish shipping and sample processing problems from analytical problems. Natural field audit samples were used to assess the overall among-batch precision during the ELS-II.

The purpose of laboratory synthetic audit samples is to identify problems affecting data quality that may occur during the analytical process. These samples help verify the accuracy of analytical procedures and ensure that the laboratory is maintaining the capability to properly analyze the samples. The synthetic laboratory audit samples were sent to the sample processing facility from a central laboratory. The audit samples were labeled at the sample processing facility, included in a batch with routine lake samples processed on the same day, and shipped to the analytical laboratory for analysis. The composition of the synthetic laboratory audit samples was designed to include each analyte at concentrations representative of the range in the survey lakes.

A field blank is a deionized water sample meeting specifications for ASTM Type 1 reagent water (ASTM 1984) that is carried to the lake and is processed through the Van Dorn sampler as though it were a routine sample. Field blank data are used to provide an overall estimate of the normal background contamination that might occur during sample collection, processing, transportation, and analysis, and to identify and correct any significant contamination problems as they occur.

A field replicate is an additional sample collected at the lake site by the same team immediately after the routine sample is collected. Field replicate data were used to estimate the overall within-batch (system) precision for the sampling, processing, transportation, and analysis process on a given day. Sixteen field replicates (one routine sample and three replicates from each of four lakes) were collected. Lakes were selected for replicate sampling to cover the concentration range expected for the ELS-II lakes.

A.6 REFERENCES

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APPENDIX B

Water Chemistry and Fish Catch Data by Individual Lakes and Sampling Dates

APPENDIX B

The variables reported in this Appendix are measured as follows:

Variable	Units
pH	pH units
Ext. Al	$\mu g/L$
Total Al	$\mu g/L$
Ca^{2+}	$\mu eq/L$
Conductivity	μS
DOC	mg/L
F^-	$\mu eq/L$
Mg^{2+}	$\mu eq/L$
Air Eq. pH	pH units
Total P	$\mu g/L$
Secchi Depth	m
Color	PCU
Na^+	$\mu eq/L$
SiO_2	mg/L
SO_4^{2-}	$\mu eq/L$
Site Depth	m
Lake Area	ha
Elevation	m
Watershed Area	ha

NAME: DEEP LAKE ID: 2B1-016
LONGITUDE: 91-14'30"W LATITUDE: 46-29'37"N STATE: WI

ELS-I CHEMISTRY SAMPLE DATE: 06NOV84

pH: 5.85 Ext. Al: 120.0 Tot. Al: 292.0 Ca: 97.30
Conductivity: 21.10 DOC: 11.30 F: 0.895 Mg: 59.23
Air Eq pH: 6.97 TP: 35.00 Secchi Depth: 0.95
Color: 99.00 Na: 22.18 Silica: 2.10 Sulfate: 54.13
Site Depth: 7.00 Lake Area: 4.2 Elevation: 361.2
Lake Type: DRAINAGE Watershed Area: 83.0

ELS-II CHEMISTRY SAMPLE DATE: 24JUN87

pH: 6.24 Inorganic Al: 0.02 Minimum DO: 0.06
DOC: 9.30 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.68

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 25JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	65.5
Trap Nets	3	66.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Largemouth Bass	0	0	0	5
Bluegill	2	4	0	12

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Largemouth Bass	12095	217	132
Largemouth Bass	12096	234	169
Largemouth Bass	12097	307	380
Largemouth Bass	12099	220	127
Bluegill	912055	153	61
Bluegill	912056	183	113
Bluegill	912057	171	85
Bluegill	912058	203	167
Bluegill	912059	166	91
Bluegill	912060	140	45
Bluegill	912061	132	40
Bluegill	912062	180	100
Bluegill	912063	137	49
Bluegill	912064	165	83

NAME: TWIN LAKES (EASTERN) ID: 2B1-022
LONGITUDE: 91-03'30"W LATITUDE: 46-41'06"N STATE: WI

ELS-I CHEMISTRY SAMPLE DATE: 01NOV84

pH: 5.90 Ext. Al: 4.00 Tot. Al: 21.00 Ca: 41.17
Conductivity: 13.00 DOC: 3.35 F: 0.737 Mg: 32.08
Air Eq pH: 6.36 TP: 14.50 Secchi Depth: 3.30
Color: 17.50 Na: 11.96 Silica: 0.02 Sulfate: 69.64
Site Depth: 3.30 Lake Area: 8.6 Elevation: 336.2
Lake Type: SEEPAGE Watershed Area: 197.0

ELS-II CHEMISTRY SAMPLE DATE: 24JUN87

pH: 5.77 Inorganic Al: 0.01 Minimum DO: 7.06
DOC: 3.90 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 25JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	66.7
Trap Nets	3	69.7
Seines	4	
Angling		

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Largemouth Bass	3	0	0	0
Bluegill	1	19	0	0
Northern Pike	3	0	0	0
Sunfish Hybrid	2	0	0	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 01SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	57.2
TRAP NETS	3	57.5
SEINES	4	
ANGLING		2.0

NAME: TWIN LAKES (EASTERN) ID: 2B1-022
LONGITUDE: 91-03'30"W LATITUDE: 46-41'06"N STATE: WI

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Largemouth Bass	1	0	0	1
Bluegill	3	56	14	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Northern Pike	264	850	4300
Northern Pike	265	620	1515
Northern Pike	266	634	1650
Largemouth Bass	267	211	120
Largemouth Bass	268	207	113
Largemouth Bass	269	220	129
Largemouth Bass	12917	255	203
Largemouth Bass	12918	240	183

NAME: LAKE NITA ID: 2B1-035
LONGITUDE: 86-03'51"W LATITUDE: 46-33'00"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 4.96 Ext. Al: 18.00 Tot. Al: 49.00 Ca: 21.96
Conductivity: 9.00 DOC: 4.70 F: 0.737 Mg: 13.16
Air Eq pH: 5.04 TP: 17.00 Secchi Depth: 1.50
Color: 80.00 Na: 6.52 Silica: 0.61 Sulfate: 16.86
Site Depth: 2.40 Lake Area: 4.3 Elevation: 281.9
Lake Type: SEEPAGE Watershed Area: 119.0

ELS-II CHEMISTRY SAMPLE DATE: 05AUG87

pH: 4.84 Inorganic Al: 0.01 Minimum DO: 6.40
DOC: 7.80 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 06AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	66.5
Trap Nets	3	72.0
Seines	4	
Angling		

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	162	245	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12629	231	134
Yellow Perch	12630	146	38
Yellow Perch	12631	152	43
Yellow Perch	12632	149	39
Yellow Perch	12633	152	47
Yellow Perch	12634	145	37
Yellow Perch	12635	151	42
Yellow Perch	12636	185	81
Yellow Perch	12637	166	61
Yellow Perch	12638	146	38
Yellow Perch	12639	156	47
Yellow Perch	12640	165	61
Yellow Perch	12641	138	35
Yellow Perch	12642	183	70
Yellow Perch	12643	201	124

NAME: LAKE NITA   ID: 2B1-035
LONGITUDE: 86-03'51"W LATITUDE: 46-33'00"N STATE: MI

Yellow Perch	12644	191	108
Yellow Perch	12645	139	37
Yellow Perch	12646	287	380
Yellow Perch	12647	296	460
Yellow Perch	12648	240	200
Yellow Perch	12649	230	180
Yellow Perch	12650	242	220
Yellow Perch	12651	229	160
Yellow Perch	12652	230	160
Yellow Perch	12653	194	93
Yellow Perch	12654	141	35
Yellow Perch	12655	140	36
Yellow Perch	12656	191	88
Yellow Perch	12657	195	97
Yellow Perch	12658	142	36
Yellow Perch	12659	140	35
Yellow Perch	12660	142	41
Yellow Perch	12661	144	38
Yellow Perch	12662	144	38
Yellow Perch	12663	143	36
Yellow Perch	12664	146	40
Yellow Perch	12665	142	36
Yellow Perch	12666	144	38
Yellow Perch	12667	140	32
Yellow Perch	12668	142	34
Yellow Perch	12669	135	29
Yellow Perch	12670	126	24

NAME: (NO NAME) ID: 2B1-038
LONGITUDE: 86-09'10"W LATITUDE: 46-30'42"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 4.56 Ext. Al: 18.00 Tot. Al: 5.00 Ca: 25.95
Conductivity: 17.40 DOC: 3.80 F: 0.579 Mg: 16.45
Air Eq pH: 4.56 TP: 12.00 Secchi Depth: 2.30
Color: 15.00 Na: 4.35 Silica: 0.06 Sulfate: 66.83
Site Depth: 1.80 Lake Area: 6.3 Elevation: 272.8
Lake Type: SEEPAGE Watershed Area: 57.0

ELS-II CHEMISTRY SAMPLE DATE: 20AUG87

pH: 4.51 Inorganic Al: 0.02 Minimum DO: 8.61
DOC: 2.00 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 21AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	63.0
Trap Nets	3	65.7
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:
NO FISH CAUGHT

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 11SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	57.0
TRAP NETS	3	58.0
SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:
NO FISH CAUGHT

NAME: WEST BRANCH LAKES (SW) ID: 2B1-039
LONGITUDE: 86-06'18"W LATITUDE: 46-30'38"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 4.98 Ext. Al: 55.00 Tot. Al: 108.0 Ca: 37.42
Conductivity: 15.70 DOC: 3.50 F: 0.842 Mg: 21.39
Air Eq pH: 4.93 TP: 13.00 Secchi Depth: 2.40
Color: 20.00 Na: 11.31 Silica: 0.21 Sulfate: 76.41
Site Depth: 2.40 Lake Area: 15.7 Elevation: 266.7
Lake Type: DRAINAGE Watershed Area: 122.0

ELS-II CHEMISTRY SAMPLE DATE: 18JUN87

pH: 4.92 Inorganic Al: 0.04 Minimum DO: 5.61
DOC: 2.40 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 19JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	71.0
Trap Nets	3	72.0
Seines	4	
Angling		1.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	245	72	0	2
Brown Bullhead	6	55	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12001	117	16
Yellow Perch	12002	158	43
Yellow Perch	12005	116	16
Yellow Perch	12007	132	19
Yellow Perch	12009	137	23
Yellow Perch	12011	115	16
Yellow Perch	12013	135	22
Yellow Perch	12015	120	14
Yellow Perch	12016	112	14
Yellow Perch	12020	117	14
Yellow Perch	12021	118	15
Yellow Perch	12022	116	13
Yellow Perch	12023	312	409
Yellow Perch	12024	335	434

NAME: WEST BRANCH LAKES (SW) ID: 2B1-039
LONGITUDE: 86-06'18"W LATITUDE: 46-30'38"N STATE: MI

Yellow Perch	12025	292	331
Yellow Perch	12026	278	216
Yellow Perch	12027	275	249
Yellow Perch	12028	241	151
Yellow Perch	12029	203	98
Yellow Perch	12032	144	29
Yellow Perch	12033	134	18
Yellow Perch	12038	118	15
Yellow Perch	12049	135	20
Yellow Perch	12050	137	21
Yellow Perch	12051	136	22
Yellow Perch	12053	132	19
Yellow Perch	12055	120	14
Yellow Perch	12056	180	62
Yellow Perch	12057	182	53

NAME: WEST BRANCH LAKES (SE) ID: 2B1-040
LONGITUDE: 86-05'46"W LATITUDE: 46-30'44"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 4.74 Ext. Al: 56.00 Tot. Al: 98.00 Ca: 36.43
Conductivity: 16.90 DOC: 5.60 F: 0.737 Mg: 18.92
Air Eq pH: 4.77 TP: 19.00 Secchi Depth: 2.05
Color: 50.00 Na: 7.39 Silica: 0.53 Sulfate: 64.13
Site Depth: 5.50 Lake Area: 4.5 Elevation: 269.8
Lake Type: DRAINAGE Watershed Area: 21.0

ELS-II CHEMISTRY SAMPLE DATE: 18JUN87

pH: 4.80 Inorganic Al: 0.02 Minimum DO: 7.34
DOC: 3.20 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 19JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	63.7
Trap Nets	3	70.2
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	84	33	0	0
Brown Bullhead	2	19	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	211	115	12
Yellow Perch	212	112	13
Yellow Perch	213	116	13
Yellow Perch	214	114	13
Yellow Perch	215	348	470
Yellow Perch	216	162	37
Yellow Perch	217	108	10
Yellow Perch	218	117	18
Yellow Perch	219	106	12
Yellow Perch	220	112	14
Yellow Perch	221	88	6
Yellow Perch	222	85	6
Yellow Perch	223	113	13
Yellow Perch	224	141	24

NAME: WEST BRANCH LAKES (SE) ID: 2B1-040
LONGITUDE: 86-05'46"W LATITUDE: 46-30'44"N STATE: MI

Yellow Perch	225	228	173
Yellow Perch	226	166	37
Yellow Perch	227	146	29
Yellow Perch	228	147	32
Yellow Perch	229	130	21
Yellow Perch	230	109	11
Yellow Perch	231	118	14
Yellow Perch	232	112	13
Yellow Perch	233	98	9
Yellow Perch	234	111	14
Yellow Perch	235	97	9
Yellow Perch	236	154	37
Yellow Perch	237	114	16
Yellow Perch	238	108	12
Yellow Perch	239	107	13
Yellow Perch	240	111	14
Yellow Perch	241	109	12
Yellow Perch	242	110	12
Yellow Perch	243	165	46
Yellow Perch	244	111	14
Yellow Perch	245	111	13
Yellow Perch	246	144	30
Yellow Perch	247	141	27
Yellow Perch	248	142	25
Yellow Perch	249	166	33
Yellow Perch	250	93	8
Yellow Perch	251	94	8
Yellow Perch	252	91	8
Yellow Perch	253	99	10
Yellow Perch	254	90	7
Yellow Perch	255	155	27
Yellow Perch	256	115	13
Yellow Perch	257	120	16
Yellow Perch	258	115	13
Yellow Perch	259	92	8
Yellow Perch	260	137	25
Yellow Perch	261	119	14
Yellow Perch	262	117	12
Yellow Perch	263	92	8

NAME: TRIANGLE LAKE ID: 2B1-041
LONGITUDE: 86-05'37"W LATITUDE: 46-31'48"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 23OCT84

pH: 5.13 Ext. Al: 28.00 Tot. Al: 34.00 Ca: 37.92
Conductivity: 15.10 DOC: 4.10 F: 0.790 Mg: 26.32
Air Eq pH: 5.12 TP: 22.00 Secchi Depth: 4.40
Color: 25.00 Na: 11.31 Silica: 0.00 Sulfate: 82.65
Site Depth: 7.00 Lake Area: 19.7 Elevation: 275.5
Lake Type: SEEPAGE Watershed Area: 60.0

ELS-II CHEMISTRY SAMPLE DATE: 10AUG87

pH: 4.80 Inorganic Al: 0.02 Minimum DO: 1.18
DOC: 2.40 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.21

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 11AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	4	77.0
Trap Nets	4	86.5
Seines	5	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	46	70	0	0
Largemouth Bass	3	0	0	0
Bluegill	0	0	10	0
Pumkinseed	17	46	0	0
Brown Bullhead	8	7	0	0
Golden Shiner	11	10	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	735	118	14
Yellow Perch	736	257	174
Yellow Perch	737	180	54
Yellow Perch	738	166	41
Yellow Perch	739	110	11
Yellow Perch	740	135	21
Yellow Perch	741	130	18
Yellow Perch	742	119	13
Yellow Perch	743	130	18
Yellow Perch	744	135	21

