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MERCURY LEVELS IN FISH FROM THE UPPER PENINSULA OF MICHIGAN (ELS SUBREGION 2B) IN RELATION TO LAKE ACIDITY

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EXECUTIVE SUMMARY

The accumulation of mercury by fish and the potential human health effects of eating mercury-contaminated fish have been well documented. However, elevated mercury concentrations in fish from dilute, low-pH lakes have only recently been associated with increased lake acidity. Nevertheless, there now is ample evidence to document that elevated levels of mercury are found in fish from lakes in remote areas with no known point sources of mercury and that an apparent relationship exists between lake pH and fish mercury level.

The U.S. Food and Drug Administration (FDA) has set an action level of 1.0 ppm methyl mercury as the limit for human consumption. Many state fisheries agencies in the United States have established advisories regarding consumption of fish with mercury levels that do not exceed the standard of 1.0 ppm, usually invoking a standard of 0.5 ppm. The World Health Organization (WHO) standard is 0.5 ppm.

Forty-nine drainage and seepage lakes in the Upper Michigan Peninsula (Subregion 2B) were sampled in conjunction with Phase II of the U.S. Environmental Protection Agency's (EPA) Eastern Lake Survey (ELS-II) to explore the relationship between chemical and physical characteristics of lakes and mercury concentrations in fish tissue. The lakes were selected using a stratified random design weighted for low pH so that acidification effects on mercury accumulation could be evaluated. By coupling this study to Phase I of the EPA's Eastern Lake Survey, (ELS-I), along with Phase II, we were able to examine the role of chemical and physical lake variables on the assimilation of mercury by fish.

Because of the concern for potential human health effects, our focus was on "game fish" species. However, we also report mercury levels for some nongame species as well. Mercury levels reported are predominantly methyl mercury (99%).

Specific objectives of this study were:

1. Archive tissue samples for representative ages of fish species collected during ELS-II.
2. Measure total mercury concentrations in selected fish samples.
3. Using statistical and deterministic approaches, identify relationships between fish tissue mercury levels and water quality and lake-watershed characteristics.
4. Estimate the number and percentage of lakes in the region which have game fish with mercury levels exceeding human health guidelines.

Although the numbers of fish analyzed for each species and each age class were dissimilar, a general trend of increasing mean mercury concentration as a function of age was evident for all species. This trend was also evident in the proportion of samples that exceeded the health criterion. For example, 7.5% of the age-4 yellow perch had mercury concentrations greater than 0.5 ppm, while 26.2% of the age-7 yellow perch had concentrations greater than this value. Overall, a large proportion of the yellow perch, northern pike, and largemouth bass exceeded the Michigan state health advisory criterion. Thirty-three percent of the northern pike and 26% of the largemouth bass exceeded 0.5 ppm. While fewer fish of all species exceeded the FDA action level of 1.0 ppm, fish with the highest mercury concentrations were well distributed among all lakes.

It is apparent from the foregoing results that a high percentage of game fish, which are the species most likely to be consumed by humans, exceed various health guidelines for mercury. The severity and extent of the mercury contamination problem depends upon whether the FDA action level of 1.0 ppm methyl mercury is used or the more conservative figure of 0.5 ppm adopted by several states, Canada, and the WHO.

Based on the probability sampling frame for the ELS-I and ELS-II surveys, data collected on fish mercury levels for 37 of the 49 ELS-II lakes were extrapolated to estimate fish mercury characteristics for Subregion 2B as a whole. Regional estimates are provided for the total number and area of lakes where fish mercury levels exceed 0.5 and 1.0 ppm. Results of these estimates show that nearly 54% of all lakes in this subregion and nearly 82% of the surface area of all lakes have one or more fish exceeding the 0.5 ppm Hg state health advisory. Over 18% of all lakes have one or more fish exceeding 1.0 ppm Hg. However, among game fish other than yellow perch (walleye, northern pike, and large-mouth bass), at least one fish exceeds the 1.0 ppm action level in 43% of the 457 lakes in which they occur. At least one of these same species exceeds 0.5 ppm in 58% of the lakes in which they occur.

Numerous statistical relationships exist between mercury levels and water chemistry variables; however, a survey study provides no basis from which to imply causal mechanisms. For example, several multiple regression models that predict mercury levels in fish have high correlation coefficients, but their variables may or may not be implicated in actual causes for increased or decreased mercury levels in fish. The variables identified in multiple regression models are not always the same as those that have the highest coefficients in simple correlation matrices. Overall, the most consistent variables related to the mercury levels found in fish were those describing fish size (total length, weight, age). Of secondary importance were variables related to lake acidity status. Therefore, the principal benefit of this study is that it begins to quantify the mercury problem in one subregion of the ELS and suggests some possible lake characteristics that may warrant further investigation as to their possible cause and effect relationships with mercury accumulation in fish.

Additional research needed to reduce the current uncertainty about the quantitative relationships between acidic deposition, bioaccumulation of mercury in fish, and human health risks includes: (1) systematic surveys designed to identify the extent and severity of mercury bioaccumulation in fish taken from lakes in regions potentially affected by acidic deposition, (2) studies designed to identify and quantify the factors affecting bioaccumulation, and (3) studies designed to quantify the consumption by humans of fish from low-ANC waters and the demography of angler populations.

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I. INTRODUCTION AND BACKGROUND

1.1 REVIEW OF RELATIONSHIPS BETWEEN LAKE ACIDITY AND MERCURY ACCUMULATION IN FISH

The accumulation of mercury by fish and the potential human health effects of eating mercury-contaminated fish have been well documented (e.g., NAS, 1978), although elevated mercury concentrations in fish from dilute, low-pH lakes have only recently been associated with increased lake acidity (Akielaszek and Haines, 1981; Hakanson et al., 1988; Helwig and Heiskary, 1985; Wiener, 1983; Wren and MacCrimmon, 1983; Lathrop et al., 1987). Nevertheless, there now is ample evidence to document that elevated levels of mercury are found in fish from lakes in remote areas with no known point sources of mercury and that an apparent relationship exists between lake pH and fish mercury content.

Several important water quality and biological variables affect mercury accumulation in fish. These factors include mercury speciation (Huckabee et al., 1979; Bjornberg et al., 1988), rates of methylation and demethylation (e.g., Jensen and Jernelov, 1969; Steffan et al., 1988), age and growth patterns of fish (e.g., Scott and Armstrong, 1972), the concentration of dissolved organic carbon (DOC) (e.g., Bodaly et al., 1984), and nutrient supply to lakes (e.g., Hakanson, 1980). The effects of these factors may be interrelated.

Richman et al. (1988) have discussed the following six hypotheses on why fish in acidic or low acid neutralizing capacity (ANC) lakes exhibit higher mercury levels than fish from circumneutral lakes, often in the same region.

1. Mercury may enter the watershed with acidic deposition (i.e., acid rain is also polluted with Hg).
2. The acidification of lake water may mobilize both existing sediment-bound Hg and Hg present in the surrounding watershed. This would increase the amount of Hg available for methylation and bioaccumulation.
3. Lower pH may favor the production of monomethyl Hg (the more available form to biota) over dimethyl Hg.

4. Acidic conditions may alter the rates of Hg methylation and/or demethylation by microorganisms.
5. The biological conditions characteristic of an acidic lake may be important to Hg transfer and bioaccumulation of Hg at different ecosystem levels.
6. The biota in acidic lakes may be more efficient bioaccumulators of Hg compared with biota from circumneutral lakes, or they may be unable to excrete Hg at an efficient rate.

Each of these hypotheses has a reasonable scientific basis and published work to at least partially substantiate it; however, none taken alone or even in combination adequately verifies that acidification of lakes or associated increases in atmospheric deposition of mercury account for observed bioaccumulation in fish. For example, the addition of mercury from atmospheric sources does not explain why the fish in lakes with very similar deposition rates have very different mercury levels. A variety of organic and inorganic chemical conditions and physical properties of sediment may regulate mercury mobilization from sediments. Factors associated with acidification may prevail only under certain conditions. Conflicting evidence exists regarding the direct effect of pH on chemical speciation of mercury (i.e., increased methyl mercury at lower pH) and there is undoubtedly an interaction with microbially-mediated methylation that probably accounts for the majority of increased methyl mercury in the water column under lower pH conditions (Xun et al., 1987) as well as increased release of methyl mercury from sediment (Ramlal et al., 1985).

Among other water quality parameters correlated with elevated mercury in fish, dissolved organic carbon (DOC) is probably the most frequently cited (McMurtry et al. 1989; Helwig and Heiskary 1985; Grieb et al. 1990). However, DOC has been hypothesized to decrease following acidification of drainage lakes (Driscoll et al. 1989). The DOC correlations in seepage or dystrophic lakes may reflect natural, but heretofore undetected, processes rather than association with acidic deposition.

Biological consequences of acidification that may alter food chains (Schindler et al. 1985) and change fish population structure (resulting in fewer, but older and larger fish) could result in more mercury being "available" to accumulate in fewer fish. This relationship is unclear at present and probably interacts with other variables (Richman et al. 1988). Indirect effects of chemical changes on biota--notably the increased permeability (Brown, 1983) of fish gill and other membranes may facilitate mercury uptake of fish. This has been demonstrated experimentally (Rodgers and Beamish, 1983), albeit at calcium levels at the high end of the range found in low ANC or acidified lakes. The lower calcium levels typical of low ANC systems may be a factor influencing mercury uptake.

The correlative evidence that exists today between fish mercury content and acidic deposition or acidity status of lakes is inadequate for extrapolating any prediction beyond the data sets from which the correlations are derived. Few, if any, causal relationships have been verified experimentally. It is probable that if dose/response relationships having predictive value can be derived, they will necessarily be specific to geographic region, lake type, fish species, and fish size, and perhaps dependent upon fairly detailed knowledge of other physical and chemical characteristics in lakes.

1.2 HUMAN HEALTH CONCERNS

There is concern about the potential indirect effects of acidic deposition and resultant mercury accumulation in fish on human health. The risk is to that portion of the human population that may consume fish with elevated or unsafe levels of mercury in muscle tissue. Mercury is an extremely toxic element that produces a variety of central nervous system disorders and even causes death in extreme cases. Documented cases of illness and death in humans have been associated with consumption of fish caught near point sources of industrial pollution (NAS, 1978; Nriagu, 1979). However, elevated levels of mercury have been reported in the blood and hair of tourists eating fish from lakes in Minnesota with high mercury levels, as well as in fish consumers versus nonconsumers in the region (Phelps, et al., 1980). No clinical symptoms of mercury poisoning existed in either case. However, the lakes in question have no known point source of mercury pollution.

The U.S. Food and Drug Administration (FDA) has set an action level of 1.0 ppm methyl mercury as the limit for human consumption (Phillips, et al., 1987). This limit was increased in 1978 from 0.5 ppm of total mercury. Many state fishery agencies in the United States have established advisories regarding consumption of fish with mercury levels that do not exceed the action level of 1.0 ppm, usually invoking the previous action level of 0.5 ppm. The World Health Organization (WHO) level is 0.5 ppm. In Canada, the province of Ontario has some restriction on the harvest and/or consumption of fish in a large portion of the 1,500 lakes (there are approximately 250,000 lakes in Ontario) where mercury data are available (Ontario Ministry of the Environment, 1989). The restriction may only involve a single species or size of fish in some cases; however, elevated mercury levels have necessitated some form of regulation in hundreds of lakes. This may, in part, reflect of the Canadian standard of 0.5 ppm--one-half the U.S. action level. Thirty percent of fish from low-ANC lakes in northeastern Minnesota had fish mercury levels over 0.5 ppm while only 8% exceeded the 1.0 ppm FDA action level. The Minnesota Health Department considers 0.5 ppm mercury of concern for long-term consumption (Helwig and Heiskary, 1985).

In the northeastern United States, generally regarded as the area in the United States most impacted by acidic deposition, elevated levels of mercury in fish have been reported to be higher in acidic than non-acidic lakes (Sloan and Schofield, 1983). Documented levels of mercury in these lakes and others in the region (Bloomfield et al., 1980 - New York; Akielaszek and Haines, 1981 - Maine) are of concern to health agencies, although they typically do not exceed the 1.0 ppm action level. None of these waters have known direct industrial sources of Hg, deriving their mercury either from natural weathering or anthropogenic sources via atmospheric deposition.

1.3 OBJECTIVES OF THE SUBREGION 2B SURVEY (UPPER PENINSULA OF MICHIGAN)

Forty-nine drainage and seepage lakes in the upper Michigan peninsula were sampled in conjunction with Phase II of the U.S. Environmental Protection Agency's (EPA) Eastern Lake Survey (ELS-II) to explore the relationship between chemical and physical characteristics of lakes and mercury concentrations in fish tissue. The lakes were selected using a stratified random design weighted for low pH so that acidification effects on mercury accumulation could be evaluated. Lake selection also covered the full range of DOC values from Phase I of the Eastern Lake Survey (ELS-I). By coupling this study to ELS-I (Landers et al., 1988; Eilers et al., 1988) and ELS-II (Cusimano et al., 1988), we were able to examine the role of chemical and physical lake variables on the assimilation of mercury by fish. The study differs markedly from previous work because the lakes were randomly selected from a subset of lakes in Subregion 2B weighted as mentioned previously. This selection procedure was designed to allow extrapolation of results to the population of lakes in this subregion. The study included both drainage and seepage lakes, providing the opportunity to investigate differences in the accumulation of mercury between lake types as well as other chemical and physical factors that affect accumulation. Because of the concern for potential human health effects, our focus was on game fish species. However, we also report mercury levels for some nongame species as well.

Specific objectives of this study were to:

1. Archive tissue samples for representative ages of fish species collected during ELS-II.
2. Measure total mercury concentrations in selected fish samples.
3. Identify relationships between fish tissue mercury levels and water quality and lake-watershed characteristics, using statistical and deterministic approaches.
4. Estimate the number and percentage of lakes in the region in which game fish have mercury levels exceeding human health action levels.

Subregion 2B, encompassing the majority of the Upper Peninsula of Michigan plus a small portion of northern Wisconsin, was chosen for the ELS-II survey of fish community status and mercury levels 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 observed mercury levels in fish from those lakes. However, it should be emphasized that the National Surface Water Survey (NSWS) was a survey, not a process-oriented, cause and effect research program. The emphasis was on developing a regional perspective on the current status of aquatic resources with regard to the potential impacts of acidic deposition.

1.4 REPORT FORMAT

This report is divided into five sections and an appendix:

- Section 1, Introduction and Background
- Section 2, Study Area and Methodology - describes the lake selection criteria, fisheries sampling protocols, tissue processing and mercury analysis, and statistical procedures.
- Section 3, Results - contains an overview of phase I and II ELS findings including lake chemical characteristics and fish species distribution as well as relationships between mercury levels in fish and various biological and chemical factors.
- Section 4, Discussion - provides interpretation of findings in relation to other geographical areas, potential factors affecting mercury accumulation in fish, and human health concerns/research needs.
- Section 5, References

Appendix - listing of individual fish mercury data by lake.