NAME: TRIANGLE LAKE ID: 2B1-041
LONGITUDE: 86-05'37"W LATITUDE: 46-31'48"N STATE: MI

Yellow Perch	745	110	11
Yellow Perch	746	120	14
Yellow Perch	747	135	19
Yellow Perch	748	110	12
Yellow Perch	749	119	13
Yellow Perch	750	118	13
Yellow Perch	751	107	11
Yellow Perch	752	120	14
Yellow Perch	753	118	12
Yellow Perch	754	135	19
Yellow Perch	756	118	13
Yellow Perch	757	118	15
Yellow Perch	758	111	13
Yellow Perch	759	111	13
Yellow Perch	760	111	11
Yellow Perch	761	110	13
Yellow Perch	762	131	19
Yellow Perch	763	133	20
Yellow Perch	764	118	14
Yellow Perch	765	110	11
Yellow Perch	766	130	18
Yellow Perch	767	105	10
Yellow Perch	768	110	12
Yellow Perch	769	111	13
Yellow Perch	770	131	18
Yellow Perch	771	111	11
Yellow Perch	772	120	15
Yellow Perch	773	118	14
Yellow Perch	774	103	9
Yellow Perch	775	132	19
Yellow Perch	776	168	41
Yellow Perch	777	105	10
Largemouth Bass	778	200	107
Largemouth Bass	779	186	84
Largemouth Bass	780	178	71

NAME: LONG LAKE ID: 2B1-042
LONGITUDE: 86-05'17"W LATITUDE: 46-30'08"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 5.01 Ext. Al: 21.00 Tot. Al: 37.00 Ca: 35.43
Conductivity: 11.50 DOC: 6.20 F: 0.684 Mg: 15.63
Air Eq pH: 5.07 TP: 18.00 Secchi Depth: 1.95
Color: 35.00 Na: 5.65 Silica: 0.59 Sulfate: 50.18
Site Depth: 4.30 Lake Area: 8.3 Elevation: 262.1
Lake Type: DRAINAGE Watershed Area: 36.0

ELS-II CHEMISTRY SAMPLE DATE: 05AUG87

pH: 4.99 Inorganic Al: 0.01 Minimum DO: 7.51
DOC: 3.30 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 06AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	64.0
Trap Nets	3	67.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Brook Stickleback	0	1	6	0

NAME: JOHNSON LAKE ID: 2B1-047
LONGITUDE: 85-02'38"W LATITUDE: 46-25'30"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 22OCT84

pH: 4.55 Ext. Al: 45.00 Tot. Al: 61.00 Ca: 57.39
Conductivity: 27.90 DOC: 0.50 F: 0.684 Mg: 30.44
Air Eq pH: 4.58 TP: 2.000 Secchi Depth: 3.40
Color: 5.00 Na: 6.09 Silica: 0.00 Sulfate: 133.0
Site Depth: 3.40 Lake Area: 16.7 Elevation: 252.1
Lake Type: SEEPAGE Watershed Area: 137.0

ELS-II CHEMISTRY SAMPLE DATE: 13AUG87

pH: 4.76 Inorganic Al: 0.01 Minimum DO: 7.91
DOC: 0.90 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 14AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	55.5
Trap Nets	3	60.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	167	579	0	0
Bluegill	1	1	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	824	94	7
Yellow Perch	826	94	7
Yellow Perch	827	94	7
Yellow Perch	830	94	8
Yellow Perch	831	84	5
Yellow Perch	833	94	8
Yellow Perch	837	85	5
Yellow Perch	838	124	19
Yellow Perch	839	122	18
Yellow Perch	840	125	18
Yellow Perch	841	123	17
Yellow Perch	842	123	17
Yellow Perch	843	120	18
Yellow Perch	844	123	18

NAME: JOHNSON LAKE ID: 2B1-047
LONGITUDE: 85-02'38"W LATITUDE: 46-25'30"N STATE: MI

Yellow Perch	845	124	19
Yellow Perch	846	123	18
Yellow Perch	847	120	17
Yellow Perch	848	203	98
Yellow Perch	849	204	91
Yellow Perch	850	83	6
Yellow Perch	851	80	5
Yellow Perch	852	82	5
Yellow Perch	853	200	82
Yellow Perch	854	175	57
Yellow Perch	855	208	94
Yellow Perch	856	263	224
Yellow Perch	857	177	58
Yellow Perch	858	174	53
Yellow Perch	859	172	50
Yellow Perch	860	224	129
Yellow Perch	861	170	52
Yellow Perch	862	241	174
Yellow Perch	863	170	54
Yellow Perch	864	177	61
Yellow Perch	865	171	49
Yellow Perch	866	246	181
Yellow Perch	867	175	56
Yellow Perch	868	176	57
Yellow Perch	869	177	52

NAME: MCNEARNEY LAKE ID: 2B1-048
LONGITUDE: 84-57'30"W LATITUDE: 46-25'35"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 22OCT84

pH: 4.43 Ext. Al: 213.0 Tot. Al: 287.0 Ca: 58.38
Conductivity: 32.60 DOC: 0.20 F: 0.790 Mg: 19.74
Air Eq pH: 4.51 TP: 0.000 Secchi Depth: 7.60
Color: 10.00 Na: 7.83 Silica: 0.00 Sulfate: 143.9
Site Depth: 7.60 Lake Area: 49.8 Elevation: 264.3
Lake Type: SEEPAGE Watershed Area: 199.0

ELS-II CHEMISTRY SAMPLE DATE: 12AUG87

pH: 4.42 Inorganic Al: 0.19 Minimum DO: 8.33
DOC: 0.32 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 13AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	6	127.0
Trap Nets	6	115.0
Seines	6	
Angling		2.0

NUMBER OF FISH CAUGHT:
NO FISH CAUGHT

NAME: PECK AND RYE LAKE ID: 2B1-052
LONGITUDE: 84-58'00"W LATITUDE: 46-23'50"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 22OCT84

pH: 4.95 Ext. Al: 6.00 Tot. Al: 23.00 Ca: 31.94
Conductivity: 14.90 DOC: 4.00 F: 1.000 Mg: 18.92
Air Eq pH: 4.99 TP: 7.000 Secchi Depth: 2.00
Color: 25.00 Na: 3.48 Silica: 0.00 Sulfate: 61.83
Site Depth: 1.80 Lake Area: 4.5 Elevation: 275.8
Lake Type: SEEPAGE Watershed Area: 39.0

ELS-II CHEMISTRY SAMPLE DATE: 12AUG87

pH: 4.67 Inorganic Al: 0.01 Minimum DO: 5.22
DOC: 3.50 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 13AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	66.5
Trap Nets	3	69.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	425	657	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	781	188	56
Yellow Perch	782	171	40
Yellow Perch	783	149	31
Yellow Perch	784	172	42
Yellow Perch	785	185	57
Yellow Perch	786	173	58
Yellow Perch	787	150	33
Yellow Perch	788	150	35
Yellow Perch	789	116	17
Yellow Perch	790	151	31
Yellow Perch	791	129	24
Yellow Perch	792	130	25
Yellow Perch	793	151	33
Yellow Perch	794	150	31
Yellow Perch	795	122	22

NAME: PECK AND RYE LAKE   ID: 2B1-052
LONGITUDE: 84-58'00"W LATITUDE: 46-23'50"N STATE: MI

Yellow Perch	796	131	25
Yellow Perch	797	130	26
Yellow Perch	798	176	47
Yellow Perch	799	150	30
Yellow Perch	800	130	23
Yellow Perch	801	129	22
Yellow Perch	802	121	21
Yellow Perch	803	131	25
Yellow Perch	804	130	25
Yellow Perch	805	176	53
Yellow Perch	806	122	22
Yellow Perch	807	130	24
Yellow Perch	808	130	25
Yellow Perch	809	118	19
Yellow Perch	810	150	34
Yellow Perch	811	123	24
Yellow Perch	812	123	20
Yellow Perch	813	123	21
Yellow Perch	814	149	34
Yellow Perch	815	119	21
Yellow Perch	816	122	22
Yellow Perch	817	150	33
Yellow Perch	818	122	23
Yellow Perch	819	123	21
Yellow Perch	820	123	22
Yellow Perch	821	180	64
Yellow Perch	822	196	75

NAME: GOPHER LAKE ID: 2B1-061
LONGITUDE: 86-03'30"W LATITUDE: 46-31'12"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 23OCT84

pH: 5.05 Ext. Al: 5.00 Tot. Al: 16.00 Ca: 29.94
Conductivity: 12.40 DOC: 1.60 F: 0.684 Mg: 14.81
Air Eq pH: 5.11 TP: 11.00 Secchi Depth: 3.40
Color: 5.00 Na: 5.22 Silica: 0.17 Sulfate: 60.38
Site Depth: 9.80 Lake Area: 6.4 Elevation: 266.7
Lake Type: SEEPAGE Watershed Area: 41.0

ELS-II CHEMISTRY SAMPLE DATE: 24AUG87

pH: 4.93 Inorganic Al: -0.00 Minimum DO: 0.08
DOC: 2.90 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.29

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 25AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	63.0
Trap Nets	3	63.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Largemouth Bass	12	1	0	0
Central Mudminnow	8	1	0	0
Brook Trout	7	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Brook Trout	870	457	1400
Brook Trout	871	451	1250
Brook Trout	872	245	200
Brook Trout	873	358	650
Brook Trout	874	361	800
Brook Trout	875	397	760
Brook Trout	876	508	1775
Largemouth Bass	877	118	21
Largemouth Bass	878	92	11
Largemouth Bass	879	108	17
Largemouth Bass	880	92	10
Largemouth Bass	881	90	11
Largemouth Bass	882	100	13

NAME: GOPHER LAKE ID: 2B1-061
LONGITUDE: 86-03'30"W LATITUDE: 46-31'12"N STATE: MI

Largemouth Bass	883	95	12
Largemouth Bass	884	96	13
Largemouth Bass	885	100	13
Largemouth Bass	886	117	23
Largemouth Bass	887	116	23
Largemouth Bass	888	90	10
Largemouth Bass	889	90	10

NAME: MALLARD LAKE ID: 2B1-064
LONGITUDE: 86-06'36"W LATITUDE: 46-33'51"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 5.06 Ext. Al: 7.00 Tot. Al: 36.00 Ca: 222.1
Conductivity: 12.40 DOC: 1.80 F: 0.579 Mg: 60.05
Air Eq pH: 5.11 TP: 10.00 Secchi Depth: 2.65
Color: 35.00 Na: 16.09 Silica: 0.32 Sulfate: 52.26
Site Depth: 3.00 Lake Area: 8.5 Elevation: 288.0
Lake Type: SEEPAGE Watershed Area: 39.0

ELS-II CHEMISTRY SAMPLE DATE: 20AUG87

pH: 4.70 Inorganic Al: 0.01 Minimum DO: 7.87
DOC: 1.70 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 21AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	69.0
Trap Nets	3	69.0
Seines	4	
Angling		

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	84	228	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12785	156	39
Yellow Perch	12786	154	39
Yellow Perch	12787	155	39
Yellow Perch	12788	155	36
Yellow Perch	12789	164	48
Yellow Perch	12790	171	51
Yellow Perch	12791	172	54
Yellow Perch	12792	185	58
Yellow Perch	12793	168	50
Yellow Perch	12794	163	39
Yellow Perch	12795	166	38
Yellow Perch	12796	171	39
Yellow Perch	12797	165	41
Yellow Perch	12798	175	55
Yellow Perch	12799	184	58

NAME: MALLARD LAKE ID: 2B1-064
LONGITUDE: 86-06'36"W LATITUDE: 46-33'51"N STATE: MI

Yellow Perch	12800	195	84
Yellow Perch	12801	191	55
Yellow Perch	12802	187	65
Yellow Perch	12803	185	56
Yellow Perch	12804	124	22
Yellow Perch	12805	126	18
Yellow Perch	12806	126	21
Yellow Perch	12807	120	18
Yellow Perch	12808	125	19
Yellow Perch	12809	130	22
Yellow Perch	12810	125	19
Yellow Perch	12811	132	23
Yellow Perch	12812	132	23
Yellow Perch	12813	135	25
Yellow Perch	12814	89	7
Yellow Perch	12815	123	20
Yellow Perch	12816	114	12
Yellow Perch	12817	123	19
Yellow Perch	12818	128	21
Yellow Perch	12819	126	21
Yellow Perch	12820	150	34
Yellow Perch	12821	150	36
Yellow Perch	12822	147	31
Yellow Perch	12823	150	35
Yellow Perch	12824	157	43
Yellow Perch	12825	148	32

NAME: LAMBERT LAKE ID: 2B1-066
LONGITUDE: 86-05'08"W LATITUDE: 46-30'33"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 4.65 Ext. Al: 71.00 Tot. Al: 103.0 Ca: 35.93
Conductivity: 19.40 DOC: 1.60 F: 0.842 Mg: 19.74
Air Eq pH: 4.66 TP: 15.00 Secchi Depth: 3.00
Color: 15.00 Na: 10.00 Silica: 0.18 Sulfate: 91.40
Site Depth: 3.00 Lake Area: 14.7 Elevation: 266.1
Lake Type: SEEPAGE Watershed Area: 91.0

ELS-II CHEMISTRY SAMPLE DATE: 06AUG87

pH: 4.59 Inorganic Al: 0.06 Minimum DO: 7.91
DOC: 1.20 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 07AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	55.5
Trap Nets	3	63.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Brook Stickleback	0	1	3	0

NAME: WRIGHT LAKE   ID: 2B2-004
LONGITUDE: 91-28'45"W LATITUDE: 46-31'15"N STATE: WI

ELS-I CHEMISTRY   SAMPLE DATE: 05NOV84

pH: 6.14 Ext. Al: 22.00 Tot. Al: 52.00 Ca: 45.41
Conductivity: 8.80 DOC: 7.90 F: 0.737 Mg: 32.90
Air Eq pH: 6.80 TP: 14.00 Secchi Depth: 1.55
Color: 42.00 Na: 12.18 Silica: 0.18 Sulfate: 26.44
Site Depth: 3.60 Lake Area: 8.1 Elevation: 350.5
Lake Type: SEEPAGE Watershed Area: 205.0

ELS-II CHEMISTRY   SAMPLE DATE: 22JUN87

pH: 6.44 Inorganic Al: 0.00 Minimum DO: 0.32
DOC: 7.70 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.24

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 23JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	54.0
Trap Nets	3	49.0
Seines	4	
Angling		

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
White Sucker	33	2	0	0
Flathead Minnow	0	10	0	0
Common Shiner	0	1013	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	12060	375	520
White Sucker	12061	410	700
White Sucker	12062	312	320
White Sucker	12063	346	500
White Sucker	12064	375	560
White Sucker	12065	298	280
White Sucker	12066	341	460
White Sucker	12067	335	420
White Sucker	12069	315	360
White Sucker	12070	340	420
White Sucker	12071	362	560
White Sucker	12072	310	350
White Sucker	12073	295	310

NAME: WRIGHT LAKE   ID: 2B2-004
LONGITUDE: 91-28'45"W LATITUDE: 46-31'15"N STATE: WI

White Sucker	12074	324	380
White Sucker	12075	356	580
White Sucker	12076	287	250
White Sucker	12077	323	340
White Sucker	12078	330	440
White Sucker	12079	308	320
White Sucker	12080	384	660
White Sucker	12081	370	560
White Sucker	12082	331	380
White Sucker	12083	370	580
White Sucker	12084	342	480
White Sucker	12085	347	480
White Sucker	12086	300	290
White Sucker	12087	349	550
White Sucker	12088	355	520
White Sucker	12089	295	300
White Sucker	12090	393	660
White Sucker	12091	351	520
White Sucker	12092	311	330
White Sucker	12093	324	380
White Sucker	12094	370	600

NAME: TOIVOLA LAKES (WEST) ID: 2B2-007
LONGITUDE: 88-48'01"W LATITUDE: 46-59'14"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 18OCT84

pH: 5.43 Ext. Al: 3.00 Tot. Al: 20.00 Ca: 23.45
Conductivity: 8.30 DOC: 2.50 F: 0.579 Mg: 14.81
Air Eq pH: 5.65 TP: 0.000 Secchi Depth: 3.65
Color: 10.00 Na: 4.35 Silica: 0.08 Sulfate: 47.68
Site Depth: 10.40 Lake Area: 6.3 Elevation: 396.9
Lake Type: SEEPAGE Watershed Area: 44.0

ELS-II CHEMISTRY SAMPLE DATE: 16JUL87

pH: 5.30 Inorganic Al: -0.00 Minimum DO: 0.77
DOC: 2.90 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.49

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 17JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	65.0
Trap Nets	3	68.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	53	143	1	1
Largemouth Bass	1	1	10	0
Bluegill	0	0	1	0
Pumkinseed	0	12	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	495	176	53
Largemouth Bass	500	420	1320
Largemouth Bass	501	122	18
Yellow Perch	502	171	52
Yellow Perch	503	201	73
Yellow Perch	504	117	15
Yellow Perch	505	116	15
Yellow Perch	506	98	9
Yellow Perch	508	115	15
Yellow Perch	509	115	15
Yellow Perch	510	117	14
Yellow Perch	511	155	38

NAME: TOIVOLA LAKES (WEST) ID: 2B2-007
LONGITUDE: 88-48'01"W LATITUDE: 46-59'14"N STATE: MI

Yellow Perch	512	117	15
Yellow Perch	513	115	15
Yellow Perch	514	119	16
Yellow Perch	515	126	18
Yellow Perch	516	126	18
Yellow Perch	517	150	35
Yellow Perch	518	115	14
Yellow Perch	519	125	18
Yellow Perch	520	136	26
Yellow Perch	521	127	20
Yellow Perch	522	135	22
Yellow Perch	523	119	15
Yellow Perch	524	143	31
Yellow Perch	525	139	26
Yellow Perch	526	125	20
Yellow Perch	527	102	10
Yellow Perch	528	128	18
Yellow Perch	529	126	20
Yellow Perch	530	153	36
Yellow Perch	531	125	20
Yellow Perch	532	127	20
Yellow Perch	533	128	20
Yellow Perch	534	100	10
Yellow Perch	537	95	8
Yellow Perch	538	100	10
Yellow Perch	540	98	10
Yellow Perch	543	146	29
Yellow Perch	544	149	36
Yellow Perch	545	141	33
Yellow Perch	546	146	35
Yellow Perch	547	158	42
Yellow Perch	548	161	43
Yellow Perch	549	160	41

NAME: (NO NAME) ID: 2B2-024
LONGITUDE: 88-12'32"W LATITUDE: 46-38'05"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 14OCT84

pH: 5.75 Ext. Al: 41.00 Tot. Al: 108.0 Ca: 79.84
Conductivity: 18.00 DOC: 8.40 F: 1.053 Mg: 46.89
Air Eq pH: 6.38 TP: 1.000 Secchi Depth: 1.70
Color: 60.00 Na: 15.23 Silica: 1.77 Sulfate: 79.12
Site Depth: 5.80 Lake Area: 8.1 Elevation: 545.6
Lake Type: SEEPAGE Watershed Area: 44.0

ELS-II CHEMISTRY SAMPLE DATE: 08JUL87

pH: 5.93 Inorganic Al: 0.01 Minimum DO: 0.97
DOC: 8.10 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.43

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 09JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	60.0
Trap Nets	3	63.0
Seines	4	
Angling		

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Iowa Darter	0	0	15	0
White Sucker	13	169	0	0
Creek Chub	0	1	0	0
Bluntnose Minnow	1	14	171	0
Finescale Dace	0	1	0	0
Golden Shiner	0	107	1	0
Sunfish Hybrid	0	38	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	389	146	24
White Sucker	389	146	24
White Sucker	390	146	27
White Sucker	390	146	27
White Sucker	391	179	48
White Sucker	391	179	48
White Sucker	392	200	62
White Sucker	392	200	62
White Sucker	393	179	46

NAME: (NO NAME) ID: 2B2-024
LONGITUDE: 88-12'32"W LATITUDE: 46-38'05"N STATE: MI

White Sucker	393	179	46
White Sucker	394	139	22
White Sucker	394	139	22
White Sucker	395	176	41
White Sucker	395	176	41
White Sucker	375	322	240
White Sucker	376	370	450
White Sucker	377	307	240
White Sucker	379	359	420
White Sucker	380	344	360
White Sucker	381	290	220
White Sucker	382	301	220
White Sucker	387	128	17
White Sucker	396	120	16
White Sucker	397	111	12
White Sucker	398	132	21
White Sucker	401	100	9
White Sucker	402	119	14
White Sucker	404	123	15
White Sucker	405	169	44
White Sucker	406	130	18
White Sucker	407	158	33
White Sucker	408	165	36
White Sucker	409	171	36
White Sucker	410	133	19
White Sucker	411	171	42
White Sucker	415	131	18
White Sucker	419	172	43
White Sucker	420	410	725
White Sucker	421	317	255
White Sucker	425	255	130
White Sucker	426	174	39
White Sucker	427	174	40

NAME: OTTER LAKE ID: 2B2-038
LONGITUDE: 85-39'32"W LATITUDE: 46-35'45"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 24OCT84

pH: 6.81 Ext. Al: 3.00 Tot. Al: 12.00 Ca: 131.2
Conductivity: 23.20 DOC: 7.40 F: 1.158 Mg: 64.16
Air Eq pH: 7.45 TP: 13.00 Secchi Depth: 1.75
Color: 25.00 Na: 26.53 Silica: 0.85 Sulfate: 52.26
Site Depth: 3.70 Lake Area: 5.5 Elevation: 230.1
Lake Type: DRAINAGE Watershed Area: 117.0

ELS-II CHEMISTRY SAMPLE DATE: 27AUG87

pH: 6.50 Inorganic Al: -0.00 Minimum DO: 8.75
DOC: 7.30 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 28AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	58.5
Trap Nets	3	57.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	45	27	0	0
Iowa Darter	0	0	13	0
Bluegill	0	0	46	0
Pumkinseed	0	14	0	0
Brown Bullhead	3	231	0	0
Creek Chub	2	0	0	0
Pugnose Minnow	0	0	75	0
Golden Shiner	28	14	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12871	221	105
Yellow Perch	12872	176	47
Yellow Perch	12873	197	74
Yellow Perch	12874	159	35
Yellow Perch	12875	193	63
Yellow Perch	12876	117	14
Yellow Perch	12877	153	29
Yellow Perch	12878	231	118

NAME: OTTER LAKE ID: 2B2-038
LONGITUDE: 85-39'32"W LATITUDE: 46-35'45"N STATE: MI

Yellow Perch	12879	219	111
Yellow Perch	12880	134	21
Yellow Perch	12881	165	40
Yellow Perch	12882	164	43
Yellow Perch	12883	166	38
Yellow Perch	12884	190	70
Yellow Perch	12885	217	98
Yellow Perch	12886	233	122
Yellow Perch	12887	150	31
Yellow Perch	12888	153	28
Yellow Perch	12889	123	19
Yellow Perch	12890	126	23
Yellow Perch	12891	125	20
Yellow Perch	12892	127	21
Yellow Perch	12893	127	21
Yellow Perch	12894	125	21
Yellow Perch	12895	154	34
Yellow Perch	12896	123	18
Yellow Perch	12897	124	19
Yellow Perch	12898	126	20
Yellow Perch	12899	262	205
Yellow Perch	12900	127	19
Yellow Perch	12901	105	12
Yellow Perch	12902	179	57
Yellow Perch	12903	180	56
Yellow Perch	12904	160	44
Yellow Perch	12905	191	72
Yellow Perch	12906	182	66
Yellow Perch	12907	134	25
Yellow Perch	12908	142	29
Yellow Perch	12909	142	25
Yellow Perch	12910	107	13
Yellow Perch	12911	109	14
Yellow Perch	12912	115	16
Yellow Perch	12913	117	18
Yellow Perch	12914	109	13

NAME: QUINLAN LAKE ID: 2B2-044
LONGITUDE: 85-46'31"W LATITUDE: 46-25'39"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 23OCT84

pH: 5.23 Ext. Al: 1.50 Tot. Al: 10.00 Ca: 25.20
Conductivity: 9.80 DOC: 3.80 F: 0.711 Mg: 15.63
Air Eq pH: 5.21 TP: 18.50 Secchi Depth: 3.00
Color: 17.50 Na: 3.48 Silica: 0.34 Sulfate: 40.91
Site Depth: 8.80 Lake Area: 4.7 Elevation: 259.4
Lake Type: SEEPAGE Watershed Area: 39.0

ELS-II CHEMISTRY SAMPLE DATE: 24AUG87

pH: 5.06 Inorganic Al: -0.00 Minimum DO: 1.69
DOC: 3.00 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.29

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 25AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	67.5
Trap Nets	3	71.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	161	18	0	0
Bluegill	47	5	0	0
Brown Bullhead	13	16	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12861	150	37
Yellow Perch	12826	180	61
Yellow Perch	12827	175	51
Yellow Perch	12828	169	47
Yellow Perch	12829	165	43
Yellow Perch	12830	155	38
Yellow Perch	12831	154	39
Yellow Perch	12832	155	38
Yellow Perch	12833	150	37
Yellow Perch	12834	164	41
Yellow Perch	12835	160	43
Yellow Perch	12836	160	44
Yellow Perch	12837	185	57

NAME: QUINLAN LAKE ID: 2B2-044
LONGITUDE: 85-46'31"W LATITUDE: 46-25'39"N STATE: MI

Yellow Perch	12838	155	39
Yellow Perch	12839	155	44
Yellow Perch	12840	155	40
Yellow Perch	12841	150	37
Yellow Perch	12842	155	42
Yellow Perch	12843	146	34
Yellow Perch	12844	162	43
Yellow Perch	12845	160	40
Yellow Perch	12846	165	51
Yellow Perch	12847	162	48
Yellow Perch	12848	160	43
Yellow Perch	12849	161	46
Yellow Perch	12850	175	58
Yellow Perch	12851	189	63
Yellow Perch	12852	170	52
Yellow Perch	12853	182	60
Yellow Perch	12854	180	66
Yellow Perch	12855	175	55
Yellow Perch	12856	175	53
Yellow Perch	12857	291	300
Yellow Perch	12858	295	300
Yellow Perch	12859	239	146
Yellow Perch	12860	240	160
Yellow Perch	12862	172	52
Yellow Perch	12863	173	49
Yellow Perch	12864	172	51
Yellow Perch	12865	249	178
Yellow Perch	12866	141	26
Yellow Perch	12867	151	30
Yellow Perch	12868	133	25
Yellow Perch	12869	113	13
Yellow Perch	12870	143	27
Bluegill	912435	147	50
Bluegill	912436	147	52
Bluegill	912438	141	45
Bluegill	912439	145	48
Bluegill	912440	148	49
Bluegill	912441	155	59
Bluegill	912442	165	57
Bluegill	912443	189	93
Bluegill	912444	152	53
Bluegill	912445	152	56

NAME: CRANBERRY LAKE ID: 2B2-049
LONGITUDE: 86-11'02"W LATITUDE: 46-27'06"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 5.10 Ext. Al: 10.00 Tot. Al: 16.00 Ca: 33.43
Conductivity: 10.60 DOC: 5.90 F: 0.684 Mg: 18.10
Air Eq pH: 5.17 TP: 39.00 Secchi Depth: 1.20
Color: 25.00 Na: 4.35 Silica: 0.18 Sulfate: 46.22
Site Depth: 12.20 Lake Area: 5.0 Elevation: 257.6
Lake Type: SEEPAGE Watershed Area: 21.0

ELS-II CHEMISTRY SAMPLE DATE: 30JUL87

pH: 4.96 Inorganic Al: 0.01 Minimum DO: 1.33
DOC: 4.00 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.73

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 30JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	67.0
Trap Nets	3	72.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	701	91	0	1

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 09SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	61.5
TRAP NETS	3	65.5
SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	291	247	0	0

NAME: CRANBERRY LAKE ID: 2B2-049
LONGITUDE: 86-11'02"W LATITUDE: 46-27'06"N STATE: MI

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12585	161	48
Yellow Perch	12586	170	54
Yellow Perch	12587	168	49
Yellow Perch	12588	165	44
Yellow Perch	12589	166	47
Yellow Perch	12590	156	40
Yellow Perch	12591	169	53
Yellow Perch	12592	166	50
Yellow Perch	12593	151	39
Yellow Perch	12594	167	47
Yellow Perch	12595	161	44
Yellow Perch	12596	153	39
Yellow Perch	12597	164	49
Yellow Perch	12598	153	40
Yellow Perch	12599	183	56
Yellow Perch	12600	158	40
Yellow Perch	12601	163	44
Yellow Perch	12602	170	45
Yellow Perch	12603	179	41
Yellow Perch	12604	109	14
Yellow Perch	12605	105	13
Yellow Perch	12606	112	14
Yellow Perch	12607	110	13
Yellow Perch	12608	115	15
Yellow Perch	12609	110	14
Yellow Perch	12610	109	14
Yellow Perch	12611	108	13
Yellow Perch	12612	112	13
Yellow Perch	12613	114	14
Yellow Perch	12614	115	16
Yellow Perch	12615	105	13
Yellow Perch	12616	114	15
Yellow Perch	12617	113	16
Yellow Perch	12618	108	13
Yellow Perch	12619	127	21
Yellow Perch	12620	134	24
Yellow Perch	12621	136	26
Yellow Perch	12622	137	27
Yellow Perch	12623	135	23
Yellow Perch	12624	130	22
Yellow Perch	12625	127	19
Yellow Perch	12626	126	19
Yellow Perch	12627	127	22
Yellow Perch	12628	136	27
Yellow Perch	918	280	230
Yellow Perch	919	286	260
Yellow Perch	922	186	68
Yellow Perch	923	121	17
Yellow Perch	924	173	49
Yellow Perch	927	122	17

NAME: CRANBERRY LAKE ID: 2B2-049
LONGITUDE: 86-11'02"W LATITUDE: 46-27'06"N STATE: MI

Yellow Perch	928	120	13
Yellow Perch	929	182	71
Yellow Perch	930	186	64
Yellow Perch	932	120	16
Yellow Perch	933	157	35
Yellow Perch	935	122	17
Yellow Perch	936	120	16
Yellow Perch	937	120	17
Yellow Perch	938	120	16
Yellow Perch	939	122	16
Yellow Perch	940	121	17
Yellow Perch	941	81	6
Yellow Perch	942	76	4
Yellow Perch	945	82	6
Yellow Perch	946	80	5
Yellow Perch	947	78	5
Yellow Perch	948	171	50
Yellow Perch	949	151	34
Yellow Perch	950	156	35
Yellow Perch	951	184	61
Yellow Perch	953	158	39
Yellow Perch	954	160	44
Yellow Perch	955	152	36
Yellow Perch	956	156	41
Yellow Perch	957	157	47
Yellow Perch	958	153	37
Yellow Perch	959	155	44
Yellow Perch	961	172	53
Yellow Perch	962	170	53
Yellow Perch	963	180	66
Yellow Perch	964	170	56