2. STUDY AREA AND METHODOLOGY

This study was conducted in conjunction with the U.S. EPA's Eastern Lake Survey - ELS-II Fish Survey. The Fish Survey involved sampling for fish in 49 lakes located in the upper peninsula of Michigan and a small portion of northern Wisconsin (Figure 2-1). This area is predominately precambrian shield bedrock overlain by relatively shallow sandy soils. The lake selection and sampling and analysis procedures are described in detail in Cusimano et al. (1988). The physical characteristics of the lakes are summarized in Table 2-1, based on data collected during Phase I of the Eastern Lake Survey (ELS-I) (Linthurst et al., 1986).

2.1 LAKE CHARACTERISTICS

A large percentage of the study lakes were acidic because the selection procedure for the ELS-II Fish Survey lakes was weighted to favor low-pH systems. For example, 11.3% of ELS-I lakes had acid neutralizing capacities (ANC) $\leq$ 0 ueq/L and 9% had pH values $\leq$ 5.0 (Eilers et al., 1988), whereas 41% of the ELS-II lakes had ANC $\leq$ 0 ueq/L, and 25% had pH values $\leq$ 5 (Cusimano et al., 1988). The pH range for the study lakes was 4.4 to 8.2, with a mean value of 6.0 and a median value of 5.8. The mean and median pH values for the seepage lakes (mean pH = 5.6; median pH = 5.2) were 1 and 1.6 units lower, respectively, than the corresponding values for the drainage lakes (mean pH = 6.6; median pH = 6.8). The ANC range was -48 to 2,726 ueq/L, with a mean of 265 ueq/L and a median of 25 ueq/L. The ANC values were also substantially lower in seepage lakes, with mean and median values of 90.3 and 8.4 ueq/L as compared to corresponding values of 528 and 143 ueq/L for drainage lakes. Although the study lakes emphasize low-pH and low-ANC systems, a wide range of values was covered in the total sample. For example, 10% of the lakes had ANC values > 1,000 ueq/L, and 18% had ANC values > 500 ueq/L.

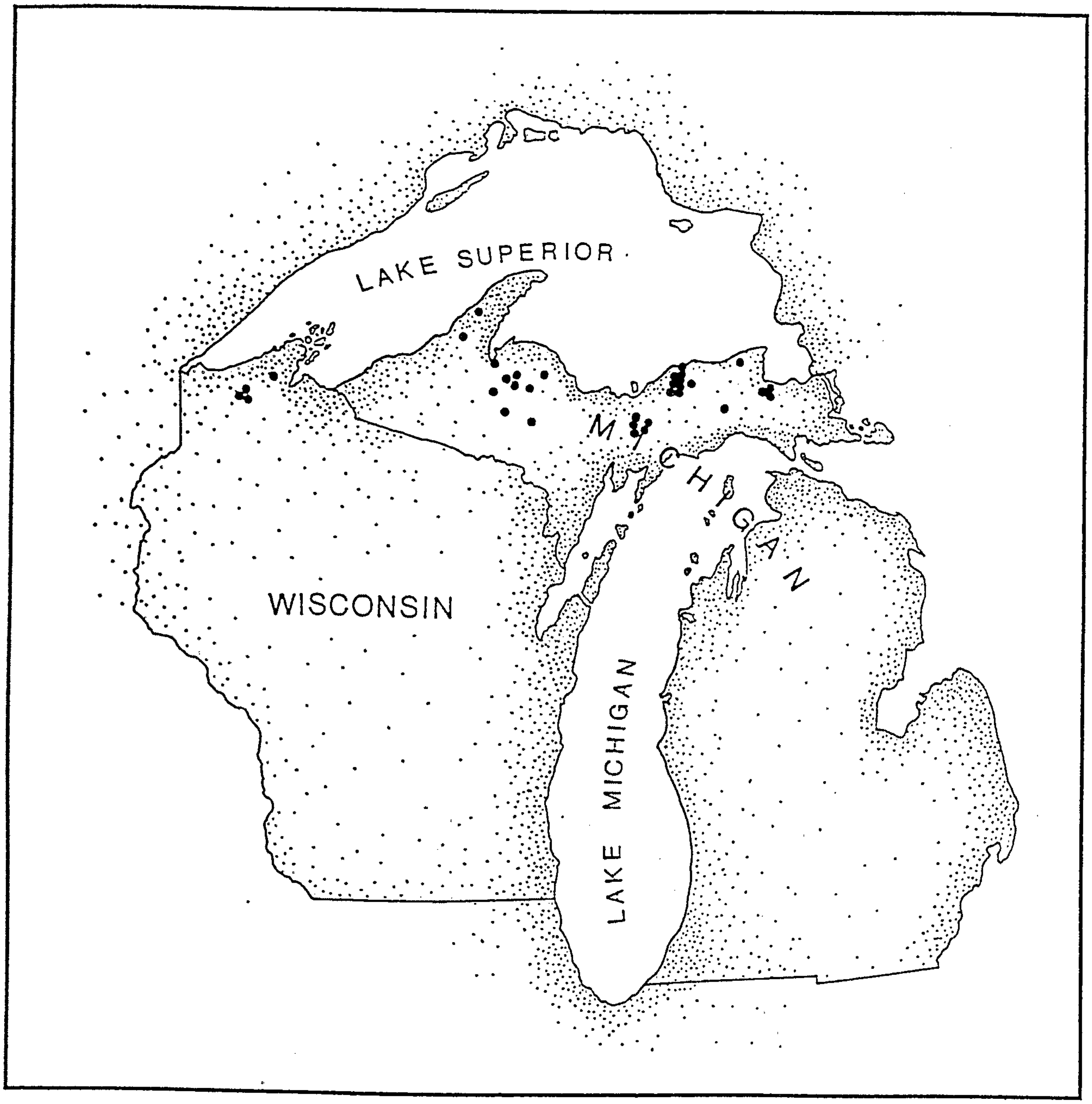


Figure 2-1. Location of ELS-II lakes sampled for fish mercury content, summer 1987.

Table 2-1. Physical Characteristics of the 49 Sampled Lakes

Parameter	Mean	Median	Range	Std. dev.
Physical characteristics				
Lake surface area (ha)	18	9	4 - 262	37
Site depth (m)	6.5	4.3	1.5 - 20.1	5.3
Secchi depth (m)	2.6	2.3	0.85 - 7.6	1.3
Elevation (m)	332	282	220 - 546	100
Watershed area (ha)	1,376	60	10 - 54,500	7,794

2.2 FISHERIES COLLECTIONS AND SAMPLE PROCESSING

The following species were classified as game fish for the purposes of this study, and are listed in order of priority for analysis of fish mercury content.

Species	Legal Size Limit (mm)
Walleye (*Stizostedion vitreum*)	380
Yellow perch (*Perca flavescens*)	150*
Northern pike (*Esox lucius*)	500
Lake trout (or splake) (*Onchorhyncus namaycush*)	250
Smallmouth bass (*Micropterus dolomeui*)	300
Largemouth bass (*M. salmoides*)	300
Brook trout (*Salvelinus fontinalis*)	250
Rainbow trout (*O. mykiss*)	250

*No legal size limit established for yellow perch; size specified represents minimum size likely to be consumed.

Species were ordered for analysis based on the likelihood that fish consumed may have high levels of mercury, with a secondary criterion based on the expected extent of distribution in lakes to be sampled. In addition to these game species, mercury data for white suckers (*Catostomus commersoni*), obtained in a companion study (Grieb et al., 1989) funded by the Electric Power Research Institute (EPRI), are reported here. The EPRI study focused on "index species", particularly yellow perch and white sucker because of their more widespread distribution in the study lakes. This focus on index species (those species available in most lakes) allowed the most comprehensive examination of the relationship between lake variables and fish mercury levels. We discuss only the yellow perch results in this report, because white sucker did not tend to have high mercury levels and are not classified as game fish.

Forty-nine lakes were sampled between June 8 and August 30, 1987. The fish were collected using variable mesh monofilament nylon gill nets, trap nets, beach seines, and hook and line fishing (Landers, 1987; Cusimano et al., 1988). The sampling effort varied with lake area, ranging from three to eight net sets for each gear type. The gill and trap nets were set for 10 to 29 hours. Each seine haul covered approximately 20 m of shoreline. Angling was conducted for 2 hours in each lake.

Following collection, individual fish from the target species of interest were selected based on the established priority and measured for total length and weight, and then sorted into several length classes. The fish were weighed using a portable electronic balance for the small fish (< 0.5 kg) and a spring balance for the larger fish (> 0.5 kg). Fish that were damaged or showed signs of decomposition were excluded from the samples.

Fish from each lake were divided into 3 length classes by species, and 10 to 15 fish from each length class (when available) were randomly selected for aging. Individual whole fish were wrapped in aluminum foil, labeled, and placed on ice as soon as practical after collection. Specimens were subsequently frozen within 24 hours of collection. All field collections and sample processing in the field were conducted by personnel of Michigan State University and Lockheed Engineering and Sciences Company, Las Vegas, NV.

Age was determined by the Wisconsin Department of Natural Resources using the cleithrum for northern pike, the first or second pectoral fin ray for white suckers, scales taken just below the lateral line below the insertion of the first dorsal spine for yellow perch, largemouth bass, and smallmouth bass, and scales taken just posterior to the dorsal fin and above the lateral line for trout.

After the size distributions were determined for each lake, small, medium, and large gamefish classes were selected for mercury analyses based on their prevalence in the study lakes. The large size class included the largest available fish for the two highest priority game species collected. Mercury analysis in a range of size classes was intended to support the development of regression equations that would allow some extrapolation to sizes not represented in the sample. For index species, following preliminary aging, five fish (when available) were randomly chosen from selected age classes, species, and lakes for mercury analyses. The total numbers of fish analyzed were 546 yellow perch, 86 northern pike, 110 white sucker, 73 largemouth bass, 4 smallmouth bass, 8 walleye, and 26 brook trout. With the exception of yellow perch, neither game fish nor index species were captured in sufficient numbers to meet all sample design criteria.

2.3 LABORATORY AND ANALYTICAL PROCEDURES

2.3.1 Sample Preparation

The fish selected for the mercury analyses were sent frozen on dry ice to Cornell University for tissue sample preparation. Processing time was kept as short as possible and all samples were refrozen to -20°C immediately after processing.

2.3.1.1 Cleaning Procedures

All equipment was cleaned before and after each use, according to the following protocol.

1. Soak 1-oz (or 4-oz) glass vials in hot tap water with detergent for 60 minutes.

   *Note: Use only glass containers to wash vials. Mercury or interference contamination may result from the use of plastics.

2. Wash vial caps in hot water with detergent and then rinse them with hot tap water and let air dry.

3. Rinse vials three times with tap water.

4. Rinse once with a nitric acid (ULTREX metal free HNO_3) solution: $HNO_3:H_2O = 1:6$

5. Rinse three times with distilled water.

6. Rinse with acetone (redistilled if possible).

7. Air dry on clean paper towels in a dust-free area.

8. Place a tape label with a sample number on each vial (to make secure, be sure tape overlaps on back of bottle).

9. Cap the vials, after they are dry, by placing acetone-rinsed aluminum foil between the vial and cap.

   Note: Rinse the shiny side of the aluminum foil with acetone.

10. Pre-weigh vial and cap to nearest 0.001 g; record the weight on the vial label and in a lab notebook along with the sample identification number.

2.3.1.2 Sample Preparation

In the preparation of samples, care was taken to avoid contamination, as small quantities of contamination are detectable at the levels of mercury that were to be measured (ppb). The preparation was carried out in a clean, dust-free area. Rigorous procedures were followed for the preparation of each sample, according to the following protocol.

1. Remove the specimen from the freezer, leaving it wrapped, and let it partially thaw, approximately 15 minutes for medium size specimens, to make it easier to cut.

2. Remove the specimen from its wrapping and place it on a clean glass dissecting tray with the left side of the fish facing up and the nose pointing toward the left.

3. Cut vertically, with a clean stainless steel scalpel, from anterior to the dorsal fin down to the lateral line; cut vertically from just posterior to the gill covering down to the lateral line, then cut along the lateral line joining the two vertical cuts. For consistency of comparison, the same tissue segment needs to be removed from each fish. (Figure 2-2).

4. Scrape the muscle tissue off the bone and off the skin using a stainless steel scalpel and forceps.

5. Place the muscle tissue in a pre-labeled, clean 1-oz glass vial.

   Note: If muscle tissue sample is too large to fit in a 1-oz glass vial, place it in a pre-weighed clean 4-oz jar. Homogenize (using Polytron tissue grinder with teflon head) the tissue in the 4-oz jar and then, after determining the weight or volume of the tissue, place approximately 20 g into a pre-weighed, pre-labeled, clean 1-oz jar. The excess tissue in the 4-oz jar may be discarded.

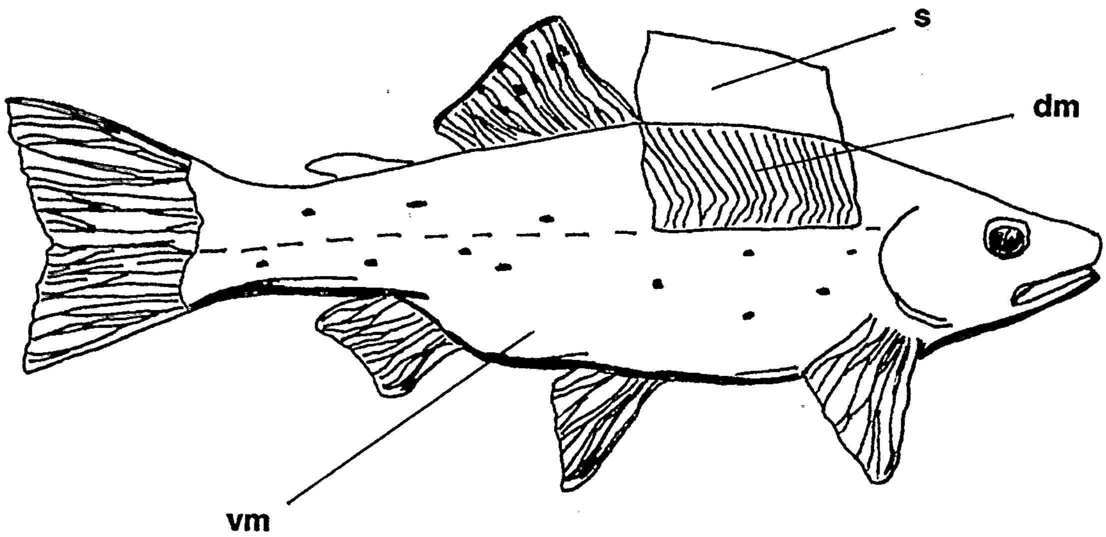
6. Within the jar, homogenize the muscle tissue to a smooth, creamy consistency.