NAME: (NO NAME) ID: 2B2-055
LONGITUDE: 86-11'30"W LATITUDE: 46-28'05"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 4.55 Ext. Al: 53.00 Tot. Al: 107.0 Ca: 36.93
Conductivity: 16.10 DOC: 7.50 F: 0.737 Mg: 18.10
Air Eq pH: 4.57 TP: 22.00 Secchi Depth: 2.10
Color: 25.00 Na: 6.09 Silica: 0.46 Sulfate: 84.00
Site Depth: 2.10 Lake Area: 4.9 Elevation: 260.9
Lake Type: SEEPAGE Watershed Area: 18.0

ELS-II CHEMISTRY SAMPLE DATE: 30JUL87

pH: 4.70 Inorganic Al: 0.04 Minimum DO: 7.50
DOC: 3.60 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 31JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	51.0
Trap Nets	3	56.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Central Mudminnow	0	25	3	0

NAME: (NO NAME) ID: 2B2-061
LONGITUDE: 88-08'30"W LATITUDE: 46-35'38"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 14OCT84

pH: 5.53 Ext. Al: 49.00 Tot. Al: 142.0 Ca: 91.32
Conductivity: 20.70 DOC: 13.90 F: 1.316 Mg: 54.29
Air Eq pH: 5.76 TP: 18.00 Secchi Depth: 0.85
Color: 125.0 Na: 22.18 Silica: 3.74 Sulfate: 86.61
Site Depth: 2.70 Lake Area: 20.6 Elevation: 522.7
Lake Type: DRAINAGE Watershed Area: 210.0

ELS-II CHEMISTRY SAMPLE DATE: 01JUL87

pH: 5.59 Inorganic Al: 0.02 Minimum DO: 7.61
DOC: 21.50 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 02JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	4	93.0
Trap Nets	4	95.0
Seines	5	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	105	165	0	0
Largemouth Bass	3	0	77	0
Pumkinseed	0	1	0	0
White Sucker	144	85	0	0
Flathead Minnow	0	0	18	0
Golden Shiner	82	101	12	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	12234	388	220
White Sucker	12236	297	250
White Sucker	12247	240	138
White Sucker	12254	196	77
White Sucker	12258	282	243
White Sucker	12261	196	75
White Sucker	12262	170	48
White Sucker	12263	178	62
White Sucker	12264	170	51
White Sucker	12267	174	74

NAME: (NO NAME) ID: 2B2-061
LONGITUDE: 88-08'30"W LATITUDE: 46-35'38"N STATE: MI

White Sucker	12269	290	231
White Sucker	12271	277	275
White Sucker	12274	214	82
White Sucker	12275	190	82
White Sucker	12276	210	80
White Sucker	12278	285	200
White Sucker	12280	284	191
White Sucker	12284	287	204
White Sucker	12285	295	209
White Sucker	12286	279	179
White Sucker	12294	420	550
White Sucker	12295	375	450
White Sucker	12297	349	300
White Sucker	12299	345	350
White Sucker	12302	365	400
White Sucker	12303	210	82
White Sucker	12304	350	400
White Sucker	12305	426	650
White Sucker	12306	360	475
White Sucker	12307	360	375
Largemouth Bass	12309	276	300
Largemouth Bass	12310	330	450
Largemouth Bass	12311	320	550
Yellow Perch	12312	166	39
Yellow Perch	12313	147	28
Yellow Perch	12314	122	17
Yellow Perch	12315	125	17
Yellow Perch	12316	126	18
Yellow Perch	12317	142	27
Yellow Perch	12318	119	16
Yellow Perch	12319	112	13
Yellow Perch	12320	113	13
Yellow Perch	12321	102	10
Yellow Perch	12322	97	8
Yellow Perch	12323	75	4
Yellow Perch	12324	83	5
Yellow Perch	12325	87	6
Yellow Perch	12326	78	5
Yellow Perch	12327	180	49
Yellow Perch	12328	239	161
Yellow Perch	12329	302	366
Yellow Perch	12330	280	262
Yellow Perch	12331	296	268
Yellow Perch	12332	257	138
Yellow Perch	12333	284	225
Yellow Perch	12334	259	194
Yellow Perch	12335	273	232
Yellow Perch	12336	234	123
Yellow Perch	12337	165	46
Yellow Perch	12338	178	60
Yellow Perch	12339	253	183
Yellow Perch	12340	256	148
Yellow Perch	12341	159	36
Yellow Perch	12342	228	113

NAME: (NO NAME) ID: 2B2-061
LONGITUDE: 88-08'30"W LATITUDE: 46-35'38"N STATE: MI

Yellow Perch	12343	170	46
Yellow Perch	12344	237	126
Yellow Perch	12345	201	71
Yellow Perch	12346	234	120
Yellow Perch	12349	222	103
Yellow Perch	12350	220	99
Yellow Perch	12351	174	50
Yellow Perch	92339	195	70
Yellow Perch	92340	285	262

NAME: ROGER LAKE ID: 2B2-074
LONGITUDE: 91-25'24"W LATITUDE: 46-31'34"N STATE: WI

ELS-I CHEMISTRY SAMPLE DATE: 05NOV84

pH: 6.35 Ext. Al: 15.00 Tot. Al: 41.00 Ca: 58.88
Conductivity: 13.20 DOC: 6.00 F: 0.737 Mg: 41.13
Air Eq pH: 6.86 TP: 9.000 Secchi Depth: 2.05
Color: 35.00 Na: 24.36 Silica: 0.12 Sulfate: 32.48
Site Depth: 3.00 Lake Area: 11.0 Elevation: 344.4
Lake Type: SEEPAGE Watershed Area: 104.0

ELS-II CHEMISTRY SAMPLE DATE: 22JUN87

pH: 6.43 Inorganic Al: 0.00 Minimum DO: 7.23
DOC: 7.20 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 24JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	40.0
Trap Nets	3	44.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Finescale Dace	0	671	39	0
Golden Shiner	20	2298	128	0
Central Mudminnow	0	11	42	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 02SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	60.0
TRAP NETS	3	56.5
SEINES	4	
ANGLING		2.0

NAME: ROGER LAKE ID: 2B2-074
LONGITUDE: 91-25'24"W LATITUDE: 46-31'34"N STATE: WI

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Finescale Dace	0	238	4	0
Golden Shiner	58	240	1	0
Central Mudminnow	0	170	3	0

NAME: RICHARDSON LAKE ID: 2B2-075
LONGITUDE: 91-27'51"W LATITUDE: 46-32'22"N STATE: WI

ELS-I CHEMISTRY SAMPLE DATE: 05NOV84

pH: 5.91 Ext. Al: 6.00 Tot. Al: 12.00 Ca: 37.92
Conductivity: 9.30 DOC: 5.50 F: 1.053 Mg: 26.32
Air Eq pH: 6.54 TP: 17.00 Secchi Depth: 4.25
Color: 21.00 Na: 9.57 Silica: 0.00 Sulfate: 47.89
Site Depth: 5.80 Lake Area: 9.5 Elevation: 344.4
Lake Type: SEEPAGE Watershed Area: 39.0

ELS-II CHEMISTRY SAMPLE DATE: 26JUN87

pH: 6.09 Inorganic Al: -0.01 Minimum DO: 7.96
DOC: 4.50 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 27JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	67.0
Trap Nets	3	65.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	37	0	0	0
Largemouth Bass	1	0	0	6
Bluegill	16	74	0	0
Northern Pike	1	0	0	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 01SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	45.0
TRAP NETS	3	48.0
SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING

NAME: RICHARDSON LAKE ID: 2B2-075
LONGITUDE: 91-27'51"W LATITUDE: 46-32'22"N STATE: WI

Yellow Perch	8	0	8	0
Largemouth Bass	1	0	6	2
Bluegill	10	75	10	0
Northern Pike	1	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Largemouth Bass	12100	310	410
Largemouth Bass	12101	314	370
Largemouth Bass	12102	261	240
Largemouth Bass	12103	183	84
Largemouth Bass	12104	180	67
Largemouth Bass	12105	203	104
Yellow Perch	12107	128	20
Yellow Perch	12108	175	52
Yellow Perch	12109	111	12
Yellow Perch	12110	115	13
Yellow Perch	12111	121	15
Yellow Perch	12112	121	17
Yellow Perch	12113	118	14
Yellow Perch	12114	120	16
Yellow Perch	12115	121	16
Yellow Perch	12116	121	17
Yellow Perch	12117	115	15
Yellow Perch	12118	111	13
Yellow Perch	12119	131	21
Yellow Perch	12120	122	19
Yellow Perch	12121	135	24
Yellow Perch	12122	125	19
Yellow Perch	12123	112	14
Yellow Perch	12124	130	21
Yellow Perch	12125	125	19
Yellow Perch	12126	106	12
Yellow Perch	12127	125	19
Yellow Perch	12128	194	80
Yellow Perch	12129	115	15
Yellow Perch	12130	120	17
Yellow Perch	12131	127	18
Yellow Perch	12132	129	18
Yellow Perch	12133	121	17
Yellow Perch	12134	118	16
Yellow Perch	12135	125	19
Yellow Perch	12136	129	22
Yellow Perch	12137	110	13
Yellow Perch	12138	115	14
Largemouth Bass	12139	303	410
Yellow Perch	892	112	12
Yellow Perch	893	113	12
Yellow Perch	894	111	10
Yellow Perch	895	107	10
Yellow Perch	896	114	13
Yellow Perch	897	122	15

NAME: RICHARDSON LAKE ID: 2B2-075
LONGITUDE: 91-27'51"W LATITUDE: 46-32'22"N STATE: WI

Largemouth Bass	899	77	5
Largemouth Bass	900	68	4
Largemouth Bass	901	78	6
Largemouth Bass	902	88	7
Largemouth Bass	903	64	3
Largemouth Bass	904	63	3
Yellow Perch	898	108	10
Yellow Perch	905	240	135
Yellow Perch	906	201	76
Yellow Perch	907	162	39
Yellow Perch	908	187	63
Yellow Perch	909	215	103
Yellow Perch	910	190	82
Yellow Perch	911	171	44
Largemouth Bass	913	266	260
Largemouth Bass	914	205	109
Largemouth Bass	915	379	800

NAME: BOHMIER LAKE ID: 2B2-078
LONGITUDE: 88-52'47"W LATITUDE: 46-50'05"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 03NOV84

pH: 5.63 Ext. Al: 2.00 Tot. Al: 11.00 Ca: 38.42
Conductivity: 10.60 DOC: 2.20 F: 0.526 Mg: 20.56
Air Eq pH: 6.45 TP: 11.00 Secchi Depth: 4.50
Color: 10.00 Na: 8.70 Silica: 0.15 Sulfate: 61.63
Site Depth: 19.50 Lake Area: 4.5 Elevation: 364.9
Lake Type: SEEPAGE Watershed Area: 18.0

ELS-II CHEMISTRY SAMPLE DATE: 13JUL87

pH: 5.77 Inorganic Al: 0.01 Minimum DO: 0.96
DOC: 2.20 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.34

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 14JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	57.0
Trap Nets	3	67.2
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Brook Stickleback	0	1	8	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 03SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	42.5
TRAP NETS	3	42.0
SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:
NO FISH CAUGHT

NAME: PINE LAKE ID: 2B2-079
LONGITUDE: 88-43'07"W LATITUDE: 46-58'57"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 18OCT84

pH: 6.07 Ext. Al: 8.00 Tot. Al: 38.00 Ca: 48.40
Conductivity: 12.30 DOC: 4.40 F: 0.684 Mg: 27.97
Air Eq pH: 6.45 TP: 15.00 Secchi Depth: 2.20
Color: 25.00 Na: 9.57 Silica: 0.08 Sulfate: 56.42
Site Depth: 2.20 Lake Area: 9.0 Elevation: 381.6
Lake Type: SEEPAGE Watershed Area: 36.0

ELS-II CHEMISTRY SAMPLE DATE: 22JUL87

pH: 6.30 Inorganic Al: -0.00 Minimum DO: 8.37
DOC: 4.00 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 23JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	53.5
Trap Nets	3	57.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	282	104	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	560	324	520
Yellow Perch	561	160	43
Yellow Perch	562	172	54
Yellow Perch	563	167	47
Yellow Perch	564	165	47
Yellow Perch	565	170	56
Yellow Perch	566	122	19
Yellow Perch	567	120	17
Yellow Perch	568	211	86
Yellow Perch	569	183	72
Yellow Perch	570	191	64
Yellow Perch	571	118	18
Yellow Perch	572	121	19
Yellow Perch	573	124	21
Yellow Perch	574	122	20

NAME: PINE LAKE ID: 2B2-079
LONGITUDE: 88-43'07"W LATITUDE: 46-58'57"N STATE: MI

Yellow Perch	575	127	22
Yellow Perch	576	118	17
Yellow Perch	577	120	19
Yellow Perch	578	125	21
Yellow Perch	579	121	17
Yellow Perch	582	167	51
Yellow Perch	583	167	51
Yellow Perch	584	161	38
Yellow Perch	585	168	42
Yellow Perch	586	167	45
Yellow Perch	587	167	55
Yellow Perch	588	158	35
Yellow Perch	589	163	40
Yellow Perch	590	153	36
Yellow Perch	591	146	31
Yellow Perch	592	158	35
Yellow Perch	593	146	33
Yellow Perch	594	159	41
Yellow Perch	595	147	34
Yellow Perch	596	150	34
Yellow Perch	597	153	37
Yellow Perch	598	146	32
Yellow Perch	599	112	15

NAME: (NO NAME) ID: 2B2-082
LONGITUDE: 88-50'48"W LATITUDE: 46-51'41"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 03NOV84

pH: 5.60 Ext. Al: 25.50 Tot. Al: 69.00 Ca: 51.40
Conductivity: 14.00 DOC: 4.00 F: 0.632 Mg: 27.97
Air Eq pH: 6.43 TP: 9.000 Secchi Depth: 4.00
Color: 25.00 Na: 13.05 Silica: 0.29 Sulfate: 65.06
Site Depth: 17.30 Lake Area: 4.4 Elevation: 367.6
Lake Type: DRAINAGE Watershed Area: 98.0

ELS-II CHEMISTRY SAMPLE DATE: 13JUL87

pH: 5.79 Inorganic Al: 0.00 Minimum DO: 0.05
DOC: 3.80 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.61

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 14JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	65.0
Trap Nets	3	63.0
Seines	4	
Angling		50.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	19	3	52	0
Largemouth Bass	0	0	25	0
Brown Bullhead	0	5	0	0
White Sucker	5	1	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12390	170	43
Yellow Perch	12391	147	29
White Sucker	12392	398	620
Yellow Perch	12393	135	23
White Sucker	12394	361	460
White Sucker	12396	333	400
White Sucker	12397	334	440
White Sucker	12398	326	360
Yellow Perch	12399	170	44
Yellow Perch	12400	184	60
Yellow Perch	12401	170	46
Yellow Perch	12402	176	41

NAME: (NO NAME) ID: 2B2-082
LONGITUDE: 88-50'48"W LATITUDE: 46-51'41"N STATE: MI

Yellow Perch	12403	168	45
Yellow Perch	12404	174	46
Yellow Perch	12405	183	55
Yellow Perch	12406	177	51
Yellow Perch	12407	168	40
Yellow Perch	12408	167	47
Yellow Perch	12409	161	37
Yellow Perch	12410	172	45
Yellow Perch	12411	167	41
Yellow Perch	12412	170	41
Yellow Perch	12413	168	47
Yellow Perch	12414	167	42
Yellow Perch	12415	111	16
Yellow Perch	12416	121	21
Yellow Perch	12417	185	56

NAME: ELEVENMILE LAKE ID: 2B2-090
LONGITUDE: 88-42'30"W LATITUDE: 47-00'57"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 18OCT84

pH: 5.13 Ext. Al: 13.00 Tot. Al: 38.00 Ca: 31.94
Conductivity: 12.70 DOC: 3.50 F: 0.579 Mg: 25.50
Air Eq pH: 5.11 TP: 2.000 Secchi Depth: 1.70
Color: 25.00 Na: 7.39 Silica: 0.00 Sulfate: 67.66
Site Depth: 1.70 Lake Area: 5.5 Elevation: 422.2
Lake Type: SEEPAGE Watershed Area: 44.0

ELS-II CHEMISTRY SAMPLE DATE: 15JUL87

pH: 5.12 Inorganic Al: 0.01 Minimum DO: 8.00
DOC: 3.40 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 15JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	54.0
Trap Nets	3	58.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	873	665	0	1
Pumkinseed	1	1	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	429	159	38
Yellow Perch	430	314	380
Yellow Perch	431	158	38
Yellow Perch	432	104	12
Yellow Perch	433	155	33
Yellow Perch	434	159	36
Yellow Perch	435	155	33
Yellow Perch	436	113	15
Yellow Perch	437	156	33
Yellow Perch	438	111	14
Yellow Perch	439	117	16
Yellow Perch	440	152	34
Yellow Perch	441	156	30
Yellow Perch	442	185	48

NAME: ELEVENMILE LAKE ID: 2B2-090
LONGITUDE: 88-42'30"W LATITUDE: 47-00'57"N STATE: MI

Yellow Perch	443	159	34
Yellow Perch	444	157	33
Yellow Perch	445	175	39
Yellow Perch	446	154	34
Yellow Perch	447	156	35
Yellow Perch	448	158	36
Yellow Perch	449	150	30
Yellow Perch	450	113	13
Yellow Perch	451	103	12
Yellow Perch	452	110	15
Yellow Perch	453	110	13
Yellow Perch	454	153	28
Yellow Perch	455	112	13
Yellow Perch	456	112	13
Yellow Perch	457	115	14
Yellow Perch	458	181	75
Yellow Perch	459	150	27
Yellow Perch	460	152	32
Yellow Perch	461	155	31
Yellow Perch	462	146	29
Yellow Perch	463	155	33
Yellow Perch	464	198	60
Yellow Perch	465	150	29
Yellow Perch	466	155	32
Yellow Perch	467	154	35
Yellow Perch	468	180	61
Yellow Perch	469	181	57
Yellow Perch	470	204	70
Yellow Perch	471	179	41
Yellow Perch	472	117	16
Yellow Perch	473	194	60
Yellow Perch	474	194	50
Yellow Perch	475	181	40
Yellow Perch	476	182	50
Yellow Perch	477	189	63
Yellow Perch	478	183	59
Yellow Perch	479	117	14
Yellow Perch	480	110	13
Yellow Perch	481	113	13
Yellow Perch	482	116	14
Yellow Perch	483	187	62
Yellow Perch	484	99	9
Yellow Perch	485	100	9
Yellow Perch	486	99	10
Yellow Perch	487	97	9
Yellow Perch	488	100	10
Yellow Perch	489	95	8
Yellow Perch	490	187	51
Yellow Perch	491	182	53
Yellow Perch	492	214	109

NAME: DELENE LAKE ID: 2B2-098
LONGITUDE: 88-24'19"W LATITUDE: 46-32'29"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 17OCT84

pH: 6.90 Ext. Al: 2.00 Tot. Al: 25.00 Ca: 125.7
Conductivity: 19.60 DOC: 10.30 F: 1.158 Mg: 49.36
Air Eq pH: 7.24 TP: 11.00 Secchi Depth: 1.40
Color: 45.00 Na: 14.35 Silica: 0.80 Sulfate: 28.52
Site Depth: 1.50 Lake Area: 26.2 Elevation: 507.5
Lake Type: SEEPAGE Watershed Area: 202.0

ELS-II CHEMISTRY SAMPLE DATE: 06JUL87

pH: 6.68 Inorganic Al: -0.00 Minimum DO: 8.50
DOC: 6.90 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 07JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	4	22.5
Trap Nets	4	88.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	22	27	0	0
Iowa Darter	0	1	0	0
Largemouth Bass	0	0	0	1
Northern Pike	1	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12352	90	6
Yellow Perch	12353	103	11
Yellow Perch	12354	106	14
Yellow Perch	12355	231	133
Yellow Perch	12356	113	13
Yellow Perch	12357	109	10
Yellow Perch	12358	102	9
Yellow Perch	12359	120	14
Yellow Perch	12360	115	12
Yellow Perch	12361	110	12
Yellow Perch	12362	110	12
Yellow Perch	12363	115	11

NAME: DELENE LAKE ID: 2B2-098
LONGITUDE: 88-24'19"W LATITUDE: 46-32'29"N STATE: MI

Yellow Perch	12364	94	6
Yellow Perch	12365	90	6
Yellow Perch	12366	81	5
Yellow Perch	12367	85	5
Yellow Perch	12368	97	8
Yellow Perch	12369	96	8
Yellow Perch	12370	120	14
Yellow Perch	12371	110	11
Yellow Perch	12372	111	12
Yellow Perch	12373	115	14
Yellow Perch	12374	115	14
Yellow Perch	12375	112	17
Yellow Perch	12376	111	15
Yellow Perch	12377	111	15
Yellow Perch	12378	107	14
Yellow Perch	12379	115	16
Yellow Perch	12380	115	15
Yellow Perch	12381	108	13
Yellow Perch	12382	120	18
Yellow Perch	12383	120	18
Yellow Perch	12384	120	19
Yellow Perch	12385	122	20

NAME: HERBERT LAKE ID: 2B2-100
LONGITUDE: 88-06'25"W LATITUDE: 46-39'00"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 17OCT84

pH: 4.83 Ext. Al: 90.00 Tot. Al: 143.5 Ca: 49.65
Conductivity: 20.50 DOC: 4.65 F: 1.211 Mg: 34.55
Air Eq pH: 4.80 TP: 0.500 Secchi Depth: 2.85
Color: 25.00 Na: 14.14 Silica: 0.13 Sulfate: 114.0
Site Depth: 3.40 Lake Area: 12.7 Elevation: 521.2
Lake Type: SEEPAGE Watershed Area: 96.0

ELS-II CHEMISTRY SAMPLE DATE: 01JUL87

pH: 4.89 Inorganic Al: 0.04 Minimum DO: 7.34
DOC: 6.20 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 03JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	57.0
Trap Nets	3	65.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	141	63	1	3

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 09SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	60.5
TRAP NETS	3	66.0
SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	56	197	0	1

NAME: HERBERT LAKE ID: 2B2-100
LONGITUDE: 88-06'25"W LATITUDE: 46-39'00"N STATE: MI

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	281	196	75
Yellow Perch	282	197	79
Yellow Perch	294	155	39
Yellow Perch	298	178	55
Yellow Perch	305	142	31
Yellow Perch	307	145	28
Yellow Perch	308	177	52
Yellow Perch	311	175	52
Yellow Perch	283	190	73
Yellow Perch	284	165	45
Yellow Perch	286	163	40
Yellow Perch	288	188	46
Yellow Perch	291	161	41
Yellow Perch	292	161	41
Yellow Perch	293	160	40
Yellow Perch	295	165	44
Yellow Perch	296	117	15
Yellow Perch	297	167	47
Yellow Perch	299	162	44
Yellow Perch	300	165	45
Yellow Perch	301	134	26
Yellow Perch	302	183	65
Yellow Perch	303	186	68
Yellow Perch	304	135	27
Yellow Perch	306	130	21
Yellow Perch	309	128	24
Yellow Perch	310	188	70
Yellow Perch	312	185	57
Yellow Perch	313	133	25
Yellow Perch	314	135	26
Yellow Perch	315	120	17
Yellow Perch	316	140	28
Yellow Perch	317	139	26
Yellow Perch	318	140	29
Yellow Perch	319	185	66
Yellow Perch	320	117	19
Yellow Perch	321	191	76
Yellow Perch	322	185	61
Yellow Perch	323	110	15
Yellow Perch	324	184	67
Yellow Perch	325	189	68
Yellow Perch	326	113	17
Yellow Perch	12918	186	63
Yellow Perch	12920	169	42
Yellow Perch	12921	154	39
Yellow Perch	12922	207	99
Yellow Perch	12924	157	39
Yellow Perch	12925	170	58
Yellow Perch	12927	154	39
Yellow Perch	12923	150	40

NAME: HERBERT LAKE ID: 2B2-100
LONGITUDE: 88-06'25"W LATITUDE: 46-39'00"N STATE: MI

Yellow Perch	12926	176	56
Yellow Perch	12928	173	53
Yellow Perch	12929	169	52
Yellow Perch	12930	176	56
Yellow Perch	12931	174	52
Yellow Perch	12932	157	39
Yellow Perch	12933	175	47
Yellow Perch	12934	171	57
Yellow Perch	12935	146	35
Yellow Perch	12936	151	35
Yellow Perch	12937	151	37
Yellow Perch	12938	151	35
Yellow Perch	12939	169	48
Yellow Perch	12940	198	88
Yellow Perch	12941	203	84
Yellow Perch	12942	205	88
Yellow Perch	12943	90	7
Yellow Perch	12944	99	9
Yellow Perch	12945	90	7
Yellow Perch	12947	115	17
Yellow Perch	12948	140	26
Yellow Perch	12949	140	27
Yellow Perch	12950	140	23
Yellow Perch	12951	140	26
Yellow Perch	12952	149	31
Yellow Perch	12953	145	27
Yellow Perch	12954	140	27
Yellow Perch	12955	144	26
Yellow Perch	12956	142	28
Yellow Perch	12957	142	23
Yellow Perch	12958	141	24

NAME: ISLAND LAKE   ID: 2B3-007
LONGITUDE: 87-47'10"W   LATITUDE: 46-40'18"N   STATE: MI

ELS-I CHEMISTRY   SAMPLE DATE: 13OCT84

pH: 6.56 Ext. Al: 26.00 Tot. Al: 70.00 Ca: 120.8
Conductivity: 20.50 DOC: 4.40 F: 1.105 Mg: 38.66
Air Eq pH: 7.01 TP: 4.000 Secchi Depth: 4.60
Color: 20.00 Na: 14.35 Silica: 1.09 Sulfate: 100.6
Site Depth: 14.90 Lake Area: 11.6 Elevation: 527.3
Lake Type: DRAINAGE   Watershed Area: 52.0

ELS-II CHEMISTRY   SAMPLE DATE: 20JUL87

pH: 6.37 Inorganic Al: 0.03 Minimum DO: 1.33
DOC: 4.70 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.11

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 21JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	58.5
Trap Nets	3	56.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Bluntnose Minnow	0	10	269	0
Finescale Dace	0	14	3	0
Brassy Minnow	0	0	43	0
Brook Trout	28	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Brook Trout	550	266	210
Brook Trout	551	190	85
Brook Trout	552	270	210
Brook Trout	553	276	245
Brook Trout	554	274	285
Brook Trout	555	195	80
Brook Trout	556	211	110
Brook Trout	557	215	100
Brook Trout	558	272	240
Brook Trout	559	188	60

NAME: SECTION FOUR LAKE ID: 2B3-008
LONGITUDE: 85-18'15"W LATITUDE: 46-40'26"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 23OCT84

pH: 6.78 Ext. Al: 2.00 Tot. Al: 37.00 Ca: 149.7
Conductivity: 29.20 DOC: 8.90 F: 0.895 Mg: 92.95
Air Eq pH: 7.22 TP: 1.000 Secchi Depth: 2.00
Color: 30.00 Na: 18.70 Silica: 0.74 Sulfate: 97.65
Site Depth: 6.10 Lake Area: 4.4 Elevation: 219.5
Lake Type: DRAINAGE Watershed Area: 10.0

ELS-II CHEMISTRY SAMPLE DATE: 27AUG87

pH: 7.02 Inorganic Al: -0.00 Minimum DO: 0.10
DOC: 6.30 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.45

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 28AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	63.0
Trap Nets	3	66.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Bluegill	5	254	0	0
Flathead Minnow	0	4	0	0
Finescale Dace	2	0	0	0
Central Mudminnow	0	1	0	0

NAME: GRAND SABLE LAKE ID: 2B3-009
LONGITUDE: 86-02'30"W LATITUDE: 46-38'15"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 20OCT84

pH: 7.86 Ext. Al: 5.50 Tot. Al: 9.00 Ca: 711.3
Conductivity: 102.70 DOC: 11.90 F: 2.158 Mg: 399.8
Air Eq pH: 8.32 TP: 14.00 Secchi Depth: 3.30
Color: 30.00 Na: 37.41 Silica: 6.49 Sulfate: 104.7
Site Depth: 18.60 Lake Area:262.3 Elevation: 226.5
Lake Type: DRAINAGE Watershed Area: 2707

ELS-II CHEMISTRY SAMPLE DATE: 03AUG87

pH: 8.17 Inorganic Al: 0.01 Minimum DO: 5.02
DOC: 4.77 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 04AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	8	153.0
Trap Nets	8	176.0
Seines	8	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Mottled Sculpin	1	0	0	0
Logperch	0	0	1	0
Yellow Perch	38	11	0	0
Iowa Darter	0	0	7	0
Smallmouth Bass	0	17	2	0
Rock Bass	23	0	0	0
White Sucker	2	3	0	0
Common Shiner	38	0	0	0
Golden Shiner	1	0	0	0
Northern Pike	9	1	0	0
Rainbow Smelt	41	0	0	0
Lake Trout	2	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Northern Pike	670	496	920
Northern Pike	671	608	1620
Northern Pike	672	591	1480
Northern Pike	673	655	1950

NAME: GRAND SABLE LAKE ID: 2B3-009
LONGITUDE: 86-02'30"W LATITUDE: 46-38'15"N STATE: MI

Northern Pike	674	587	1280
Northern Pike	675	598	900
Northern Pike	676	705	2110
Northern Pike	677	578	1220
Northern Pike	678	556	1140
White Sucker	679	315	321
White Sucker	680	232	121
White Sucker	681	228	131
Yellow Perch	684	236	143
Yellow Perch	685	197	74
Yellow Perch	686	189	71
Yellow Perch	687	196	84
Yellow Perch	688	181	63
Yellow Perch	690	161	48
Yellow Perch	692	161	48
Yellow Perch	693	163	42
Yellow Perch	694	112	14
Yellow Perch	695	176	55
Yellow Perch	696	165	48
Yellow Perch	697	122	17
Yellow Perch	698	165	44
Yellow Perch	700	241	124
Yellow Perch	701	191	66
Yellow Perch	702	164	40
Yellow Perch	703	126	17
Yellow Perch	705	115	14
Yellow Perch	707	168	45
Yellow Perch	709	180	58
Yellow Perch	710	114	15
Yellow Perch	712	168	55
Yellow Perch	713	178	59
Yellow Perch	714	207	88
Yellow Perch	715	200	87
Yellow Perch	716	166	53
Yellow Perch	718	166	47
Yellow Perch	721	103	10
White Sucker	722	234	128
Yellow Perch	723	115	14
Yellow Perch	724	176	53
Yellow Perch	726	119	17
White Sucker	727	146	31
Yellow Perch	728	175	54
Yellow Perch	729	118	17
Northern Pike	731	656	1800
Smallmouth Bass	732	297	380
Smallmouth Bass	733	256	260
Yellow Perch	734	116	16