7. Cap the vial with acetone-rinsed aluminum foil-lined caps.

8. Weigh the muscle, vial, and cap. Record the weight in the lab notebook with the appropriate sample identification.

9. Place the sample in the freezer.

10. Clean equipment, dissecting tray and instruments after each sample.



Dissection of a fish for metal analysis

s - skin
dm - dorsolateral muscle
vm - ventrolateral muscle

Figure 2-2. Diagram of location from which muscle tissue was removed from fish for mercury analysis.

a. Wash in hot tap water with detergent.

b. Rinse three times with hot tap water.

c. Rinse once with 10% nitric acid, $HNO_3:H_2O = 1:9$

d. Rinse three times with distilled water.

e. Rinse with acetone.

f. Let air dry.

2.3.1.3 Preservation of Subsample

It was important that the integrity of the contaminant in the sample be maintained until analysis could be performed at Syracuse University. Processing time was as short as possible and aliquots were refrozen immediately.

The samples were shipped frozen to Syracuse University for total mercury analyses and to Battelle Pacific Northwest Laboratory for methylmercury analyses and an interlaboratory comparison.

2.3.2 Total Mercury Analyses

Samples were thawed and up to 1.2 g of wet tissue homogenate was measured into 250 mL Pyrex boiling flasks. Twenty-five mL of concentrated sulfuric acid was added to each flask, which was capped with a glass bead-filled packed air condenser tube, and placed in a 70°C water bath for 30 minutes. Then, 3 mL of 30% hydrogen peroxide was added to further the digestion, and the flasks were returned to the water bath for an additional 2 hours.

The flasks were removed at the end of the digestion period and cooled in an ice bath to room temperature. Then, 100 mL of distilled water was added to each flask through the air condenser to recover any mercury that might have volatilized and been retained within the condenser during the digestion process. After the addition of the distilled water, the flasks were further cooled to near room temperature. The condenser tubes were removed, and 4 mL of 5% potassium permanganate was added to each flask to oxidize the tissue mercury to the mercuric (Hg^{2+}) form. The flasks were stoppered until analysis.

Mercury was analyzed with a LDC/Milton Roy Mercury Monitor (Elemental Mercury Detector - #920404), a high-performance UV photometer that allows for continuous and quantitative absorbance of mercury vapor at 253.7 nm in a gaseous stream (nitrogen) referenced to a mercury-free stream.

Twenty milliliters of hydroxylamine hydrochloride/sodium chloride solution (15 g of each diluted to 1 L of distilled deionized water) to reduce excess potassium permanganate was added followed by 10 mL of 10% stannous chloride to reduce Hg^{2+} to elemental mercury. The samples were immediately purged with a nitrogen stream through the mercury monitor sequentially, and peak heights were recorded.

The detection limit, defined as three times the standard deviation of 10 nonconsecutive reagent blank and 10 calibration blank analyses, was 0.002 ppm (ug/g, wet weight). Each batch of 8 to 14 fish samples analyzed was preceded by a reagent blank, a calibration blank, and four standards. An analytical triplicate, a matrix spike, and a National Bureau of Standards (NBS) tuna audit sample were analyzed for every 30 samples. The monitor was calibrated every day before the analysis of tissue samples. Output peaks from sample determinations were then compared to a calibration curve obtained from regression analysis of standard concentrations and standard peak heights to determine tissue concentrations. Fish samples that did not fall within the concentration range of the standards were reanalyzed using a more appropriate amount of tissue.

2.3.3 Quality Assurance - Precision and Accuracy

Fish collected in a pilot study from Lake Rondaxe and White Lake in the Adirondacks, for which we had prior Hg level analyses, were used as field blanks. Field blanks were dispersed from Cornell University and handled the same as the ELS-II samples in the field (i.e., weighed, measured, packaged). Values of concentration difference (initial sample concentration minus field blank concentration) were very low (mean - 0.006 ppm; range = 0.0 - 0.015 ppm; n = 12), suggesting little or no contamination of fish samples with mercury associated with sample collection, handling, and processing. One out of every 30 samples was digested and analyzed in triplicate. The coefficient of variation ranged from 0.0 to 17% with a mean of 3% (n = 30).

Samples of NBS albacore tuna with known concentrations of total mercury (0.95 ± 0.1 ppm) were analyzed and showed good agreement, with mean concentration of 0.88 ppm (SD = 0.03 ppm; range = 0.80 - 0.94 ppm; n = 39).

Ten samples of muscle tissue were split and analyzed for total mercury at Syracuse University and Battelle Pacific Northwest Laboratory. Results of this interlaboratory comparison showed good agreement between analytical determinations (r^2 = 0.92).

Throughout this study, analyses of standards were very consistent, showing a strong linear relationship (mean r^2 = 0.9992; range r^2 = 0.9956 to 1.0; n = 99) and slope (mean slope = 205.7 abs/ppm; SD = 10.7 abs/ppm; range = 186.4 - 224.3 abs/ppm). The observed concentrations of the calibration blanks were consistently at 0 ppm and thus were less than or equal to twice the required detection limit. Reagent blank concentrations were always at 0 ppm.

Every 30 samples, a small amount of the NBS albacore tuna was added to a fish sample, and the percent spike recovery was calculated with recoveries ranging from 86% to 115% with a mean of 99% (SD = 5.4 percent; n = 30).

As part of the companion EPRI study, 30 fish were also analyzed for methyl mercury by Battelle Pacific Northwest Laboratory to test the assumption that most of the mercury in fish was in the methyl form. Yellow perch were selected for most of these analyses (24 out of 30), although 3 of each species of northern pike and white sucker were analyzed. A range of age classes, pH values, DOC values, total mercury levels in fish, and lake types (seepage and drainage) were included in this subsample. Methyl mercury procedures were those described in Grieb et al. (1990). Thirteen of the 30 samples were also analyzed for total mercury by Battelle and almost all of the total mercury in these fish was methyl mercury. Neither inorganic nor dimethyl mercury was detected (less than 0.02 ug/g, wet weight basis) in any of the samples. The correlation between methyl mercury measured at Battelle Pacific Northwest Laboratory and total mercury determined at Syracuse University is shown in Figure 2-3. The methyl mercury fraction of the total

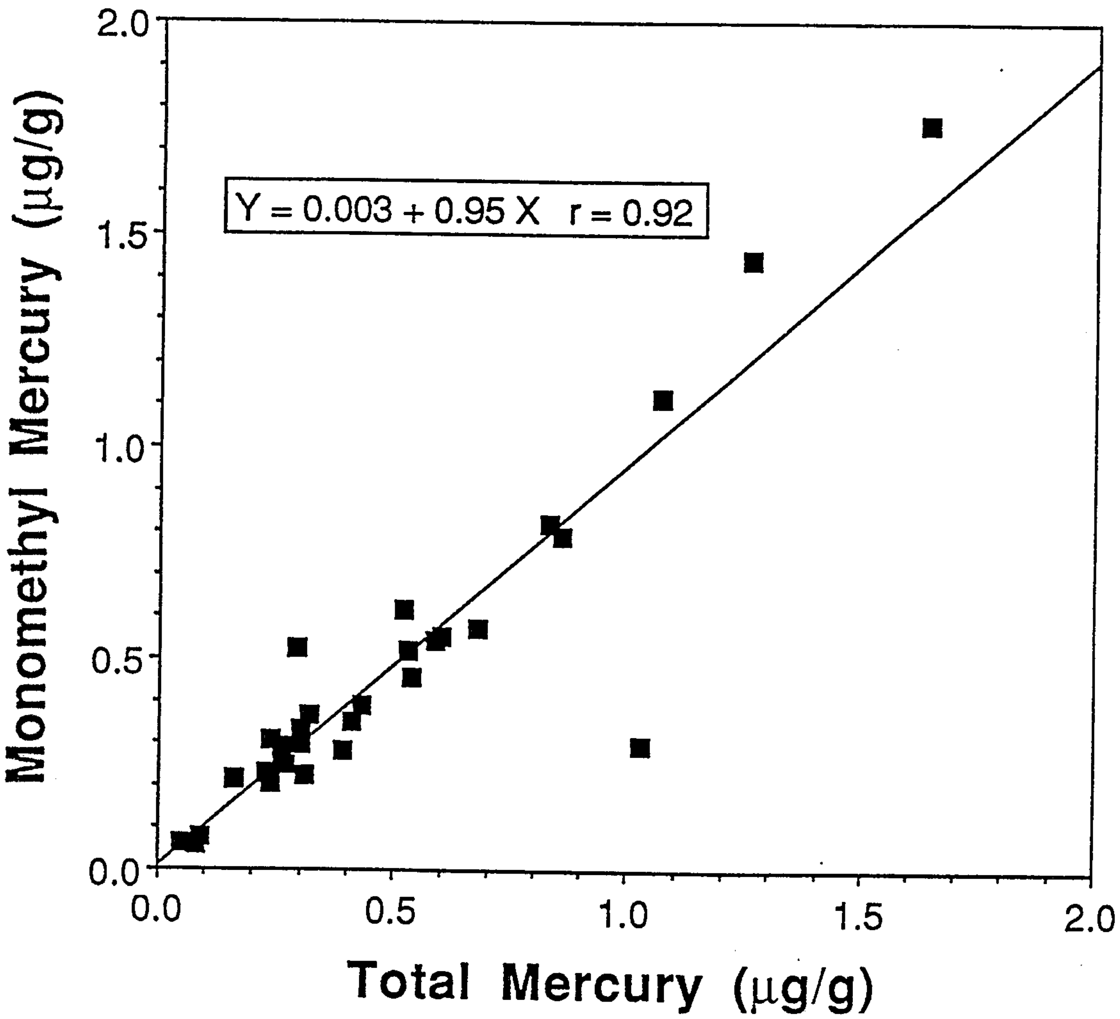


Figure 2-3. Relationship between total mercury and methyl mercury in a subsample of 30 fish from ELS-II lakes (from Greib et al. 1990).

mercury averaged 99%. Huckabee et al. (1979) have reported similar findings.

2.3.4 Statistical Analyses

Correlation and simple linear regression analyses were used to identify factors affecting mercury concentrations in yellow perch, northern pike, white sucker, and largemouth bass. These species were collected from 37 of the 49 lakes sampled. The numbers of seepage and drainage lakes with fish were 18 and 16, respectively, the remaining 3 lakes included a reservoir, a closed lake (i.e., no outlet), and a lake classified as a seepage lake that was excluded from the analyses due to exceptionally high dissolved silica and ANC values (perhaps a groundwater flow-through system).

Pearson product-moment correlation coefficients were calculated between fish mercury concentrations and fish age and size characteristics, and between fish mercury concentrations and water quality variables. For the evaluation of the relationships between mercury concentrations and fish age and size, correlation coefficients were calculated using fish from all 37 lakes from which yellow perch, northern pike, white sucker, and largemouth bass were collected. The analyses of the relationships between fish mercury concentrations and water quality variables were then limited to a subset of 27 lakes that contained yellow perch in age classes 2 to 4. The only species widely distributed among both seepage and drainage lakes was yellow perch, and it was necessary to combine samples from age classes 2 to 4 to obtain at least 3 fish from each lake. The subset of 27 lakes consisted of 15 seepage lakes and 12 drainage lakes.

In addition to simple correlations, multiple stepwise regressions were performed between fish mercury concentrations and lake chemical and physical characteristics. Variables were included in the models if they had significant coefficients ($p \leq 0.05$) and increased the r^2.

Partial correlations were performed in order to determine the influence of lake chemistry and lake physical characteristics on fish mercury concentrations with the effects of fish size and age removed. The partial correlations removed the variance due to fish size then correlated the remaining variance with the physical and chemical variable of interest.

In order to distinguish what set of variables best discriminates between high- and low-mercury levels in yellow perch, the fish were classified into two groups and a discriminate analysis was performed. The groups were low-mercury fish ($Hg < 0.5$) and high-mercury fish ($Hg \geq 0.5$). For these two groups, a discriminate function based on physical and chemical variables was developed using a stepwise method.

The Mann-Whitney rank-sum test was employed to determine if mercury levels, at different ages, in drainage lakes were significantly different from those in seepage lakes. Statistical analyses were conducted using SPSS (Nie et al., 1975) and BMDP (Dixon, 1985) on a VAX mainframe computer.

3. RESULTS

3.1 OVERVIEW OF ELS-I & ELS-II FINDINGS

The results of ELS-I and ELS-II regarding lake chemistry and fish community status have been described in considerable detail by Eilers et al. (1988), Landers et al. (1988), and Cusimano et al. (1988). Most recently, Cusimano et al. (1988) discussed the relationship between ELS-I and ELS-II and provided an overview of the fish community status in ELS-II Subregion 2B lakes. The salient aspects of those findings and discussion are repeated here because they provide important background information for the presentation and discussion of the mercury results.

3.1.1 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, researchers 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 ELS-I, a single water sample was collected at 1.5 m depth in 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. The chemical analysis for the fall 1984 sample provides a representative index of lake chemistry, which can be compared with the chemistry of other lakes sampled in order to detect regional patterns.

For the most part, the ELS-II data on fish mercury levels in Subregion 2B reported here 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 3-month sampling period (8 June to 30 August 1987). Since fish grow and live through a number of years, fish mercury levels in 1987 were expected to 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. We recognize that the ELS-I data may not be direct measures of chemical conditions during specific times and locales critical to mercury accumulation by fish, but we assume that the ELS-I index chemistry is at least correlated with these water quality values of interest. We did not examine fish from a resurvey of 10 lakes conducted in late August and early September for mercury. However, we did correlate fish mercury levels with collection time and found no effect on measured mercury levels.

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 3-1. Lake-specific data for each of the 49 lakes sampled are presented by Cusimano et al. (1988).

Tn 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. In addition, lakes selected for sampling for the ELS-II were specifically weighted to favor systems with low pH. Forty-one percent (40.8%) of the lakes sampled were acidic, with ANC $\leq$ 0 ueq/L, and 24.5% had pH $\leq$ 5.0. Thus, the proportion of low-ANC and low-pH

Table 3-1. Chemical Characteristics of Lakes in Subregion 2B, for the ELS-I Target Population (N = 1050), ELS-II Target Population (N = 597), and the 49 Lakes Sampled for Fish During ELS-II

Variable	ELS-I Target Population		ELS-II Target Population		Lakes Sampled for Fish in ELS-II	
	Median	Range	Median	Range	Median	Range
ANC (ueq/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 (ueq/L)	246	13-1826	179	22-1826	51	22-1826
Mg (ueq/L)	148	11-984	95	13-984	32	13-984
Na (ueq/L)	29	3-245	25	3-171	12	3-171
K (ueq/L)	13	3-30	14	5-30	12	5-30
Sum Base Cations (ueq/L)	468	54-2966	282	54-2966	119	54-2966
Ext. Al (ug/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 (ueq/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 (ug/L)	13	0-146	12	0-39	12	0-39

lakes among the 49 ELS-II Fish Survey lakes is distinctly higher than that for either the ELS-I target population or the ELS-II target population. Ca and pH levels in lakes in the subregion were highly correlated. As a result, lakes sampled in the ELS-II Fish Survey lakes also had generally lower Ca levels than either the ELS-I or ELS-II target populations. Calcium concentrations for the 49 ELS-II Fish Survey lakes ranged between 22 and 1,826 ueq/L; 49% of the lakes had Ca levels < 50 ueq/L (1.0 mg/L).

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 3-2 for the 49 ELS-II Fish Survey lakes. Levels of ANC, Ca, Mg, Na, sum of base cations, color, pH, K, DOC, SO_4 and SiO_2 were significantly lower in seepage lakes than in nonseepage lakes. Sixteen of the 20 acidic lakes 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 3-1).

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 ug/L (Eilers et al., 1988). Values for the 49 ELS-II lakes ranged between 0 and 213 ug/L (Table 3-1), although 85.7% of the lakes sampled had extractable Al levels ≤ 50 ug/L.

Sulfate levels in Subregion 2B (median value 78 ueg/L for the ELS-I target population) were slightly higher than the levels for other subregions in the Upper Midwest (regional median 57 ueq/L), although lower than the levels in lakes in the northeastern United States (regional median 115 ueq/L) (Linthurst et al., 1986, Eilers et al., 1988). Concentrations for the 49 ELS-II lakes ranged between 17 and 161 ueq/L, with a median value of 67 ueq/L. 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 3-1).

Correlations among selected water quality variables in 27 lakes where age 2-4 yellow perch were collected, as well as separate analyses for drainage lakes and seepage lakes in this group, are presented in Tables 3-3, 3-4 and 3-5, respectively. These results were generally

Table 3-2. Comparison of Lake Chemistry by Lake Type: Seepage Lakes Versus Other Lake Types (Drainage, Reservoir, Closed) for the 49 Lakes Sampled During ELS-II

	Seepage Lakes		Other Lakes		Test Statistics[a]	
Variable	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 (ueq/L)	-1	-46-1665	134	-20-2699	0.0014*	0.0227*
Inorg. Al (ug/L)	9	0-192	12	0-39	>0.05	>0.05
Ext. Al (ug/L)	11	0-213	10	0-120	>0.05	>0.05
Ca (ueq/L)	38	22-860	131	35-1826	0.0004*	0.0007*
Mg (ueq/L)	26	13-766	83	16-984	0.0005*	0.0004*
Na (ueq/L)	10	3-34	25	6-171	0.0002*	0.0004*
K (ueq/L)	10	5-21	14	5-30	0.0050	0.0074
Sum Base Cations (ueq/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 (ueq/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 (ug/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 $\alpha = 0.05$ adjusted for 14 tests, i.e., $p \leq 0.0036$.

Table 3-3. Correlation Matrix for Water Quality Variables Measured in All Seepage and Drainage Lakes (n=27)

	ANC (ueq/L)	Calcium (ueq/L)	Conductivity (u MHOS/cm)	Aluminum (ueq/L)	Total phosphorus (ug/L)	DOC (mg/L)	Color (pcu)	Sulfate (ueq/L)
pH	0.77●● (<0.01)**	0.77●● (<0.01)	0.73●● (<0.01)	-0.40●● (0.02)	-0.01 (0.48)	0.44●● (0.01)	0.05 (0.41)	0.45●● (0.01)
Alkalinity		0.99●● (<0.01)	0.99●● (<0.01)	-0.31● (0.06)	-0.03 (0.43)	0.18 (0.19)	-0.04 (0.42)	0.70●● (<0.01)
Calcium			0.99●● (<0.01)	-0.30● (0.06)	-0.06 (0.39)	0.15 (0.22)	-0.05 (0.41)	0.71●● (<0.01)
Conductivity				-0.25 (0.10)	-0.06 (0.39)	0.17 (0.20)	-0.03 (0.44)	0.74●● (<0.01)
Aluminum					0.09 (0.32)	0.25● (0.10)	0.52●● (<0.01)	0.16 (0.21)
Total phosphorus						0.36●● (0.03)	0.26● (0.10)	-0.27● (0.09)
DOC							0.68●● (<0.01)	0.06 (0.39)
Color								-0.04 (0.42)

** p value associated with correlation coefficient

● denotes statistically significant correlation coefficient ($p \leq 0.10$)

●● denotes statistically significant correlation coefficient ($p \leq 0.05$)

Table 3-4. Correlation Matrix for Water Quality Variables Measured in Drainage Lakes (n=12)

	ANC (ueq/L)	Calcium (ueq/L)	Conductivity (u MHOS/cm)	Aluminum (ueq/L)	Total phosphorus (ug/L)	DOC (mg/L)	Color (pcu)	Sulfate (ueq/L)
pH	0.79●● (<0.01)**	0.80●● (<0.01)	0.77●● (<0.01)	-0.79●● (<0.01)	-0.35● (0.10)	-0.09 (0.39)	-0.29● (0.18)	0.72●● (<0.01)
Alkalinity		0.99●● (<0.01)	0.99●● (<0.01)	-0.63● (0.02)	-0.28 (0.19)	-0.10 (0.37)	-0.33 (0.14)	0.93●● (<0.01)
Calcium			0.99●● (<0.01)	-0.63●● (0.02)	-0.31 (0.16)	-0.11 (0.36)	-0.34 (0.14)	0.93●● (<0.01)
Conductivity				-0.59●● (0.02)	-0.26 (0.20)	-0.09 (0.38)	-0.31 (0.17)	0.93●● (<0.01)
Aluminum					0.54●● (0.04)	0.32 (0.15)	0.64●● (0.01)	-0.41 (0.09)
Total phosphorus						0.67●● (0.01)	0.59●● (0.02)	-0.23● (0.49)
DOC							0.70●● (0.01)	-0.01 (0.49)
Color								-0.13 (0.35)

** p value associated with correlation coefficient

● denotes statistically significant correlation coefficient ($p \leq 0.10$)

●● denotes statistically significant correlation coefficient ($p \leq 0.05$)

Table 3-5. Correlation Matrix for Water Quality Variables Measured in Seepage Lakes (n=15)

	ANC (ueq/L)	Calcium (ueq/L)	Conductivity (u MHOS/cm)	Aluminum (ueq/L)	Total phosphorus (ug/L)	DOC (mg/L)	Color (pcu)	Sulfate (ueq/L)
pH	0.93●● (≪ 0.01)**	0.49●● (0.03)	0.12 (0.34)	-0.40● (0.07)	0.07 (0.41)	0.64●● (≪ 0.01)	0.01 (0.49)	-0.33 (0.12)
Alkalinity		0.58●● (0.01)	0.31 (0.13)	-0.20 (0.24)	0.03 (0.45)	-0.65●● (<0.01)	0.09 (0.37)	-0.19 (0.25)
Calcium			0.38● (0.08)	-0.08 (0.39)	-0.12 (0.33)	0.05 (0.43)	0.02 (0.47)	0.04 (0.44)
Conductivity				0.43●● (0.05)	-0.39● (0.07)	-0.06 (0.42)	0.26 (0.18)	0.76●● (<0.01)
Aluminum					0.44●● (0.05)	-0.15 (0.30)	0.10 (0.36)	0.60●● (0.01)
Total phosphorus						0.36● (0.10)	0.20 (0.24)	-0.43●● (0.05)
DOC							0.39● (0.07)	-0.49●● (0.03)
Color								-0.57●● (0.01)

** p value associated with correlation coefficient

● denotes statistically significant correlation coefficient ($p \leq 0.10$)

●● denotes statistically significant correlation coefficient ($p \leq 0.05$)

consistent with the relationships expected between pH, ANC, calcium, and DOC in drainage and seepage systems. In the drainage systems, pH and calcium concentrations were highly correlated. Alkalinity and pH were highly correlated in both lake types.

The relationships between other water quality variables provide additional evidence of differences in the water chemistry between drainage and seepage lakes. Sulfate showed a statistically significant positive correlation with the indicators of lake acidification in the complete set of lakes, as well as in drainage lakes. However, in seepage lakes, a negative relationship was found between sulfate and pH. In drainage lakes, a strong negative relationship was observed between aluminum and pH, ANC, calcium, and conductivity. In seepage lakes, these relationships were different. For example, the correlation coefficient between conductivity and aluminum was of approximately equal magnitude in seepage and drainage lakes, but the signs were opposite. Additional evidence of differences between the two types of lakes was the observed relationships between total phosphorus and aluminum concentrations.

3.1.2 Fish Species Distribution

Thirty-one fish species were caught in the surveys of 49 lakes in Subregion 2B (Table 3-6). 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 (L. gibbosus), white sucker, brown bullhead (Ictalurus nebulosus), golden shiner (Notemigonus crysoleucas), and northern pike. The remaining 23 species were caught in fewer than 10 lakes, although some of these species were collected in large numbers in individual lakes. 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. In two lakes, no fish were caught, and in several lakes only one species was caught. In one lake only brook stickleback

Table 3-6. Fish Species Caught and Frequency of Occurrence (*denotes game fish)

Family and Species	Common name	Number 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

Table 3-6. Fish Species Caught and Frequency of Occurrence (*denotes game fish) (cont.)

Family and Species	Common name	Number of Lakes in Which Species Caught: All Gear Types	Gill Net, Trap Net & Angling	Gill Net & Trap Net
Ictaluridae				
Ictalurus nebulosus	brown bullhead	13	13	13
Cyprinodontidae				
Fundulus diaphanus	banded killfish	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 hybrid	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

(*Culaea inconstans*) were caught. In six lakes (12.2%) only yellow perch were caught. Game fish were collected in 36 of the 49 lakes (73.5%).

The distribution of fish collected for mercury analysis presented in Table 3-7 shows clearly that only yellow perch had a very representative distribution among lakes and age classes. The number of lakes for which mercury analyses were conducted does not necessarily equal the number of lakes in which a species was caught. Samples excluded included young-of-the-year fish and fish too decomposed for use.

3.2 MERCURY CONCENTRATIONS IN FISH MUSCLE TISSUE

The results of the mercury analyses for each species and age class are summarized in Table 3-8. The number and percentage of fish exceeding the state and WHO health advisory criterion (0.5 ppm) and the U.S. Food and Drug Administration (FDA) action level (1.0 ppm) are shown by age class. The number of mercury measurements on yellow perch exceeded the measurements for all other species combined. Yellow perch were abundant in a wide range of age classes at most of the lakes, whereas the other species were less abundant, particularly in seepage lakes. The number of lakes in which fish were analyzed for mercury is less than the total number in which fish were caught, because no game or index species were captured in some lakes.

Although the numbers of fish analyzed in each age class were dissimilar, a general trend of increasing mean mercury concentration as a function of age was evident for all species. For example, although the average mercury concentration in yellow perch was relatively constant over age classes 1 through 6, increased concentrations were observed in age classes 7 through 10+. This trend was also evident in the proportion of samples that exceeded the health criterion. For example, 7.5% of the age-4 yellow perch had mercury concentrations greater than 0.5 ppm, whereas 26.2% of the age-7 yellow perch had concentrations greater than this value. Overall, a large proportion of the yellow perch, northern pike, and largemouth bass exceeded the Michigan state health advisory criterion. Thirty-three percent of the northern pike and 26% of the largemouth bass exceeded 0.5 ppm. Fewer fish of all species exceeded the FDA action level of 1 ppm, but fish with the highest

Table 3-7. Number of Lakes with Fish Available for Mercury Analysis by Species and Age

Age/ Species	Yellow Perch	White Sucker	Northern Pike	Smallmouth Bass	Largemouth Bass	Walleye	Brook Trout
0	1	-	-	-	2	-	-
1	14	3	1	-	2	1	2
2	24	3	5	-	1	1	3
3	24	8	7	-	4	1	1
4	25	4	6	2	6	1	1
5	22	4	8	-	5	-	-
6	18	7	3	-	3	-	1
7	17	7	3	-	2	-	1
8	17	3	3	-	2	1	-
9	14	1	-	-	1	-	-
10	3	-	1	-	1	-	-
11	8	-	-	-	-	-	-
12	1	-	-	-	-	-	-
Total	31	13	8	2	10	1	4

Table 3-8. Summary of Fish Mercury Analysis Results by Species and Age Class.

			Mercury concentration						
				Range					
Species	Age class	Number of fish	Average (ppm)	Min. (ppm)	Max. (ppm)	Number ≥0.5 ppm	Percent	Number ≥1.0 ppm	Percent
Yellow perch	0	1	0.25	0.25	0.25	0	0.0	0	0.0
	1	76	0.19	0.01	0.42	0	0.0	0	0.0
	2	87	0.22	0.01	0.72	7	8.0	0	0.0
	3	107	0.20	0.01	0.67	5	4.7	0	0.0
	4	67	0.25	0.02	0.76	5	7.5	0	0.0
	5	56	0.27	0.03	0.84	9	16.1	0	0.0
	6	43	0.28	0.01	0.97	9	20.9	0	0.0
	7	42	0.38	0.01	2.36	11	26.2	3	7.1
	8	27	0.49	0.01	1.19	12	44.4	4	14.8
	9	22	0.56	0.05	2.25	7	31.8	4	18.2
	10+	19	0.94	0.04	1.94	13	68.4	9	47.4
		547				78	14.3	20	3.7
Northern pike	1	1	0.08	0.08	0.08	0	0.0	0	0.0
	2	16	0.23	0.07	0.41	0	0.0	0	0.0
	3	22	0.43	0.10	1.07	8	36.4	2	9.1
	4	12	0.43	0.11	0.88	4	33.3	0	0.0
	5	18	0.47	0.24	1.64	5	27.8	1	5.6
	6	4	0.50	0.15	0.78	2	50.0	0	0.0
	7	7	0.69	0.29	0.99	5	71.4	0	0.0
	8+	6	0.75	0.35	1.12	4	66.7	2	33.3
		86				28	32.6	5	5.8

Table 3-8. Summary of Fish Mercury Analysis Results by Species and Age Class (cont.)

			Mercury concentration						
				Range					
Species	Age class	Number of fish	Average (ppm)	Min. (ppm)	Max. (ppm)	Number ≥0.5 ppm	Percent	Number ≥1.0 ppm	Percent
White sucker	1	4	0.07	0.03	0.09	0	0.0	0	0.0
	2	6	0.13	0.03	0.24	0	0.0	0	0.0
	3	36	0.07	0.01	0.39	0	0.0	0	0.0
	4	7	0.16	0.02	0.49	0	0.0	0	0.0
	5	9	0.05	0.01	0.10	0	0.0	0	0.0
	6	26	0.16	0.01	0.45	0	0.0	0	0.0
	7	14	0.16	0.01	0.56	1	7.1	0	0.0
	8	6	0.13	0.03	0.27	0	0.0	0	0.0
	9	2	0.54	0.49	0.59	1	50.0	0	0.0
		110				2	1.8	0	0.0
Largemouth bass	0	14	0.17	0.06	0.32	0	0.0	0	0.0
	1	7	0.18	0.08	0.35	0	0.0	0	0.0
	2	1	0.16	0.16	0.16	0	0.0	0	0.0
	3	9	0.27	0.15	0.73	1	11.1	0	0.0
	4	23	0.43	0.11	0.81	9	39.1	0	0.0
	5	9	0.33	0.13	0.60	2	22.2	0	0.0
	6	4	0.66	0.29	0.88	3	75.0	0	0.0
	7	2	0.68	0.36	1.00	1	50.0	1	50.0
	8	2	0.63	0.42	0.83	1	50.0	0	0.0
	9	1	0.64	0.64	0.64	1	100.0	0	0.0
	10	1	0.55	0.55	0.55	1	100.0	0	0.0
		73				19	26.0	1	1.4

Table 3-8. Summary of Fish Mercury Analysis Results by Species and Age Class (cont.)