NAME: ROUND LAKE ID: 2B3-012
LONGITUDE: 87-56'52"W LATITUDE: 46-33'24"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 14OCT84

pH: 6.93 Ext. Al: 25.00 Tot. Al: 111.0 Ca: 182.1
Conductivity: 31.30 DOC: 10.70 F: 1.474 Mg: 96.24
Air Eq pH: 7.38 TP: 17.00 Secchi Depth: 1.20
Color: 85.00 Na: 24.36 Silica: 2.13 Sulfate: 91.61
Site Depth: 4.60 Lake Area: 16.7 Elevation: 485.9
Lake Type: DRAINAGE Watershed Area: 728.0

ELS-II CHEMISTRY SAMPLE DATE: 06JUL87

pH: 6.73 Inorganic Al: 0.03 Minimum DO: 0.05
DOC: 12.20 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.80

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 07JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	63.0
Trap Nets	3	69.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	0	41	3	0
Iowa Darter	0	0	2	0
Pumkinseed	0	8	0	0
White Sucker	0	5	0	0
Bluntnose Minnow	0	0	1	0
Common Shiner	1	0	11	0
Golden Shiner	0	30	0	0
Northern Pike	0	1	0	5

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Northern Pike	324	576	980
Northern Pike	325	466	515
Northern Pike	326	485	610
Northern Pike	327	520	760
Northern Pike	328	533	830
Northern Pike	329	578	840
White Sucker	330	101	10
White Sucker	331	107	12

NAME: ROUND LAKE ID: 2B3-012
LONGITUDE: 87-56'52"W LATITUDE: 46-33'24"N STATE: MI

White Sucker	332	102	10
White Sucker	333	102	10
Yellow Perch	334	99	8
Yellow Perch	335	109	11
Yellow Perch	336	101	9
Yellow Perch	337	116	15
Yellow Perch	338	101	9
Yellow Perch	339	121	18
Yellow Perch	340	109	12
Yellow Perch	341	121	18
Yellow Perch	342	127	20
Yellow Perch	343	134	23
Yellow Perch	344	144	30
Yellow Perch	345	167	52
Yellow Perch	346	105	11
Yellow Perch	347	143	26
Yellow Perch	348	108	12
Yellow Perch	349	110	8
Yellow Perch	350	96	9
Yellow Perch	351	104	11
Yellow Perch	352	107	15
Yellow Perch	353	95	8
Yellow Perch	354	105	10
Yellow Perch	355	252	190
Yellow Perch	356	106	11
Yellow Perch	357	102	10
Yellow Perch	358	100	9
Yellow Perch	359	107	11
Yellow Perch	360	140	25
Yellow Perch	361	102	9
Yellow Perch	362	140	27
Yellow Perch	363	120	17
Yellow Perch	364	159	42
Yellow Perch	365	126	20
Yellow Perch	366	131	22
Yellow Perch	367	110	11
Yellow Perch	368	96	8
Yellow Perch	369	110	13
Yellow Perch	370	104	10
Yellow Perch	371	105	10
Yellow Perch	372	122	17
Yellow Perch	373	96	8
Yellow Perch	374	102	9
Pumpkinseed	9169	149	65
Pumpkinseed	9170	87	14
Pumpkinseed	9171	61	4
Pumpkinseed	9172	77	8
Pumpkinseed	9173	69	5
Pumpkinseed	9174	101	19
Pumpkinseed	9175	67	5
Pumpkinseed	9176	76	8

NAME: FOX LAKE   ID: 2B3-013
LONGITUDE: 86-02'04"W   LATITUDE: 46-35'32"N   STATE: MI

ELS-I CHEMISTRY   SAMPLE DATE: 20OCT84

pH: 4.94 Ext. Al: 50.00 Tot. Al: 116.0 Ca: 43.41
Conductivity: 13.50 DOC: 2.70 F: 0.684 Mg: 22.21
Air Eq pH: 5.03 TP: 20.00 Secchi Depth: 1.55
Color: 75.00 Na: 7.39 Silica: 0.63 Sulfate: 52.88
Site Depth: 7.30 Lake Area: 4.6 Elevation: 281.9
Lake Type: CLOSED   Watershed Area: 132.0

ELS-II CHEMISTRY   SAMPLE DATE: 17AUG87

pH: 4.80 Inorganic Al: 0.02 Minimum DO: 0.05
DOC: 5.80 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.72

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 18AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	64.0
Trap Nets	3	59.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	417	163	0	0
Pumkinseed	0	1	4	0
Brown Bullhead	2	47	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12745	143	26
Yellow Perch	12746	135	20
Yellow Perch	12747	135	22
Yellow Perch	12748	173	46
Yellow Perch	12749	125	18
Yellow Perch	12750	143	27
Yellow Perch	12751	121	13
Yellow Perch	12752	115	12
Yellow Perch	12753	137	22
Yellow Perch	12754	132	23
Yellow Perch	12755	125	17
Yellow Perch	12756	120	15
Yellow Perch	12757	128	18

NAME: FOX LAKE ID: 2B3-013
LONGITUDE: 86-02'04"W LATITUDE: 46-35'32"N STATE: MI

Yellow Perch	12758	111	12
Yellow Perch	12759	145	29
Yellow Perch	12760	113	14
Yellow Perch	12761	192	73
Yellow Perch	12762	217	105
Yellow Perch	12763	164	43
Yellow Perch	12764	309	410
Yellow Perch	12765	90	7
Yellow Perch	12766	92	7
Yellow Perch	12767	93	8
Yellow Perch	12768	95	8
Yellow Perch	12769	95	8
Yellow Perch	12770	90	7
Yellow Perch	12771	95	8
Yellow Perch	12772	91	7
Yellow Perch	12773	92	7
Yellow Perch	12774	95	8
Yellow Perch	12775	93	7
Yellow Perch	12776	92	7
Yellow Perch	12777	95	8
Yellow Perch	12778	95	8
Yellow Perch	12779	90	7
Yellow Perch	12780	120	15
Yellow Perch	12781	123	17
Yellow Perch	12782	110	13
Yellow Perch	12783	110	14
Yellow Perch	12784	115	13

NAME: BUTO LAKE ID: 2B3-020
LONGITUDE: 87-59'45"W LATITUDE: 46-26'44"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 16OCT84

pH: 6.10 Ext. Al: 15.00 Tot. Al: 65.00 Ca: 89.82
Conductivity: 22.40 DOC: 7.80 F: 2.106 Mg: 74.03
Air Eq pH: 7.01 TP: 13.00 Secchi Depth: 1.00
Color: 110.0 Na: 25.23 Silica: 2.32 Sulfate: 83.07
Site Depth: 5.50 Lake Area: 9.7 Elevation: 478.5
Lake Type: DRAINAGE Watershed Area: 60.0

ELS-II CHEMISTRY SAMPLE DATE: 15JUL87

pH: 5.79 Inorganic Al: 0.00 Minimum DO: 0.03
DOC: 11.50 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.57

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 16JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	66.0
Trap Nets	3	72.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	121	39	0	0
Pumkinseed	0	1	0	0
Brown Bullhead	0	37	0	0
White Sucker	39	16	0	0
Creek Chub	2	5	0	1
Common Shiner	3	0	0	0
Golden Shiner	93	100	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12418	180	47
Yellow Perch	12419	326	400
Yellow Perch	12420	295	320
Yellow Perch	12422	343	400
Yellow Perch	12423	286	280
Yellow Perch	12424	113	14
Yellow Perch	12425	120	16
Yellow Perch	12426	121	16
Yellow Perch	12464	138	25

NAME: BUTO LAKE ID: 2B3-020
LONGITUDE: 87-59'45"W LATITUDE: 46-26'44"N STATE: MI

Yellow Perch	12465	172	49
Yellow Perch	12466	126	19
Yellow Perch	12467	117	16
Yellow Perch	12468	156	40
Yellow Perch	12469	113	14
Yellow Perch	12470	133	19
Yellow Perch	12471	117	17
Yellow Perch	12472	116	16
Yellow Perch	12473	127	18
Yellow Perch	12474	126	20
Yellow Perch	12475	112	13
Yellow Perch	12476	122	18
Yellow Perch	12477	122	19
Yellow Perch	12478	127	18
Yellow Perch	12479	140	24
Yellow Perch	12480	132	20
Yellow Perch	12482	168	42
Yellow Perch	12483	138	23
Yellow Perch	12484	135	19
Yellow Perch	12485	89	6
Yellow Perch	12487	93	6
Yellow Perch	12488	94	7
Yellow Perch	12489	93	7
Yellow Perch	12490	92	7
Yellow Perch	12491	122	15
Yellow Perch	12492	116	14
Yellow Perch	12493	120	14
Yellow Perch	12494	121	15
Yellow Perch	12495	118	14
Yellow Perch	12496	121	14
White Sucker	12427	362	440
White Sucker	12428	356	440
White Sucker	12429	325	300
White Sucker	12430	303	280
White Sucker	12432	366	460
White Sucker	12433	316	320
White Sucker	12437	355	400
White Sucker	12441	351	390
White Sucker	12442	365	460
White Sucker	12443	225	100
White Sucker	12444	195	68
White Sucker	12446	172	49
White Sucker	12447	333	350
White Sucker	12448	310	310
White Sucker	12449	305	250
White Sucker	12454	359	450
White Sucker	12455	310	300
White Sucker	12456	375	460
White Sucker	12458	316	310
White Sucker	12460	356	440
White Sucker	12461	189	62
White Sucker	12462	170	49
White Sucker	12463	190	63
White Sucker	12504	185	54

NAME: BUTO LAKE   ID: 2B3-020
LONGITUDE: 87-59'45"W LATITUDE: 46-26'44"N STATE: MI

White Sucker	12505	205	69
White Sucker	12509	316	280
White Sucker	12510	292	220
White Sucker	12511	352	400
White Sucker	12512	180	48
White Sucker	12513	160	33

NAME: BONE LAKE ID: 2B3-023
LONGITUDE: 88-18'22"W LATITUDE: 46-22'30"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 14OCT84

pH: 7.65 Ext. Al: 6.00 Tot. Al: 31.00 Ca: 694.6
Conductivity: 114.00 DOC: 9.30 F: 2.421 Mg: 422.0
Air Eq pH: 8.44 TP: 19.00 Secchi Depth: 1.60
Color: 55.00 Na: 58.29 Silica: 4.36 Sulfate: 101.4
Site Depth: 2.10 Lake Area: 63.2 Elevation: 490.7
Lake Type: DRAINAGE Watershed Area: 5467

ELS-II CHEMISTRY SAMPLE DATE: 30JUN87

pH: 7.53 Inorganic Al: 0.00 Minimum DO: 7.95
DOC: 9.10 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 30JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	7	82.0
Trap Nets	7	117.5
Seines	8	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Walleye	8	0	0	0
Yellow Perch	37	3	0	1
Largemouth Bass	0	1	1	0
Bluegill	0	2	0	0
Pumkinseed	46	8	0	0
White Sucker	53	30	0	0
Common Shiner	0	1	0	0
Golden Shiner	30	0	0	0
Northern Pike	41	2	0	1

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	12106	144	33
Yellow Perch	12140	220	120
Yellow Perch	12141	175	58
Yellow Perch	12142	75	5
White Sucker	12143	470	1180
White Sucker	12144	322	340
White Sucker	12145	385	590

NAME: BONE LAKE ID: 2B3-023
LONGITUDE: 88-18'22"W LATITUDE: 46-22'30"N STATE: MI

White Sucker	12146	326	360
White Sucker	12147	306	330
White Sucker	12148	320	250
White Sucker	12149	380	540
White Sucker	12150	380	510
White Sucker	12151	420	780
White Sucker	12152	405	690
White Sucker	12153	349	440
White Sucker	12154	311	310
White Sucker	12155	440	900
White Sucker	12156	451	1000
White Sucker	12157	470	990
White Sucker	12158	419	770
White Sucker	12159	462	1070
White Sucker	12160	395	690
White Sucker	12161	393	650
White Sucker	12162	457	925
White Sucker	12163	336	490
White Sucker	12164	405	660
White Sucker	12165	419	720
White Sucker	12166	381	620
White Sucker	12167	366	580
White Sucker	12168	502	1080
White Sucker	12169	516	1300
White Sucker	12170	496	1100
Northern Pike	12171	540	900
Yellow Perch	12172	106	13
Northern Pike	12174	504	660
Walleye	12182	560	1380
Walleye	12183	196	65
Walleye	12184	431	660
Walleye	12185	404	540
Yellow Perch	12186	215	105
Yellow Perch	12187	188	81
Yellow Perch	12188	211	93
Yellow Perch	12189	156	48
Yellow Perch	12190	111	21
Yellow Perch	12191	111	15
Yellow Perch	12192	109	16
Yellow Perch	12193	172	57
Yellow Perch	12194	169	58
Northern Pike	12201	410	340
Northern Pike	12202	464	500
Yellow Perch	12203	171	69
Yellow Perch	12204	157	43
Yellow Perch	12205	91	10
Northern Pike	12206	620	1340
Northern Pike	12207	490	640
Northern Pike	12211	437	400
Northern Pike	12212	625	1390
Northern Pike	12213	476	500
Northern Pike	12214	367	250
Northern Pike	12215	396	320
Northern Pike	12216	402	360

NAME: BONE LAKE ID: 2B3-023
LONGITUDE: 88-18'22"W LATITUDE: 46-22'30"N STATE: MI

Yellow Perch	12217	260	200
Walleye	12218	321	280
Yellow Perch	12219	267	250
Walleye	12220	368	420
Yellow Perch	12221	193	60
Yellow Perch	12222	197	100
Walleye	12223	409	680
Yellow Perch	12224	174	50
Yellow Perch	12225	216	140
Walleye	12226	415	600
Yellow Perch	12227	114	18
Yellow Perch	12228	92	10
Yellow Perch	12229	242	160
Yellow Perch	12230	127	25
Yellow Perch	12231	145	39
Yellow Perch	12232	192	90
Yellow Perch	12233	147	42
Pumpkinseed	912079	182	134
Pumpkinseed	912097	183	129
Pumpkinseed	912098	180	123
Pumpkinseed	912100	153	82
Pumpkinseed	912101	150	73
Pumpkinseed	912102	166	100
Pumpkinseed	912103	110	25
Pumpkinseed	912104	170	119
Pumpkinseed	912105	149	72
Pumpkinseed	912107	137	58
Pumpkinseed	912112	182	130
Pumpkinseed	912122	129	45
Pumpkinseed	912123	110	27
Pumpkinseed	912124	74	8
Pumpkinseed	912125	100	19
Pumpkinseed	912127	77	8
Pumpkinseed	912128	70	6
Pumpkinseed	912129	174	112
White Sucker	912167	366	580

NAME: CASEY LAKE ID: 2B3-027
LONGITUDE: 87-55'00"W LATITUDE: 46-17'20"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 16OCT84

pH: 8.25 Ext. Al: 1.00 Tot. Al: 29.00 Ca: 859.8
Conductivity: 157.20 DOC: 4.00 F: 2.158 Mg: 765.8
Air Eq pH: 8.69 TP: 5.000 Secchi Depth: 3.35
Color: 15.00 Na: 32.63 Silica: 2.53 Sulfate: 74.54
Site Depth: 4.90 Lake Area: 21.7 Elevation: 447.8
Lake Type: SEEPAGE Watershed Area: 52.0

ELS-II CHEMISTRY SAMPLE DATE: 30JUN87

pH: 8.74 Inorganic Al: 0.01 Minimum DO: 8.61
DOC: 4.20 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 01JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	4	73.2
Trap Nets	4	80.0
Seines	5	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Iowa Darter	0	0	5	0
Largemouth Bass	8	0	0	4
Bluegill	22	2	104	0
Bluntnose Minnow	0	0	181	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Largemouth Bass	270	285	300
Largemouth Bass	271	318	400
Largemouth Bass	272	297	400
Largemouth Bass	273	297	350
Largemouth Bass	274	275	300
Largemouth Bass	275	297	350
Largemouth Bass	276	261	200
Largemouth Bass	277	267	240
Largemouth Bass	278	263	450
Largemouth Bass	279	271	500