			Mercury concentration						
				Range					
Species	Age class	Number of fish	Average (ppm)	Min. (ppm)	Max. (ppm)	Number ≥0.5 ppm	Percent	Number ≥1.0 ppm	Percent
Walleye	1	1	0.11	-	-	0	0	0	0
	2	1	0.20	-	-	0	0	0	0
	3	1	0.19	-	-	0	0	0	0
	4	3	0.30	0.26	0.36	0	0	0	0
	8	2	0.42	-	-	0	0	0	0
		8				0	0	0	0
Smallmouth bass	4	4	0.30	0.19	0.39	0	0	0	0
	1	13	0.09	0.02	0.37	0	0	0	0
	2	6	0.16	0.02	0.15	0	0	0	0
	3	2	0.13	0.04	0.29	0	0	0	0
	4	2	0.20	0.02	0.23	0	0	0	0
	6	2	0.32	0.06	0.34	0	0	0	0
	7	1	0.36	-	-	0	0	0	0
						0	0	0	0

mercury concentrations were well distributed among all lakes. Although not shown in Table 3-8, the concentration of mercury in muscle tissue for at least one fish of one of these species exceeded the state public health advisory criterion in 24 of the 38 lakes. Eleven lakes contained fish with concentrations greater than the FDA action level.

Differences in mercury concentrations among species were also observed. For example, the mean mercury concentration in age-3 yellow perch was 0.20 ppm, in comparison to 0.43 ppm for age-3 northern pike. Likewise, the mercury concentrations in age-5 yellow perch and northern pike were 0.27 ppm and 0.47 ppm, respectively. The mercury concentrations in northern pike exceeded the concentrations in the other species in all age classes that had a sample size greater than four fish. On the other hand, the mercury in white sucker tissue samples was relatively low in all age classes. The average concentration was 0.16 ppm or lower in all but age-9 fish, and the maximum concentration was 0.59 ppm in one age-9 fish. In contrast, the maximum concentrations in yellow perch, northern pike, and largemouth bass were 2.36, 1.64, and 1.00 ppm, respectively. Walleye, which was the number one priority game fish in the survey, was collected in only two lakes (one and eight individuals each). The mean mercury concentration in walleye was 0.280; no walleye exceeded health guidelines and the maximum concentration observed was 0.42 ppm.

3.2.1 Relationships Between Mercury Concentrations and Fish Age, Weight, and Length

All game fish species for which sufficient samples were obtained showed increased mercury concentrations with increased age, length, and weight. Among these variables, there were species differences as to which showed the strongest correlation with mercury concentrations. In addition, the strength of these correlations varied among seepage and drainage systems and among all lakes considered together.

The abundance and wide distribution of yellow perch provided an excellent opportunity to evaluate the relationships between mercury concentration and age, weight, and length of fish. The results indicated differences in mercury accumulation between drainage and seepage lakes (Table 3-9). Although the mercury concentrations were very similar in both types of lakes for yellow perch ages 2 through 5, higher concentrations were found in older fish from drainage lakes. However, statistically significant differences in total mercury concentrations in fish from seepage and from drainage lakes were found only in age-1 and age-7 yellow perch (Table 3-10). Generally, there were more large yellow perch with higher mercury concentrations in drainage lakes, and in seepage lakes there was greater variability in mercury concentrations in all sizes of yellow perch (Figure 3-1). The slopes of the regression lines in Figure 3-1 are significantly different ($p < .05$), with drainage lakes showing a much greater effect of length on mercury concentration than seepage lakes. Similar differences existed between seepage and drainage lakes for age and weight of yellow perch, indicating the importance of age and size on increasing mercury levels in fish from drainage lakes. Other game fish showed similar results, with total length usually providing a stronger relationship to mercury level than weight (Table 3-11). Age, although often highly correlated with mercury, is an impractical parameter from a health advisory standpoint.

An examination of mercury levels by fish size for major game fish species indicates that a high proportion of fish of legal size exceeded state health guidelines (Table 3-12). For example, from 35% to 100% of legal size northern pike exceeded 0.5 ppm, and 12% to 85% of yellow perch over 150 mm exceeded the guideline. These results, if the assumption of representative sampling is accepted, mean that at least from one in eight to one in three game fish exceed standards.

3.2.2 Relationships Between Lake Characteristics and Fish Mercury Concentrations

Among game fish species collected for mercury analysis, yellow perch provided the largest numbers overall and were the most widely distributed among lakes. Therefore, in terms of relating mercury concentrations to lake characteristics, perch allow the most comprehensive comparisons. Only yellow perch in age classes 1 and 7 had statistically different mercury levels between seepage and drainage lakes. Mercury levels in young perch, ages 2 through 4, showed little effect of age. This group was represented in 27 lakes and was used for initial comparisons to lake characteristics.

Table 3-9. Regression Equations and Correlation Coefficients (R) for Age, Total Length, and Weight in Yellow Perch (All Ages Separated by Lake Type)

Lake Type	Equation	R	# of Fish	
Seepage	.021 Age + .177	.24	312	*
Drainage	.089 Age - .061	.60	203	*
All Lakes	.052 Age + .073	.45	547	*
Seepage	.0015 TL + .023	.32	312	*
Drainage	.0049 TL - .454	.69	203	*
All Lakes	.0032 TL - .215	.54	547	*
Seepage	.0009 WT + .212	.29	312	*
Drainage	.0037 WT + .105	.77	203	*
All Lakes	.0021 WT + .167	.54	547	*

* = significant correlation, $p \leq .05$.

Table 3-10. Average Total Mercury Concentration (ppm) in Yellow Perch by Lake Type and Age Class (Number of Fish)

Lake Type	Age Class									
	1*	2	3	4	5	7*	8	9	10	11
All lakes	.19 (76)	0.22 (87)	0.20 (107)	0.25 (67)	0.27 (56)	0.38 (42)	0.49 (27)	0.56 (22)	.90 (9)	.94 (9)
Seepage	.20 (63)	0.23 (47)	0.22 (59)	0.27 (39)	0.30 (32)	0.26 (23)	0.45 (11)	0.44 (8)	.190 (1)	.36 (2)
Drainage	.13 (13)	0.22 (39)	0.20 (36)	0.23 (23)	0.25 (20)	0.54 (17)	0.59 (13)	0.70 (12)	.989 (8)	1.51 (4)

*Statistically significant difference in total mercury concentrations between seepage and drainage lakes; Mann-Whitney U Test: age class 1, $p = 0.02$; age class 7, $p = 0.03$.

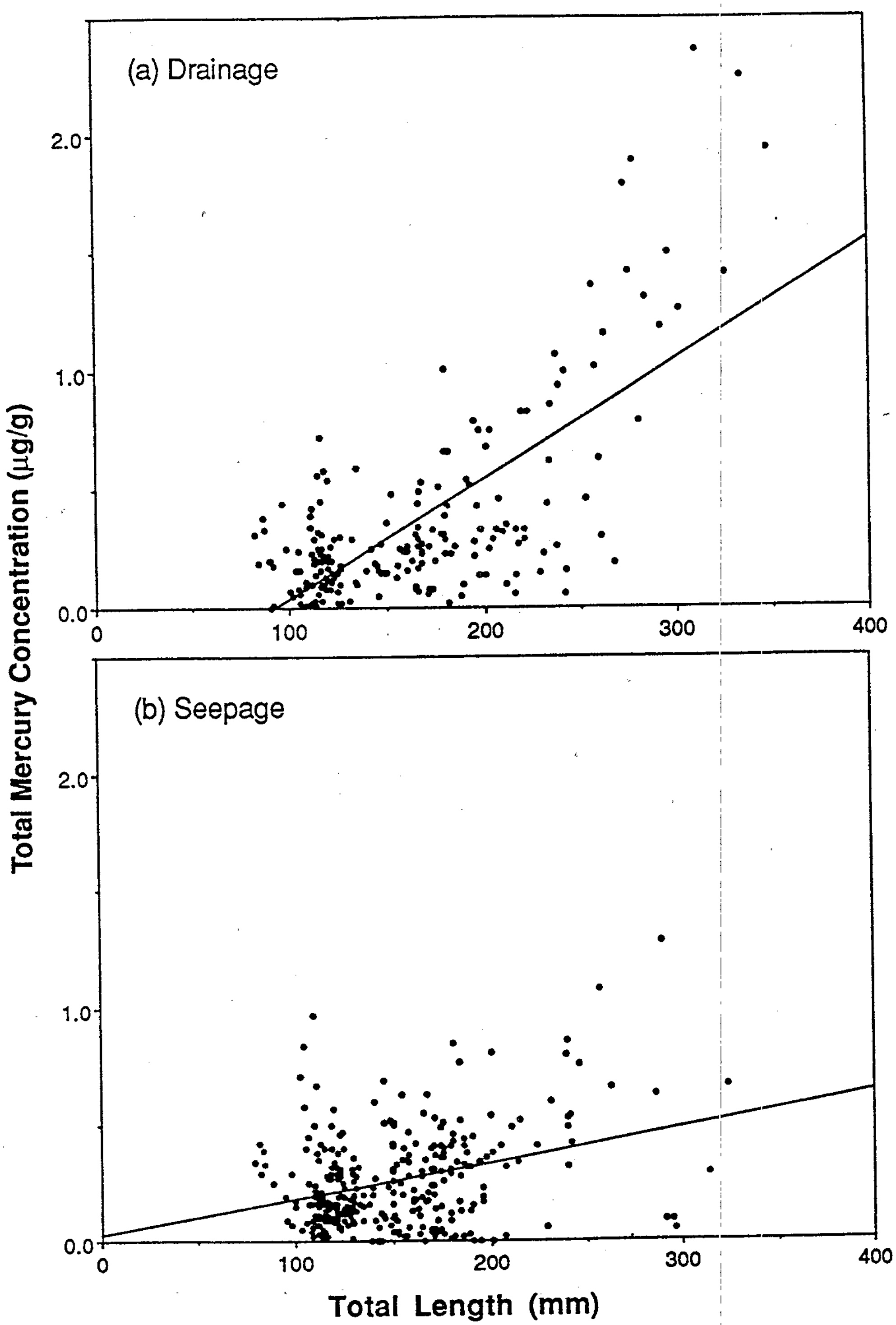


Figure 3-1. Comparison of mercury levels in yellow perch from (A) drainage lakes and (B) seepage lakes in ELS-II lakes.

Table 3-11. Correlation Coefficients (r) Between Total Mercury and Age, Weight, or Total Length for Game Fish Species by Lake Type. (N = Number of Fish in Parentheses)

Species	Drainage	Seepage	All Lakes
Yellow Perch			
Age	.60 (202)	.24 (310)	.45 (545)
Weight	.77 (202)	.29 (310)	.54 (545)
Length	.69 (202)	.32 (310)	.54 (545)
Largemouth Bass			
Age	.72 (26)	.52 (44)	.58 (72)
Weight	.66 (26)	.49 (45)	.55 (72)
Length	.82 (26)	.52 (45)	.63 (72)
Northern Pike			
Age	.44 (66)	.94 (8)	.48 (85)
Weight	.51 (66)	.94 (8)	.55 (85)
Length	.61 (66)	.90 (8)	.62 (85)
Walleye			
Age	.93 (8)	---	.93 (8)
Weight	.85 (8)	---	.85 (8)
Length	.87 (8)	---	.87 (8)
Brook Trout			
Age	.42 (18)	.67 (7)	.67 (25)
Weight	.65 (18)	.78 (7)	.77 (25)
Length	.71 (18)	.85 (7)	.82 (25)

Table 3-12. Mercury Levels and Percent Exceeding Health Guidelines for Three Game Fish Species in Samples From Subregion 2B

Size Class (mm)	X Hg	Total # Fish	Hg Min	Hg Max	#≥.05	%≥.05	#≥.1	%≥.1
			Northern Pike					
200-300	.210	2	.13	.29	0	0.0	0	0.0
301-400	.193	8	.10	.33	0	0.0	0	0.0
401-500	.390	22	.20	1.07	3	13.6	2	9.1
501-600	.470	23	.17	1.64	8	34.8	1	4 [illegible]
601-700	.628	16	.30	.99	11	68.8	0	0 [illegible]
701-800	.548	4	.40	.68	3	75.0	0	0 [illegible]
801-900	1.12	1	1.12	1.12	1	100.0	1	100.0
901-1000	1.00	2	.93	1.07	2	100.0	1	50.0
All	.471	78	.10	1.64	28	35.9	5	6.4
			Yellow Perch					
50-100	.237	23	.00	.44	0	0.0	0	0.0
101-150	.205	250	.00	.97	18	7.2	0	0.0
151-200	.269	165	.00	1.01	20	12.1	1	0.4
201-250	.446	49	.00	1.07	17	34.7	2	4.1
251-300	.890	25	.05	1.89	17	68.0	13	52.0
301-350	1.45	7	.29	2.36	6	85.7	5	71.4
All	.300	519	.00	2.36	78	15.0	21	4.1
			Largemouth Bass					
50-100	.132	11	.06	.20	0	0.0	0	0.0
101-150	.201	9	.12	.35	0	0.0	0	0.0
151-200	.170	2	.16	.18	0	0.0	0	0.0
201-250	.261	12	.15	.44	0	0.0	0	0.0
251-300	.576	11	.20	.81	8	72.7	0	0.0
301-350	.553	13	.21	.88	7	53.8	0	0.0
351-400	.628	4	.36	1.00	2	50.0	1	50.0
401-450	.595	2	.55	.64	2	100.0	0	0.0
All	.375	64	.06	1.00	19	29.7	1	1.6

Pearson product-moment correlation coefficients were calculated between the average mercury concentrations in yellow perch ages 2-4 and water quality variables obtained from the ELS-I (Linthurst et al., 1986). The variables presented (Table 3-13) are those that have shown significant relationships with fish mercury in this or other published studies. Each element of the correlation matrix gives the correlation coefficient (r), the number of observations (lakes), and the statistical significance of the coefficient. Correlation coefficients were derived using regression weighted by the inverse of the variance about the mean for mercury levels in each lake. All statistically significant ($p \leq 0.05$) r values are denoted.