NAME: CATARACT BASIN ID: 2B3-028
LONGITUDE: 87-31'00"W LATITUDE: 46-18'50"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 16OCT84

pH: 7.41 Ext. Al: 4.00 Tot. Al: 64.50 Ca: 525.9
Conductivity: 101.75 DOC: 7.15 F: 3.764 Mg: 315.1
Air Eq pH: 8.37 TP: 11.00 Secchi Depth: 1.25
Color: 82.50 Na: 171.4 Silica: 8.49 Sulfate: 104.8
Site Depth: 3.40 Lake Area: 32.3 Elevation: 357.2
Lake Type: RESERVOI Watershed Area: 54501

ELS-II CHEMISTRY SAMPLE DATE: 08JUN87

pH: 7.24 Inorganic Al: 0.00 Minimum DO: 7.45
DOC: 14.80 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 09JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	5	135.0
Trap Nets	5	94.5
Seines	6	
Angling		

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Walleye	0	1	0	0
Yellow Perch	68	10	0	0
Black Crappie	0	0	0	1
Smallmouth Bass	2	0	0	0
White Sucker	20	5	0	0
Northern Pike	10	2	0	1
Central Mudminnow	0	0	5	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	2	414	810
Smallmouth Bass	3	268	250
White Sucker	4	320	372
White Sucker	5	502	1261
Yellow Perch	8	219	173
Northern Pike	9	466	545
Yellow Perch	10	195	126
Yellow Perch	12	175	81
Yellow Perch	14	176	86

NAME: CATARACT BASIN ID: 2B3-028
LONGITUDE: 87-31'00"W LATITUDE: 46-18'50"N STATE: MI

Yellow Perch	15	192	111
Yellow Perch	16	210	142
Northern Pike	19	398	380
Northern Pike	20	349	260
White Sucker	23	390	824
White Sucker	24	410	943
White Sucker	26	342	600
Yellow Perch	29	276	340
White Sucker	32	320	385
Yellow Perch	33	292	372
Yellow Perch	35	272	350
Yellow Perch	36	258	277
Yellow Perch	37	261	299
Yellow Perch	39	220	163
Yellow Perch	43	155	54
Yellow Perch	44	153	39
White Sucker	46	306	348
White Sucker	48	180	64
Northern Pike	50	552	878
Northern Pike	51	467	590
White Sucker	53	541	1600
White Sucker	55	480	1100
White Sucker	56	484	1100
Smallmouth Bass	57	355	520
Yellow Perch	70	184	93
Yellow Perch	76	142	38
Yellow Perch	77	145	40
Yellow Perch	78	145	41
Northern Pike	79	369	285
White Sucker	81	505	1360
White Sucker	82	429	820
White Sucker	83	419	800
Yellow Perch	86	200	117
Northern Pike	98	430	409
Northern Pike	103	325	191
Yellow Perch	108	162	51
Yellow Perch	109	165	66
Yellow Perch	110	143	38
Yellow Perch	111	130	28
Yellow Perch	112	146	41
White Sucker	114	573	1840
White Sucker	117	503	1380
Northern Pike	118	289	118
White Sucker	119	566	1920
Northern Pike	122	415	350
Yellow Perch	17	146	40
Yellow Perch	58	260	258
Yellow Perch	59	285	327
Yellow Perch	84	270	313
Yellow Perch	85	281	335
Yellow Perch	107	160	59

NAME: ISLAND LAKE ID: 2B3-030
LONGITUDE: 86-38'51"W LATITUDE: 46-16'05"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 25OCT84

pH: 5.34 Ext. Al: 11.00 Tot. Al: 27.00 Ca: 43.41
Conductivity: 10.20 DOC: 4.49 F: 0.684 Mg: 18.10
Air Eq pH: 5.62 TP: 16.00 Secchi Depth: 3.25
Color: 15.00 Na: 6.09 Silica: 0.19 Sulfate: 52.67
Site Depth: 3.50 Lake Area: 14.7 Elevation: 252.1
Lake Type: SEEPAGE Watershed Area: 47.0

ELS-II CHEMISTRY SAMPLE DATE: 15JUN87

pH: 5.10 Inorganic Al: 0.01 Minimum DO: 7.82
DOC: 3.20 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 16JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	69.0
Trap Nets	3	69.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	7	4	1	0
Largemouth Bass	29	0	0	0
Bluegill	12	446	125	0
Brown Bullhead	4	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	1202	124	23
Largemouth Bass	1206	257	210
Largemouth Bass	1208	351	530
Largemouth Bass	1209	273	270
Yellow Perch	1212	100	10
Largemouth Bass	1213	334	480
Largemouth Bass	1219	370	640
Largemouth Bass	1224	275	270
Largemouth Bass	1226	268	230
Largemouth Bass	1227	269	225
Largemouth Bass	1228	330	430
Yellow Perch	1232	176	59

NAME: ISLAND LAKE ID: 2B3-030

LONGITUDE: 86-38'51"W LATITUDE: 46-16'05"N STATE: MI

Yellow Perch	1233	182	65
Yellow Perch	1234	120	18
Yellow Perch	1235	112	13
Yellow Perch	1236	110	12
Yellow Perch	1237	107	13
Yellow Perch	1238	158	38
Yellow Perch	1239	129	18
Yellow Perch	1240	160	9
Yellow Perch	1241	154	31
Largemouth Bass	1203	284	300
Largemouth Bass	1204	293	340
Largemouth Bass	1205	282	370
Largemouth Bass	1207	285	300
Largemouth Bass	1210	301	370
Largemouth Bass	1211	301	380
Largemouth Bass	1214	331	400
Largemouth Bass	1216	280	280
Largemouth Bass	1217	292	320
Largemouth Bass	1218	284	300
Largemouth Bass	1220	310	360
Largemouth Bass	1222	310	375
Largemouth Bass	1223	291	330
Largemouth Bass	1225	287	295
Largemouth Bass	1229	286	280
Largemouth Bass	1230	290	285
Largemouth Bass	1231	289	310
Bluegill	912000	101	15
Bluegill	912001	114	22
Bluegill	912002	111	18
Bluegill	912003	97	13
Bluegill	912005	155	36
Bluegill	912006	114	20
Bluegill	912007	117	21
Bluegill	912008	118	23
Bluegill	912009	118	24
Bluegill	912010	113	21
Bluegill	912011	112	21
Bluegill	912012	98	13
Bluegill	912013	137	33
Bluegill	912014	148	50
Bluegill	912015	135	36
Bluegill	912016	150	44
Bluegill	912017	140	36
Bluegill	912018	136	37
Bluegill	912019	150	47
Bluegill	912020	160	58
Bluegill	912021	171	77
Bluegill	912022	95	13
Bluegill	912023	95	12
Bluegill	912024	95	12
Bluegill	912025	190	102
Bluegill	912026	93	11

NAME: TWIN LAKES ID: 2B3-031
LONGITUDE: 85-32'00"W LATITUDE: 46-18'29"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 22OCT84

pH: 8.03 Ext. Al: 2.00 Tot. Al: 24.00 Ca: 1826
Conductivity: 279.10 DOC: 6.80 F: 3.264 Mg: 983.8
Air Eq pH: 8.85 TP: 12.00 Secchi Depth: 2.90
Color: 40.00 Na: 120.5 Silica: 9.62 Sulfate: 160.5
Site Depth: 20.10 Lake Area: 38.0 Elevation: 221.0
Lake Type: DRAINAGE Watershed Area: 456.0

ELS-II CHEMISTRY SAMPLE DATE: 10AUG87

pH: 8.33 Inorganic Al: 0.02 Minimum DO: 1.62
DOC: 7.90 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.77

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 11AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	5	114.0
Trap Nets	5	120.0
Seines	5	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	14	8	8	0
Johnny Darter	0	0	2	0
Largemouth Bass	8	0	0	0
Smallmouth Bass	0	0	2	0
Bluegill	23	30	0	0
Pumkinseed	6	10	0	0
Rock Bass	7	18	4	0
Brown Bullhead	8	1	0	0
White Sucker	61	7	0	0
Creek Chub	0	0	19	0
Emerald Shiner	0	0	1	0
Golden Shiner	16	147	0	0
Brook Trout	9	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	12671	380	620
White Sucker	12672	351	520
White Sucker	12673	362	515

NAME: TWIN LAKES ID: 2B3-031
LONGITUDE: 85-32'00"W LATITUDE: 46-18'29"N STATE: MI

White Sucker	12674	374	570
White Sucker	12675	359	200
White Sucker	12676	326	420
White Sucker	12677	320	380
White Sucker	12678	238	140
White Sucker	12679	217	120
White Sucker	12680	324	380
White Sucker	12681	338	400
White Sucker	12682	367	530
White Sucker	12684	353	440
White Sucker	12685	321	380
White Sucker	12686	234	150
White Sucker	12687	246	170
White Sucker	12688	220	120
White Sucker	12689	260	190
White Sucker	12690	223	120
White Sucker	12691	247	170
White Sucker	12692	205	90
White Sucker	12693	232	140
White Sucker	12694	354	490
White Sucker	12695	366	530
White Sucker	12696	363	580
White Sucker	12697	343	500
White Sucker	12698	339	420
White Sucker	12699	307	310
White Sucker	12700	331	420
White Sucker	12701	331	420
Yellow Perch	12702	157	49
Yellow Perch	12703	216	103
Yellow Perch	12704	230	132
Yellow Perch	12705	177	51
Yellow Perch	12706	180	55
Yellow Perch	12707	166	42
Yellow Perch	12708	172	48
Yellow Perch	12709	164	43
Yellow Perch	12710	180	58
Yellow Perch	12711	165	45
Yellow Perch	12712	126	19
Yellow Perch	12713	170	47
Brook Trout	12714	246	144
Brook Trout	12715	383	550
Brook Trout	12716	240	129
Brook Trout	12717	233	106
Brook Trout	12718	217	92
Brook Trout	12719	221	87
Largemouth Bass	12720	302	370
Largemouth Bass	12721	296	350
Largemouth Bass	12722	292	290
Largemouth Bass	12723	296	380
Largemouth Bass	12724	333	520
Largemouth Bass	12725	304	400
Yellow Perch	12726	192	57
Yellow Perch	12727	166	47
Largemouth Bass	12728	241	200

NAME: TWIN LAKES
ID: 2B3-031
LONGITUDE: 85-32'00"W LATITUDE: 46-18'29"N STATE: MI

Largemouth Bass	12729	319	440
Brook Trout	12730	367	470
Brook Trout	12731	211	73
Brook Trout	12732	209	72
Yellow Perch	12733	112	11
Yellow Perch	12734	146	25
Yellow Perch	12735	120	15
Yellow Perch	12736	99	9
Yellow Perch	12737	105	10
Yellow Perch	12738	106	10
Yellow Perch	12739	120	14
Yellow Perch	12740	122	14

NAME: KLONDIKE LAKE ID: 2B3-034
LONGITUDE: 86-30'10"W LATITUDE: 46-13'18"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 25OCT84

pH: 7.62 Ext. Al: 0.00 Tot. Al: 3.00 Ca: 984.5
Conductivity: 133.40 DOC: 6.17 F: 1.684 Mg: 389.1
Air Eq pH: 8.46 TP: 9.000 Secchi Depth: 3.05
Color: 25.00 Na: 29.58 Silica: 6.14 Sulfate: 47.89
Site Depth: 13.70 Lake Area: 16.8 Elevation: 240.8
Lake Type: DRAINAGE Watershed Area: 54.0

ELS-II CHEMISTRY SAMPLE DATE: 11JUN87

pH: 8.33 Inorganic Al: 0.00 Minimum DO: 0.68
DOC: 4.60 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.39

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 12JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	53.5
Trap Nets	3	61.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	6	0	7	0
Johnny Darter	0	0	5	0
Largemouth Bass	2	0	0	0
Smallmouth Bass	1	0	0	0
Pumkinseed	0	2	0	0
Rock Bass	2	17	0	0
White Sucker	2	0	0	0
Bluntnose Minnow	0	0	17	0
Northern Pike	19	2	0	6

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	130	169	46
Northern Pike	131	421	372
Northern Pike	132	449	422
Northern Pike	133	493	550
Northern Pike	134	403	324
Northern Pike	135	490	680
Northern Pike	136	410	332

NAME: KLONDIKE LAKE ID: 2B3-034
LONGITUDE: 86-30'10"W LATITUDE: 46-13'18"N STATE: MI

Northern Pike	137	440	417
Northern Pike	138	430	379
Northern Pike	139	410	357
Northern Pike	140	451	456
Northern Pike	141	370	245
Northern Pike	142	470	500
Northern Pike	143	461	480
Northern Pike	144	463	480
Smallmouth Bass	145	315	400
Largemouth Bass	146	351	590
Northern Pike	147	425	450
Northern Pike	148	436	460
Northern Pike	149	434	460
Northern Pike	150	526	740
Northern Pike	151	408	340
Largemouth Bass	153	320	410
Yellow Perch	155	251	203
Yellow Perch	156	267	221
Yellow Perch	157	220	108
Yellow Perch	158	239	138
Yellow Perch	159	165	46
Northern Pike	160	384	285
Northern Pike	161	473	420
Northern Pike	162	440	405
Northern Pike	163	414	365
Northern Pike	164	478	524
Northern Pike	165	393	324
Northern Pike	166	409	356
Northern Pike	167	390	296
Rock Bass	910	143	56
Rock Bass	911	142	54
Rock Bass	912	114	26
Rock Bass	913	113	27
Rock Bass	914	167	104
Rock Bass	915	189	121
Rock Bass	916	185	114
Rock Bass	917	153	67
Rock Bass	920	75	6
Rock Bass	921	75	7
Rock Bass	922	95	16
Rock Bass	925	84	12
Rock Bass	926	82	11
Rock Bass	927	117	33
Pumpkinseed	929	158	93

NAME: RUMBLE LAKE ID: 2B3-037
LONGITUDE: 86-33'33"W LATITUDE: 46-11'00"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 25OCT84

pH: 8.00 Ext. Al: 0.00 Tot. Al: 3.00 Ca: 1118
Conductivity: 155.10 DOC: 3.46 F: 2.000 Mg: 486.2
Air Eq pH: 8.50 TP: 9.000 Secchi Depth: 2.25
Color: 10.00 Na: 41.32 Silica: 5.06 Sulfate: 137.6
Site Depth: 7.60 Lake Area: 7.6 Elevation: 234.7
Lake Type: DRAINAGE Watershed Area: 47.0

ELS-II CHEMISTRY SAMPLE DATE: 28JUL87

pH: 8.70 Inorganic Al: 0.02 Minimum DO: 1.39
DOC: 3.70 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.25

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 29JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	63.0
Trap Nets	3	69.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	54	0	4	0
Iowa Darter	0	0	2	0
Black Crappie	0	1	0	0
Largemouth Bass	1	4	0	0
Bluegill	0	147	5	0
Pumkinseed	2	4	0	0
Brown Bullhead	0	1	0	0
White Sucker	12	0	0	0
Bluntnose Minnow	0	0	160	0
Golden Shiner	5	0	0	0
Northern Pike	7	0	0	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 12SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	53.0
TRAP NETS	3	52.0

NAME: RUMBLE LAKE | ID: 2B3-037
LONGITUDE: 86-33'33"W LATITUDE: 46-11'00"N STATE: MI

SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	20	0	0	0
Iowa Darter	0	0	10	0
Largemouth Bass	4	1	0	1
Bluegill	8	18	0	0
Pumkinseed	2	0	0	0
Brown Bullhead	0	1	0	0
White Sucker	12	0	0	0
Bluntnose Minnow	0	0	1	0
Golden Shiner	2	0	0	0
Northern Pike	8	1	0	0
Central Mudminnow	0	0	1	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	600	424	820
White Sucker	601	255	160
White Sucker	602	371	560
White Sucker	603	261	213
White Sucker	604	320	360
Largemouth Bass	605	83	8
Largemouth Bass	607	81	6
White Sucker	608	272	226
White Sucker	609	234	137
White Sucker	610	256	175
White Sucker	611	328	410
White Sucker	612	460	460
White Sucker	613	332	440
Northern Pike	614	486	620
Northern Pike	615	723	2200
Northern Pike	616	659	1300
Northern Pike	617	659	1620
Northern Pike	618	610	1280
Northern Pike	619	675	1740
Northern Pike	620	612	1480
Largemouth Bass	621	150	42
Largemouth Bass	622	94	10
Yellow Perch	623	228	134
White Sucker	624	170	51
Yellow Perch	625	125	18
Yellow Perch	626	121	16
Yellow Perch	627	121	14
Yellow Perch	628	130	19
Yellow Perch	629	120	16

NAME: RUMBLE LAKE ID: 2B3-037
LONGITUDE: 86-33'33"W LATITUDE: 46-11'00"N STATE: MI

Largemouth Bass	630	105	11
Largemouth Bass	631	110	13
Yellow Perch	632	124	19
Yellow Perch	633	118	15
Yellow Perch	634	118	13
Yellow Perch	635	198	77
Yellow Perch	636	192	68
Yellow Perch	637	217	108
Yellow Perch	638	119	15
Yellow Perch	639	123	20
Yellow Perch	640	102	12
Yellow Perch	641	108	14
Yellow Perch	643	121	16
Yellow Perch	644	121	16
Yellow Perch	645	161	43
Yellow Perch	646	104	11
Yellow Perch	647	232	121
Yellow Perch	648	117	15
Yellow Perch	649	116	16
Yellow Perch	650	126	17
Yellow Perch	651	109	14
Yellow Perch	652	118	15
Yellow Perch	653	115	15
Yellow Perch	654	117	16
Yellow Perch	655	109	14
Yellow Perch	656	111	15
Yellow Perch	657	126	16
Yellow Perch	658	115	16
Yellow Perch	659	117	12
Yellow Perch	660	104	12
Yellow Perch	661	118	14
Yellow Perch	662	119	16
Yellow Perch	663	113	15
Yellow Perch	664	106	12
Yellow Perch	665	125	19
Yellow Perch	666	123	17
Yellow Perch	667	114	16
Yellow Perch	668	109	13
Yellow Perch	669	101	11
White Sucker	12968	420	850
White Sucker	12970	261	209
White Sucker	12971	260	196
White Sucker	12972	169	50
White Sucker	12973	180	58
White Sucker	12974	320	378
White Sucker	12975	320	320
White Sucker	12976	285	256
White Sucker	12979	283	251
White Sucker	12980	337	440
White Sucker	12982	296	281
Largemouth Bass	12959	216	139
Northern Pike	12960	927	5000
Northern Pike	12961	565	1150
Northern Pike	12962	610	1200

NAME: RUMBLE LAKE
ID: 2B3-037
LONGITUDE: 86-33'33"W LATITUDE: 46-11'00"N STATE: MI

Northern Pike	12963	686	1800
Northern Pike	12964	551	1000
Northern Pike	12965	620	1450
Northern Pike	12966	721	1150
Northern Pike	12967	535	850
Largemouth Bass	12977	114	18
Largemouth Bass	12981	102	13
Largemouth Bass	12983	446	1620
Largemouth Bass	12984	108	14
Yellow Perch	12985	123	17
Yellow Perch	12986	118	14
Yellow Perch	12987	126	19
Yellow Perch	12988	127	18
Yellow Perch	12989	122	15
Yellow Perch	12990	110	13
Yellow Perch	12991	118	15
Yellow Perch	12992	121	16
Yellow Perch	12993	114	13
Yellow Perch	12994	114	14
Yellow Perch	12995	115	13
Yellow Perch	12996	101	11
Yellow Perch	12997	113	13
Yellow Perch	12998	121	17
Yellow Perch	12999	113	12
Yellow Perch	13000	116	14
Yellow Perch	13001	117	15
Yellow Perch	13002	125	18
Yellow Perch	13003	115	14
Yellow Perch	13004	118	16
Northern Pike	92967	650	1477

NAME: JOHNS LAKES (WESTERN) ID: 2B3-051
LONGITUDE: 85-54'16"W LATITUDE: 46-31'50"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 23OCT84

pH: 4.91 Ext. Al: 13.00 Tot. Al: 42.00 Ca: 25.95
Conductivity: 13.80 DOC: 3.60 F: 0.684 Mg: 17.27
Air Eq pH: 4.85 TP: 1.000 Secchi Depth: 4.70
Color: 15.00 Na: 5.22 Silica: 0.00 Sulfate: 58.09
Site Depth: 18.90 Lake Area: 6.6 Elevation: 289.0
Lake Type: SEEPAGE Watershed Area: 26.0

ELS-II CHEMISTRY SAMPLE DATE: 17AUG87

pH: 4.85 Inorganic Al: 0.01 Minimum DO: 1.72
DOC: 2.30 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.56

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 18AUG87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	52.7
Trap Nets	3	60.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Central Mudminnow	0	3	90	0

NAME: (NO NAME) ID: 2B3-055
LONGITUDE: 86-39'37"W LATITUDE: 46-15'52"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 25OCT84

pH: 7.41 Ext. Al: 0.00 Tot. Al: 7.00 Ca: 684.6
Conductivity: 92.90 DOC: 2.54 F: 1.421 Mg: 289.6
Air Eq pH: 8.29 TP: 9.000 Secchi Depth: 2.40
Color: 20.00 Na: 31.32 Silica: 6.19 Sulfate: 94.73
Site Depth: 2.40 Lake Area: 5.5 Elevation: 246.9
Lake Type: DRAINAGE Watershed Area: 41.0

ELS-II CHEMISTRY SAMPLE DATE: 28JUL87

pH: 7.55 Inorganic Al: -0.00 Minimum DO: 6.96
DOC: 1.90 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 29JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	68.5
Trap Nets	3	67.5
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	24	8	0	0
Johnny Darter	0	0	3	0
Pumkinseed	0	18	1	0
Banded Killifish	0	0	1	0
Brown Bullhead	11	79	1	0
White Sucker	18	39	0	0
Creek Chub	5	15	320	0
Finescale Dace	0	0	7	0
Common Shiner	0	7	15	0
Golden Shiner	0	5	0	0
Brook Trout	3	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	12539	250	157
White Sucker	12540	254	170
White Sucker	12541	228	124
White Sucker	12542	233	140
White Sucker	12543	243	142

NAME: (NO NAME) ID: 2B3-055
LONGITUDE: 86-39'37"W LATITUDE: 46-15'52"N STATE: MI

White Sucker	12544	237	141
White Sucker	12545	240	146
White Sucker	12546	246	151
White Sucker	12547	237	138
White Sucker	12548	182	58
White Sucker	12549	180	58
White Sucker	12551	195	72
White Sucker	12552	260	180
White Sucker	12553	225	122
White Sucker	12554	218	97
White Sucker	12555	195	59
White Sucker	12556	211	81
White Sucker	12557	221	106
White Sucker	12558	223	108
White Sucker	12559	225	99
White Sucker	12560	205	81
White Sucker	12561	213	84
White Sucker	12562	205	81
White Sucker	12563	212	87
White Sucker	12564	218	95
White Sucker	12565	243	132
White Sucker	12566	126	19
White Sucker	12567	138	23
White Sucker	12568	132	21
White Sucker	12569	130	19
White Sucker	12570	126	20
White Sucker	12571	131	20
White Sucker	12572	132	22
White Sucker	12573	145	27
White Sucker	12574	120	15
White Sucker	12575	130	18
Brook Trout	12584	344	560

NAME: PINERY LAKES (LARGEST) ID: 2B3-056
LONGITUDE: 88-23'30"W LATITUDE: 46-46'03"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 17OCT84

pH: 6.90 Ext. Al: 2.00 Tot. Al: 24.00 Ca: 374.3
Conductivity: 56.40 DOC: 8.00 F: 2.053 Mg: 136.6
Air Eq pH: 8.12 TP: 13.00 Secchi Depth: 1.10
Color: 50.00 Na: 33.93 Silica: 3.17 Sulfate: 31.02
Site Depth: 2.40 Lake Area: 9.1 Elevation: 253.0
Lake Type: SEEPAGE Watershed Area: 194.0

ELS-II CHEMISTRY SAMPLE DATE: 22JUL87

pH: 7.27 Inorganic Al: -0.00 Minimum DO: 7.39
DOC: 6.60 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 23JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	68.0
Trap Nets	3	66.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Pumkinseed	0	48	0	0
Finescale Dace	0	105	90	0

NAME: TWIN LAKE ID: 2B3-057
LONGITUDE: 87-59'57"W LATITUDE: 46-27'50"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 16OCT84

pH: 6.83 Ext. Al: 2.00 Tot. Al: 21.00 Ca: 131.7
Conductivity: 29.50 DOC: 5.00 F: 1.842 Mg: 106.1
Air Eq pH: 7.71 TP: 12.00 Secchi Depth: 1.55
Color: 45.00 Na: 25.23 Silica: 5.66 Sulfate: 70.37
Site Depth: 3.00 Lake Area: 18.5 Elevation: 488.0
Lake Type: DRAINAGE Watershed Area: 98.0

ELS-II CHEMISTRY SAMPLE DATE: 08JUL87

pH: 6.67 Inorganic Al: 0.01 Minimum DO: 1.67
DOC: 5.40 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.47

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 08JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	56.5
Trap Nets	3	57.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	1	1	0	0
Black Crappie	10	1	0	0
Largemouth Bass	0	0	0	1
Bluegill	8	71	0	0
White Sucker	2	0	0	0
Northern Pike	0	1	0	0
Sunfish Hybrid	0	2	0	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 04SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	44.5
TRAP NETS	3	45.0
SEINES	4	
ANGLING		2.0

NAME: TWIN LAKE ID: 2B3-057
LONGITUDE: 87-59'57"W LATITUDE: 46-27'50"N STATE: MI

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Black Crappie	3	3	0	2
Bluegill	3	2	0	0
White Sucker	1	0	0	0
Golden Shiner	0	1	0	0
Northern Pike	0	1	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
White Sucker	12386	337	290
White Sucker	12387	371	570
Yellow Perch	12388	170	50
Yellow Perch	12388	170	50
Yellow Perch	12389	106	11
Yellow Perch	12389	106	11

NAME: LAKE ANNIE ID: 2B3-058
LONGITUDE: 88-35'25"W LATITUDE: 47-10'39"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 18OCT84

pH: 6.25 Ext. Al: 12.00 Tot. Al: 93.00 Ca: 36.43
Conductivity: 11.40 DOC: 3.40 F: 0.948 Mg: 27.15
Air Eq pH: 6.77 TP: 13.00 Secchi Depth: 1.80
Color: 15.00 Na: 16.96 Silica: 0.00 Sulfate: 43.72
Site Depth: 1.80 Lake Area: 13.2 Elevation: 293.2
Lake Type: SEEPAGE Watershed Area: 91.0

ELS-II CHEMISTRY SAMPLE DATE: 09JUL87

pH: 5.74 Inorganic Al: 0.00 Minimum DO: 7.75
DOC: 4.00 Thermal Stratification: MIXED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 10JUL87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	3	69.0
Trap Nets	3	75.0
Seines	4	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Brown Bullhead	339	2064	0	0

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 03SEP87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
GILL NETS	3	64.5
TRAP NETS	3	66.0
SEINES	4	
ANGLING		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Brown Bullhead	275	4280	0	0

NAME: OSTRANDER LAKE ID: 2B3-071
LONGITUDE: 86-36'43"W LATITUDE: 46-10'05"N STATE: MI

ELS-I CHEMISTRY SAMPLE DATE: 25OCT84

pH: 7.05 Ext. Al: 0.00 Tot. Al: 16.00 Ca: 207.1
Conductivity: 22.20 DOC: 4.80 F: 0.948 Mg: 42.78
Air Eq pH: 7.59 TP: 11.00 Secchi Depth: 2.85
Color: 15.00 Na: 10.00 Silica: 0.09 Sulfate: 77.45
Site Depth: 9.10 Lake Area: 21.7 Elevation: 234.7
Lake Type: SEEPAGE Watershed Area: 65.0

ELS-II CHEMISTRY SAMPLE DATE: 15JUN87

pH: 7.03 Inorganic Al: 0.01 Minimum DO: 4.91
DOC: 5.60 Thermal Stratification: STRATIFIED
% Water Column < 4 mg/L DO: 0.00

ELS-II FISH CATCH SUMMARY -- SAMPLE DATE: 16JUN87

SAMPLING EFFORT:

NET TYPE	UNITS OF GEAR	TOTAL HOURS FISHED
Gill Nets	4	72.5
Trap Nets	4	85.0
Seines	5	
Angling		2.0

NUMBER OF FISH CAUGHT:

SPECIES	GILL NET	TRAP NET	SEINE	ANGLING
Yellow Perch	83	1	2	0
Largemouth Bass	3	0	0	0
Smallmouth Bass	1	0	0	0
Bluegill	0	51	9	1
Pumkinseed	0	2	3	0
Rock Bass	8	3	4	3
Bluntnose Minnow	0	0	117	0
Common Shiner	4	0	0	0
Northern Pike	7	0	0	0

ELS-II INDIVIDUAL FISH DATA

SPECIES	FISH ID	LENGTH	WEIGHT
Yellow Perch	168	117	11
Yellow Perch	169	118	11
Yellow Perch	170	110	11
Yellow Perch	171	116	11
Yellow Perch	172	118	12
Yellow Perch	173	109	13
Largemouth Bass	174	431	1060

NAME: OSTRANDER LAKE ID: 2B3-071
LONGITUDE: 86-36'43"W LATITUDE: 46-10'05"N STATE: MI

Yellow Perch	175	125	15
Yellow Perch	176	114	14
Yellow Perch	177	130	18
Yellow Perch	178	114	13
Yellow Perch	179	116	10
Yellow Perch	180	121	14
Yellow Perch	181	115	13
Yellow Perch	182	118	14
Yellow Perch	183	131	18
Yellow Perch	184	115	11
Northern Pike	185	734	2400
Northern Pike	186	577	1250
Northern Pike	187	506	790
Northern Pike	188	549	950
Northern Pike	189	536	950
Northern Pike	190	581	1260
Northern Pike	191	555	1130
Largemouth Bass	192	356	550
Largemouth Bass	193	330	320
Smallmouth Bass	194	365	560
Yellow Perch	196	121	10
Yellow Perch	197	196	74
Yellow Perch	198	118	11
Yellow Perch	199	111	10
Yellow Perch	200	115	11
Yellow Perch	201	109	9
Yellow Perch	202	125	15
Yellow Perch	203	130	19
Yellow Perch	204	116	11
Yellow Perch	205	106	11
Yellow Perch	206	129	18
Yellow Perch	207	130	17
Yellow Perch	208	122	11
Yellow Perch	209	120	15
Yellow Perch	210	116	14

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