The results for the complete set of 27 lakes indicate consistent, negative relationships between pH and mercury in muscle tissue. The strongest relationship was that observed between pH and mercury ($r^2 = 0.48$) in drainage lakes (Figure 3-2). Statistically significant correlations were also observed between fish mercury and total aluminum. There was no relationship apparent, however, between fish mercury and DOC, total phosphorus, color, or sulfate.

The results of the correlation analyses between fish mercury and water quality variables in seepage lakes are different from those obtained for the drainage lakes, and the influence of the seepage lakes on the relationships observed in the complete set of 27 lakes is easily seen. The relationships between fish mercury and pH were similar in all three sets of lakes, but a negative correlation was also observed between mercury and ANC in the seepage lakes. Seepage lakes showed no correlation between aluminum and mercury values.

Seepage lakes also exhibited a negative correlation between fish mercury and DOC, whereas drainage lakes exhibited no relationships with DOC. This strong negative correlation between DOC and fish mercury in seepage lakes was not anticipated based on results of previous studies, which showed either no relationship (Helwig and Heiskary, 1985; Lathrop et al., 1987) or a positive relationship between mercury and DOC (McMurtry et al. 1989). Another distinct difference among these three sets of lakes was the statistically significant positive correlation that was observed between fish mercury and sulfate in seepage lakes.

Table 3-13. Correlation Matrix for Average Values of Mercury in Yellow Perch Ages 2-4 and ELS-I Water Quality Variables Measured in Seepage Lakes, Drainage Lakes, and Seepage and Drainage Lakes Combined

Variable	All Lakes (n = 27)[1]	Seepage Lakes (n = 15)	Drainage Lakes (n = 12)
pH	-0.41*	-0.56*	-0.69*
ANC (ueq/L)	-0.15	-0.55*	-0.49
Calcium (ueq/L)	-0.12	-0.42	-0.46
Conductivity (u MHOS/cm)	-0.09	0.18	-0.47
Aluminum (ueq/L)	0.38*	0.32	0.41
Total phosphorus (ug/L)	-0.27	-0.29	-0.11
DOC (mg/L)	-0.37	-0.69*	-0.04
Color (pcu)	-0.05	-0.52*	-0.24
Sulfate (ueq/L)	0.36	0.74*	-0.44
Silica (mg/L SiO_2)	-0.01	-0.56*	-0.28
Watershed Area/ Lake Area	-0.13	-0.10	-0.58*
Watershed Area (ha)	-0.19	-0.40	-0.57*
Elevation (m)	-0.21	-0.28	-0.10
Lake Size (ha)	-0.02	-0.32	-0.10

[1] n = number of lakes

*denotes statistically significant correlation coefficient ($p \leq 0.05$)

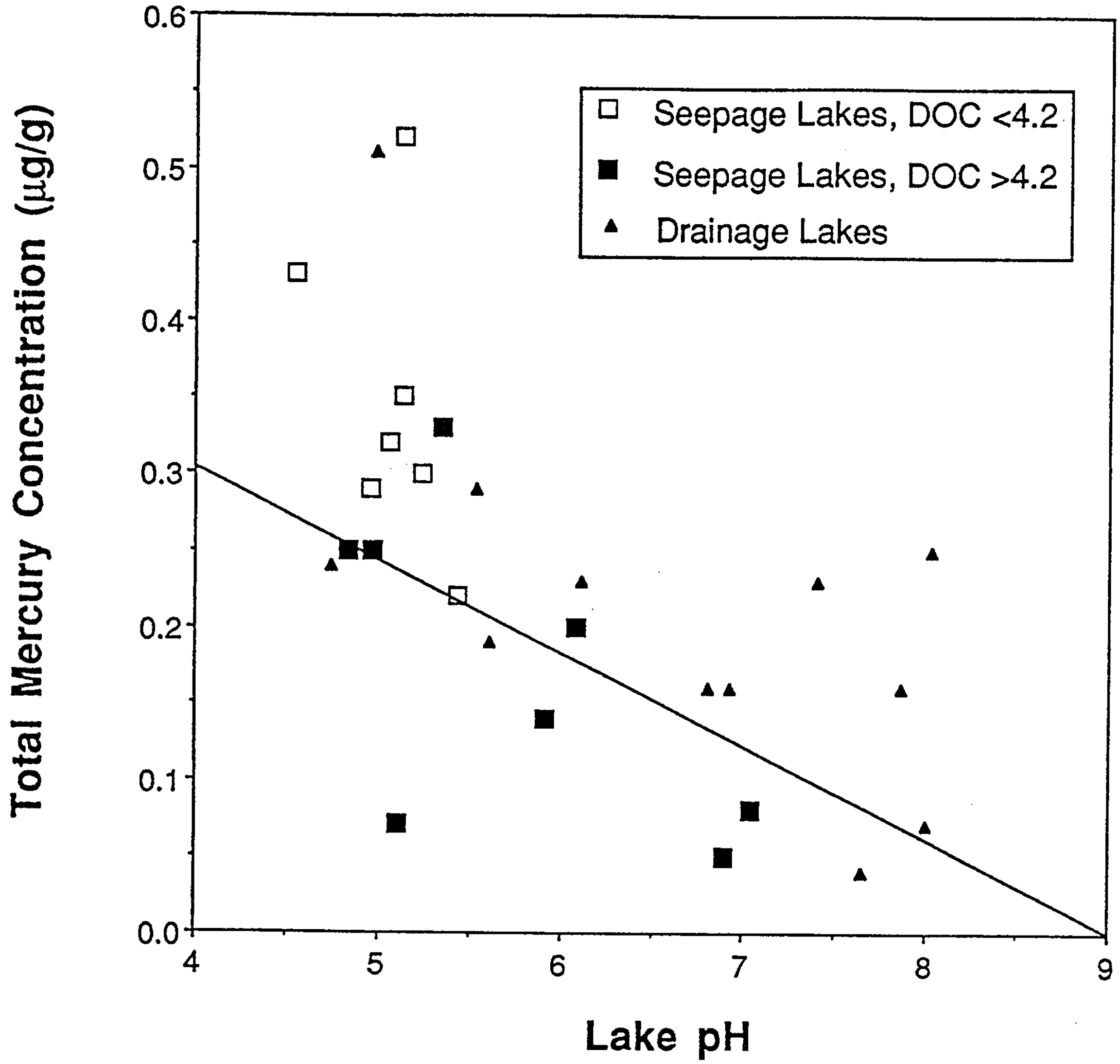


Figure 3-2. Relationship between lake pH and total mercury concentration for yellow perch ages 2-4 in 27 ELS-II lakes. (DOC value of 4.2 mg/L is mean value for all seepage lakes.)

Among the physical characteristics of the lakes examined for correlation with average mercury levels (Table 3-13), only watershed area and the ratio of watershed area to lake area showed significant ($p \leq .05$) correlations. In both cases, these correlations were for drainage lakes and were negative. These results suggest that smaller drainage lakes with lower flushing rates tend to have higher mercury levels in yellow perch ages 2-4.

Older yellow perch, which tended to have higher overall mercury levels, did not show the same correlations with acidity indicator variables as the younger perch in seepage lakes (Table 3-14). Although sample sizes (lakes) varied somewhat and were smaller than sample sizes for the age 2-4 group, none showed significant correlations with pH, Ca, or ANC. However, in drainage lakes the relationship with pH was similar for older (> 7) perch. Mercury levels in older fish from drainage lakes showed a negative (-0.69) correlation for pH ($p < 0.001$) based on average values for mercury.

Both aluminum and total phosphorus were correlated with mercury levels in all lakes and in seepage lakes. The negative correlation for DOC and silica in seepage lakes was stronger for older perch than for the 2-4 age groups, as was the positive relationship with sulfate. In addition, older perch showed positive relationships to watershed area, elevation, and lake size in seepage lakes.

Other game fish species were collected in smaller numbers than yellow perch. Furthermore, when these samples were broken down by lake type, it was unusual to find more than three (maximum of five) different lakes represented for any species/age class combination (Table 3-15). Therefore, meaningful statistical analyses were precluded for lake chemical and physical variables in these groups.

3.2.3 Interactive Effects of Fish Size and Lake Characteristics on Mercury Levels

The previous analyses demonstrate that in many cases both biological (age, length, weight) factors and lake chemical and physical variables may be correlated with fish mercury levels. We conducted a series of stepwise forward multiple regression analyses to ascertain the

Table 3-14. Correlation Matrix for Average Values of Mercury in Age 7 and Older Yellow Perch and ELS-I Water Quality Variables Measured in Seepage Lakes, Drainage Lakes, and Seepage and Drainage Lakes Combined

Variable	All Lakes (n = 27)[1]	Seepage Lakes (n = 15)	Drainage Lakes (n = 12)
N	17	8	9
pH	.40	.58	-.69*
ANC (ueq/L)	.29	.11	-.25
Calcium (ueq/L)	.30	.26	-.19
Conductivity (u MHOS/cm)	.30	.62	-.20
Aluminum (ueq/L)	.58*	.79*	.52
Total phosphorus (ug/L)	-.84*	-.88*	-.15
DOC (mg/L)	-.43	-.84*	-.03
Color (pcu)	.02	-.37	.08
Sulfate (ueq/L)	.53*	.78*	.02
Silica (mg/l SiO_2)	.27	-.85*	-.18
Watershed Area/ Lake Area	.12	.66	-.41
Watershed Area (ha)	.07	.92*	-.44
Elevation (m)	.60*	.84*	-.26
Lake Size (ha)	.17	.77	-.10

[1] n = number of lakes
* denotes statistically significant correlation coefficient ($p \leq 0.05$)

Table 3-15. Numbers of Lake Types Represented in Mercury Analyses for Game Fish Species

Species name	Common name	Age	# Seepage Lakes	# Drainage
Salvelinus fontinalis	brook trout	1	0	1
		2	0	3
		3	1	0
		4	1	0
		6	1	0
		7	1	0
		All	1	3
Esox lucius	northern pike	2	1	4
		3	1	5
		4	1	4
		5	2	5
		6	0	2
		7	0	1
		8	1	2
		10	0	1
Micropterus dolomieui	smallmouth bass	4	0	1
Micropterus salmoides	largemouth bass	0	1	1
		1	1	1
		2	1	0
		3	1	3
		4	3	2
		5	3	1
		6	1	2
		7	2	0
		8	2	0
		9	0	1
		10	0	1

Table 3-15. Numbers of Lake Types Represented in Mercury Analyses for Game Fish Species (cont.)

Species name	Common name	Age	# Seepage Lakes	# Drainage
Perca flavescens	yellow perch	0	1	0
		1	8	5
		2	12	11
		3	11	10
		4	13	10
		5	9	11
		6	10	8
		7	6	9
		8	7	8
		9	6	7
		10	1	2
		11	2	4
		12	0	1
Stizostedion vitreum	walleye	1	0	1
		2	0	1
		3	0	1
		4	0	1
		8	0	1

relative importance of these parameters in determining observed mercury levels. In addition, we included lake type as an indicator variable to see if drainage or seepage lake was a significant factor. Seepage lakes were assigned a value of zero and drainage lakes a value of one. The combination of all variables considered together generally provided the highest r values, although in several instances the variable, lake type, was not selected in the regression equation (Table 3.16). For example, five variables together comprise a multiple r value of 0.71 for all ages of yellow perch. Multiple regression for largemouth bass in all lakes identified nine variables (Table 3-16) with a multiple r = 0.93, with total length alone having an r = 0.74. Northern pike had a multiple r = 0.91 for seven variables.

In all multiple regression equations, the first variable chosen was either related to a biological characteristic or a measure of lake acidity status (e.g., pH, AlT). However, numerous other parameters that were not significantly correlated by themselves with mercury levels were selected as less important variables. Lake type was selected only for yellow perch ages 2-4 and for largemouth bass.

Despite the fairly robust relationships observed in the stepwise multiple regressions, there is considerable variation in the places where individual fish that exceed health guidelines may be found (Table 3.17). Chemical variables associated with lake acidity status appear important in many analyses, but the strong relationships between mercury and biological variables tend to confound the situation. The chemical data suggest that larger numbers of fish with high mercury levels may occur in more acidic lakes. However it is obvious from Table 3-17 that some individual fish with high mercury levels may be found in a variety of lake types. Figures 3-3 to 3-8 depict the mercury levels of individual fish for yellow perch, largemouth bass, and northern pike as a function of lake pH and total length. Again, the occurrence of individual fish with high mercury levels is somewhat sporadic.

The complexity of variables apparently related to mercury levels in fish led us to examine these relationships in additional ways. First, we conducted partial correlation analyses in order to better understand how much interaction or influence existed among various parameters and their correlation with mercury levels. We did these analyses on yellow

Table 3-16. Stepwise Multiple Regressions Combining Biological, Chemical, and Physical Variables for Three Game Fish Species, Along With Lake Type

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<u>Yellow Perch (all ages)</u>

Hg (ppm) = 0.174 + .002 (wt) + .003 (AlT) - .003 (WA/LA) + 0.26 (age)
- .0005 (elevation), r = 0.71

<u>Yellow Perch (age 2-4)</u>

Hg (ppm) = .660 - .103 (pH) + .0001 (Ca) + .001 (TL) + .076 (lake type)
- .002 (WA/LA), r = 0.60

<u>Yellow Perch (age 7)</u>

Hg (ppm) = -0.279 + .005 (TL) + .007 (AlT) - .031 (DOC)
- .001 (elevation), r = .80

<u>Largemouth Bass (all ages)</u>

Hg (ppm) = 2.06 + .002 (TL) - .309 (pH) - .002 (ANC) - .003 (AlT)
+ .965 (lake type) - .0004 (wt) + .066 (age)
- .002 (elevation) + .007 (lake size), r = .93

<u>Northern Pike (all ages)</u>

Hg (ppm) = 1.774 + .016 (AlT) - .008 (Ca) - .022 (WA/LA) + .006 (ANC)
+ .046 (age) + .00009 (wt) - .175 (pH), r = .91

WA/LA = Watershed Area/Lake Area

Table 3-17. Lakes in Which at Least One Fish of a Given Species Exceeded Health Guidelines

SPECIES	LAKE NAME	HYDRO TYPE	PH	HG>0.5	HG>1.0
BROOK TROUT	GOPHER LAKE	S	5.05	-	-
	ISLAND LAKE	D	6.56	-	-
	(NO NAME) 2B3-055	D	7.41	-	-
	TWIN LAKES	D	8.03	-	-
LARGE MOUTH BASS	GOPHER LAKE	S	5.05	-	-
	ISLAND LAKE	S	5.34	X	-
	TWIN LAKES (EASTERN)	S	5.90	X	-
	RICHARDSON LAKE	S	5.91	X	-
	OSTRANDER LAKE	S	7.05	X	-
	CASEY LAKE	S	8.25	-	-
	(NO NAME) 2B2-061	D	5.53	X	-
	DEEP LAKE	D	5.85	-	-
	RUMBLE LAKE	D	8.00	X	-
	TWIN LAKES	D	8.03	X	-
NORTHERN PIKE	TWIN LAKES (EASTERN)	S	5.90	X	X
	OSTRANDER LAKE	S	7.05	-	-
	ROUND LAKE	D	6.93	X	X
	KLONDIKE LAKE	D	7.62	-	-
	BONE LAKE	D	7.65	X	X
	GRAND SABLE LAKE	D	7.86	X	-
	RUMBLE LAKE	D	8.00	X	-
SMALL MOUTH BASS	GRAND SABLE LAKE	D	7.86	-	-
	CATARACT BASIN	R	7.42	-	-
WALLEYE	BONE LAKE	D	7.65	-	-
WHITE SUCKER	(NO NAME) 2B2-024	S	5.75	-	-
	WRIGHT LAKE	S	6.14	-	-
	CATARACT BASIN	R	7.42	X	-
	(NO NAME) 2B2-082	D	5.60	X	-
	BUTO LAKE	D	6.10	-	-
	TWIN LAKE	D	6.83	-	-
	(NO NAME) 2B3-055	D	7.41	-	-
	BONE LAKE	D	7.65	-	-
	GRAND SABLE LAKE	D	7.86	-	-
	RUMBLE LAKE	D	8.00	-	-
	TWIN LAKES	D	8.03	-	-

Table 3-17. Lakes in Which at Least One Fish of a Given Species Exceeded Health Guidelines

SPECIES	LAKE NAME	HYDRO TYPE	PH	HG>0.5	HG>1.0
YELLOW PERCH	JOHNSON LAKE	S	4.55	X	-
	HERBERT LAKE	S	4.83	-	-
	PECK AND RYE LAKE	S	4.95	X	-
	LAKE NITA	S	4.96	X	-
	MALLARD LAKE	S	5.06	X	-
	CRANBERRY LAKE	S	5.10	-	-
	ELEVENMILE LAKE	S	5.13	-	-
	TRIANGLE LAKE	S	5.13	X	X
	QUINLAN LAKE	S	5.24	X	-
	ISLAND LAKE	S	5.34	X	-
	TOIVOLA LAKES (WEST)	S	5.43	X	-
	RICHARDSON LAKE	S	5.91	X	-
	PINE LAKE	S	6.07	X	-
	DELENE LAKE	S	6.90	-	-
	OSTRANDER LAKE	S	7.05	-	-
	CATARACT BASIN	R	7.42	-	-
	WEST BRANCH LAKES (SE)	D	4.74	X	X
	(NO NAME) 2B2-061	D	5.53	X	X
	(NO NAME) 2B2-082	D	5.60	-	-
	BUTO LAKE	D	6.10	X	X
	OTTER LAKE	D	6.81	X	X
	TWIN LAKE	D	6.83	-	-
	ROUND LAKE	D	6.93	-	-
	(NO NAME) 2B3-055	D	7.41	-	-
	KLONDIKE LAKE	D	7.62	-	-
	BONE LAKE	D	7.65	-	-
	GRAND SABLE LAKE	D	7.86	X	-
	RUMBLE LAKE	D	8.00	-	-
	TWIN LAKES	D	8.03	X	-
	FOX LAKE	C	4.94	X	X

YELLOW PERCH – ALL AGES AND ALL LAKES

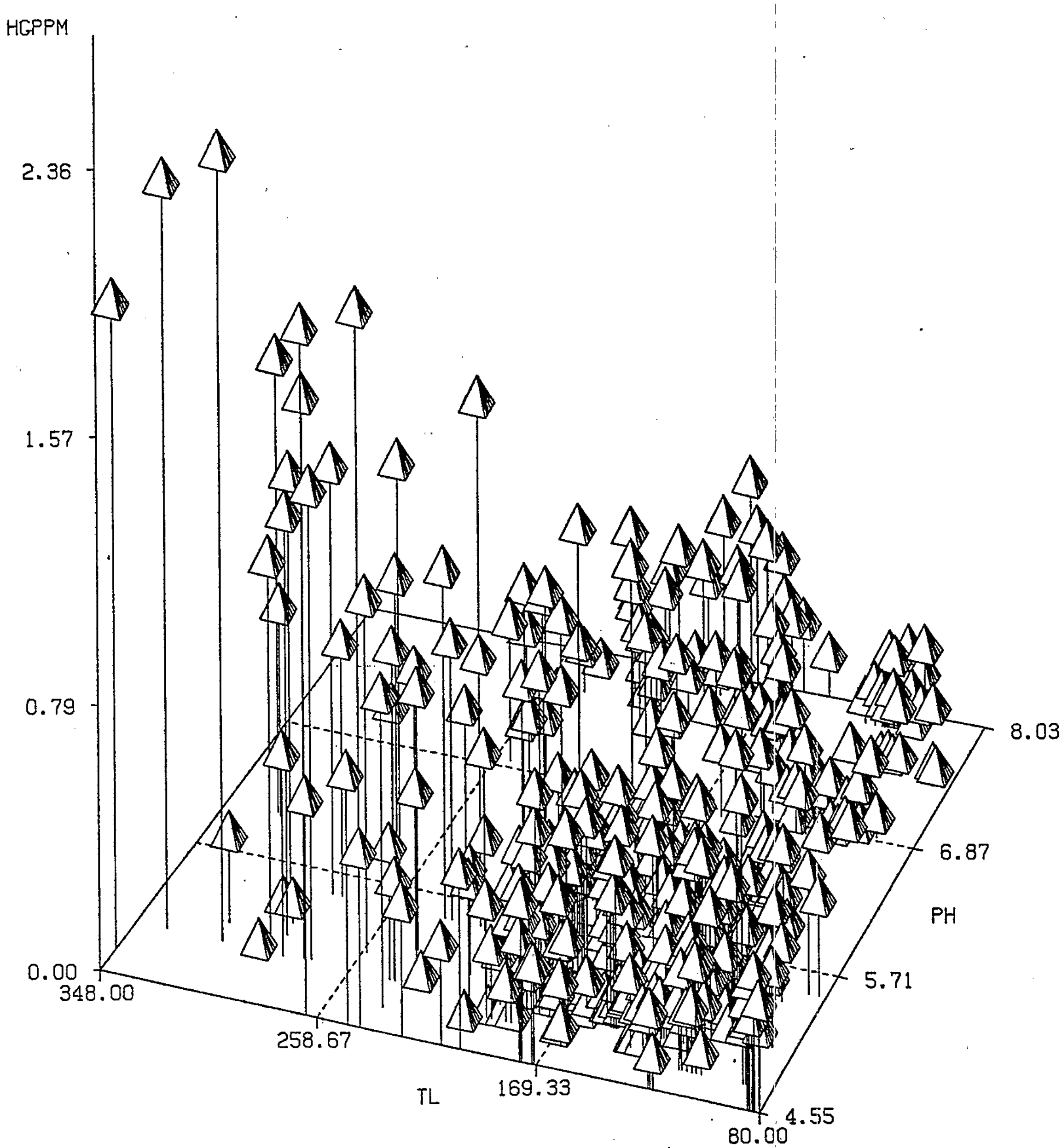

Figure 3-3. Plot of individual yellow perch mercury levels (HG ppm) as a function of lake pH (pH) and total length (TL).

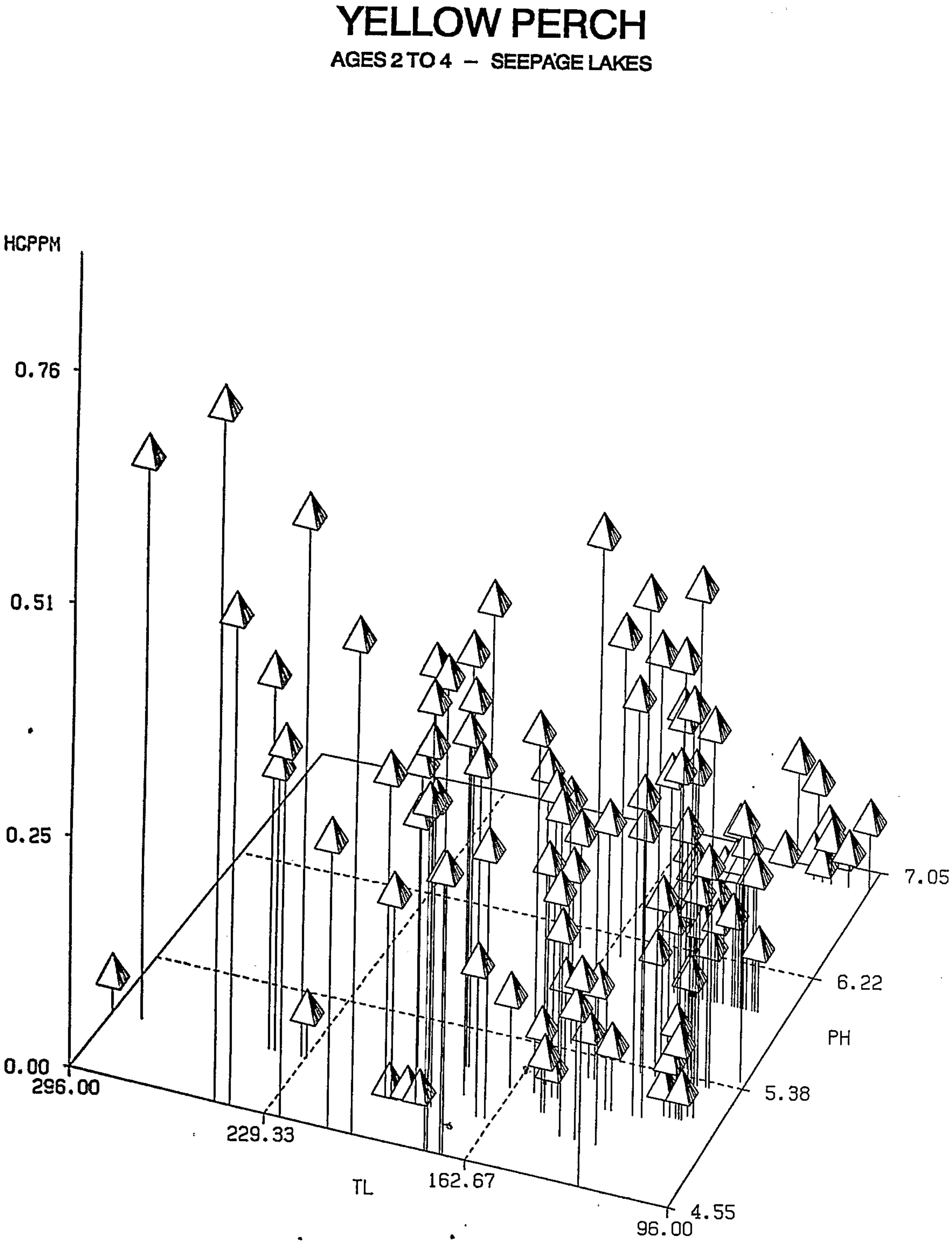

Figure 3-4. Plot of individual mercury levels (HG ppm) for yellow perch ages 2-4 in seepage lakes as a function of lake pH (pH) and total length (TL).

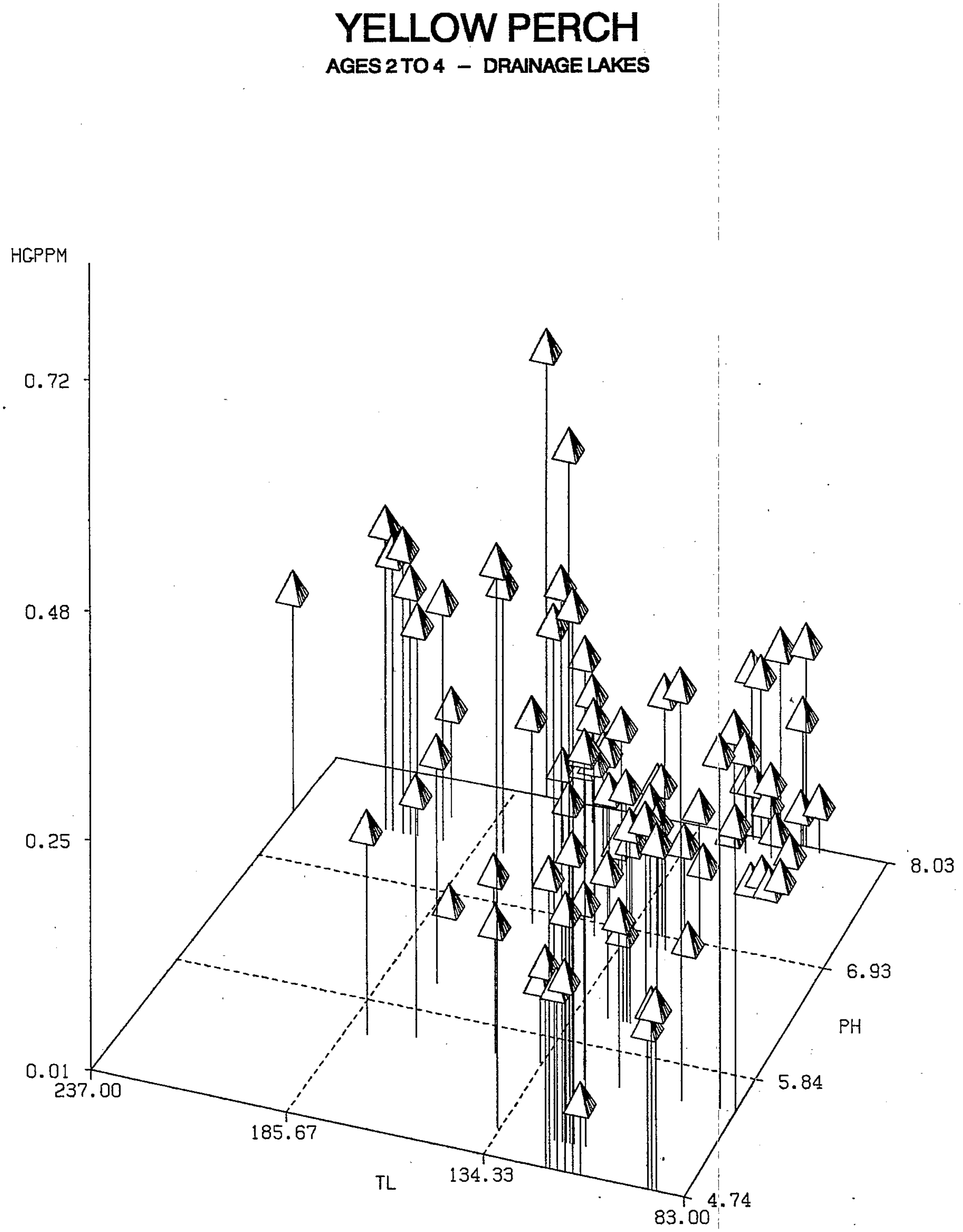

Figure 3-5. Plot of individual mercury levels (HG ppm) for yellow perch ages 2-4 in drainage lakes as a function of lake pH (pH) and total length (TL).

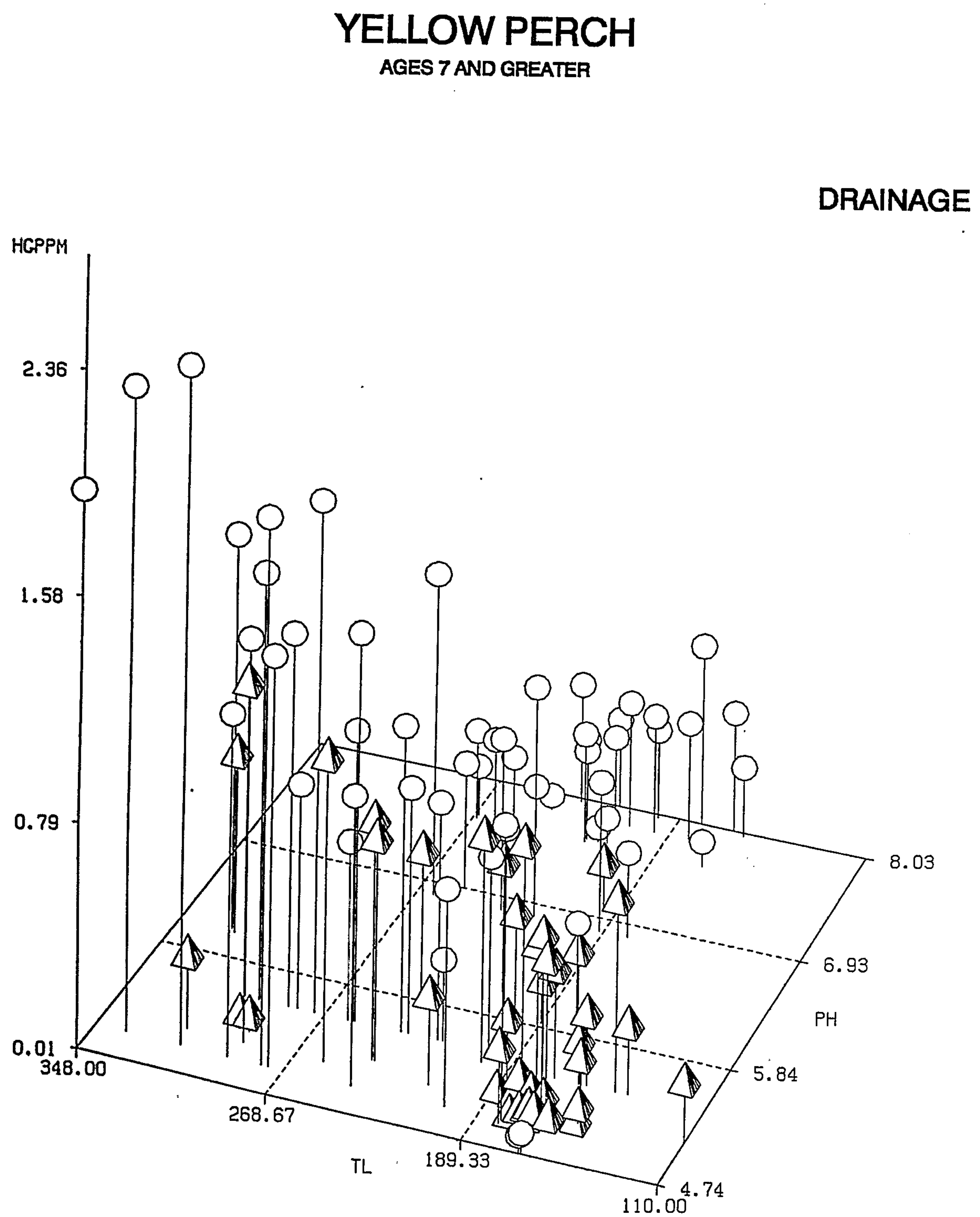

Figure 3-6. Plot of individual mercury levels (HG ppm) for yellow perch age 7 and older in drainage lakes as a function of lake pH (pH) and total length (TL).

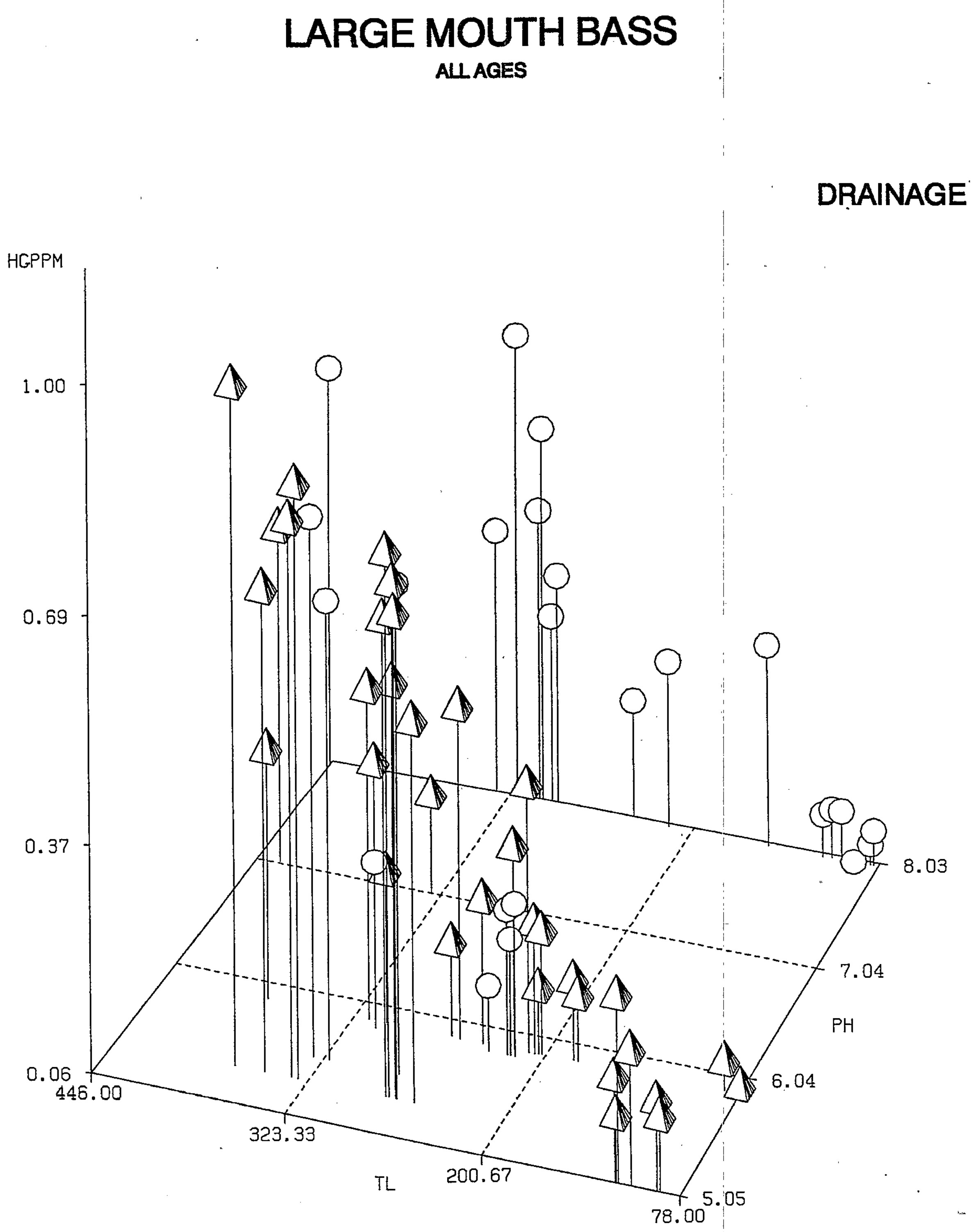

Figure 3-7. Plot of individual mercury levels (HG ppm) for largemouth bass in drainage lakes as a function of lake pH (pH) and total length (TL).

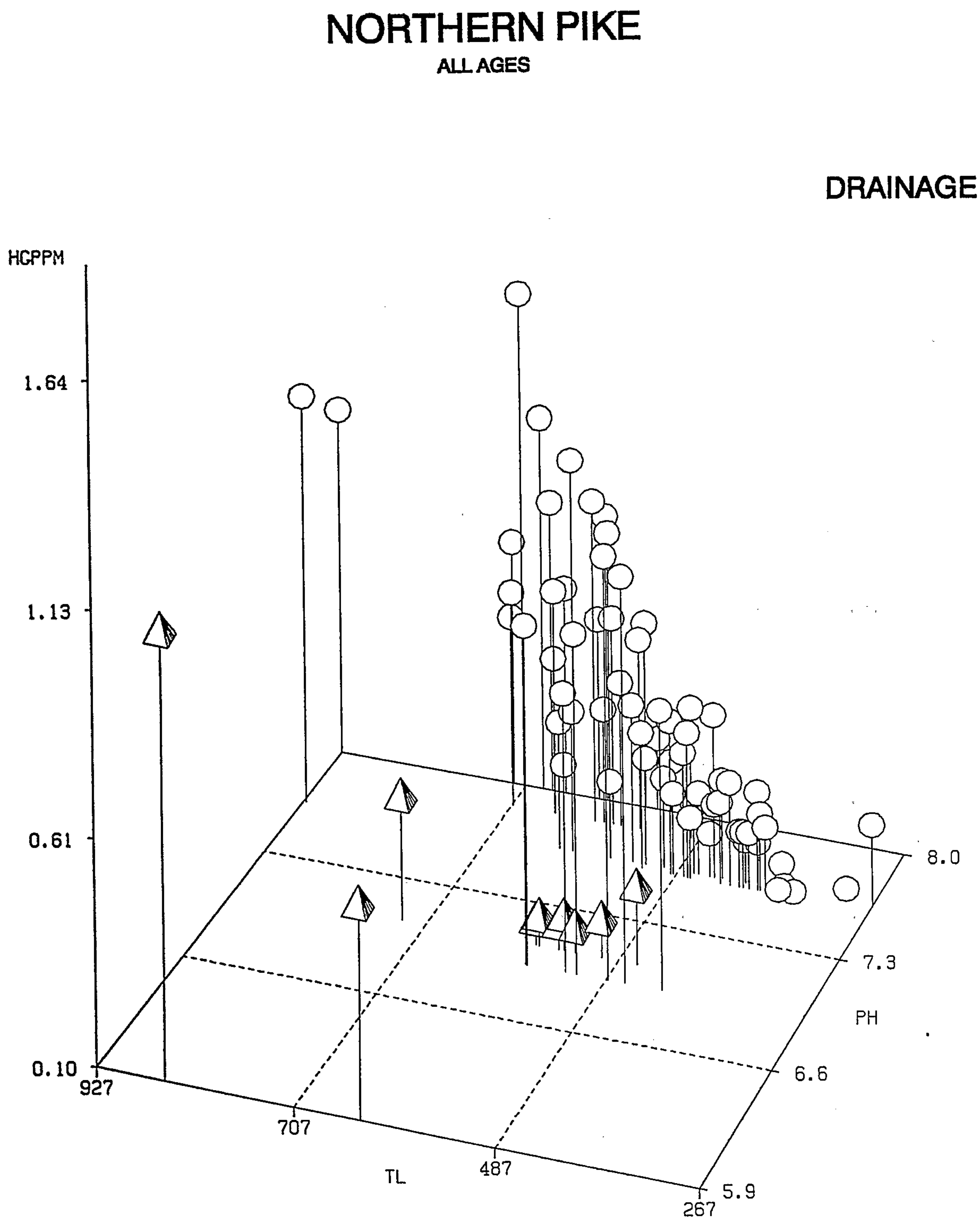

Figure 3-8. Plot of individual mercury levels (HG ppm) for northern pike in drainage lakes as a function of lake pH (pH) and total length (TL).

perch ages 2-4 and all ages of yellow perch combined. Generally speaking, few meaningful effects were observed, although some exceptions exist. For example, in seepage lakes for yellow perch ages 2-4, significant ($p \leq .05$) portions of the variation in mercury levels due to length and weight are explained by pH. However, the correlations with length and weight are still significant. In addition, the effect of DOC on length and weight correlation was minimal.

Drainage lake results, on the other hand, indicate that correlations of mercury levels with length and weight are largely affected by the variables DOC, lake size, watershed area/lake area, and watershed size. When partial correlation coefficients were computed controlling for these variables, either singly or in combination for yellow perch ages 2-4, the relationships between mercury levels and fish size (length, age, weight) were not significant. However, these correlation coefficients, while significant to begin with, are typically low ($r < .4$) for yellow perch ages 2-4 because mercury levels do not vary greatly in this group.

When all ages of yellow perch were considered for all lakes, as well as for seepage and drainage lakes separately, partial correlations indicated that across this large broader range of sizes, the correlation due to size was affected very little by any physical or chemical variable. Therefore, size variables were truly and not spuriously correlated with mercury levels.

Further verification of these results for all ages of yellow perch was obtained by performing a discriminant analysis, which included the same biological, chemical, physical, and lake type variables employed in the stepwise multiple regressions, to differentiate between fish with high (≥ 0.5) or low (<0.5) mercury levels. This analysis determined the classification variables most useful in discriminating between fish with high and low levels of mercury (Table 3-18). The final classification variables selected were dominated by fish size and lake acidity status variables. This discriminant function successfully classified 82% of all yellow perch in high or low mercury groups. Interestingly, although total length was not among the final classification variables in the function, it was the first variable chosen in the analysis and had the strongest individual correlation.

Table 3-18. Discriminant Analysis Results for All Ages Yellow Perch ≥ 0.5 ppm and < 0.5 ppm Mercury

Chi-Square	Standardized Canonical Discriminant Function Coefficients	Correlation Between Discriminating Variables and Canonical Discriminant Functions
179.91	Age 0.61	TL 0.74
($p < .001$)	Wt 0.42	Wt 0.72
	pH -0.21	Age 0.70
	Alt -0.57	Alt 0.36
	Elevation -0.44	pH -0.25
		(all other variables < 0.17)

We examined possible differences in growth rates among lake types (seepage versus drainage) because of the importance of size variables in determining mercury levels. Although yellow perch and largemouth bass generally appear to grow faster in drainage lakes (Figures 3-9 to 3-13), the opposite is true for northern pike (Figures 3-14 and 3-15). Furthermore, if we examine the distribution of individual fish with high mercury levels in Figures 3-3 to 3-8, it is apparent that, with the exception of yellow perch age 7 and older, large older fish in seepage and drainage lakes have similar mercury levels.

The apparent and somewhat unanticipated negative relationship between fish mercury and DOC in seepage lakes (Tables 3-10, and 3-11) led us to examine relationships between pH and DOC in these lakes (Figure 3-16). Although there is a significant positive correlation between DOC and pH for all seepage lakes, if DeLene Lake (pH 6.9, DOC = 10.3) is dropped from the analysis, the relationship for the other seepage lakes is insignificant. Therefore, the DOC effect on mercury levels does not appear to be related to a pH effect.

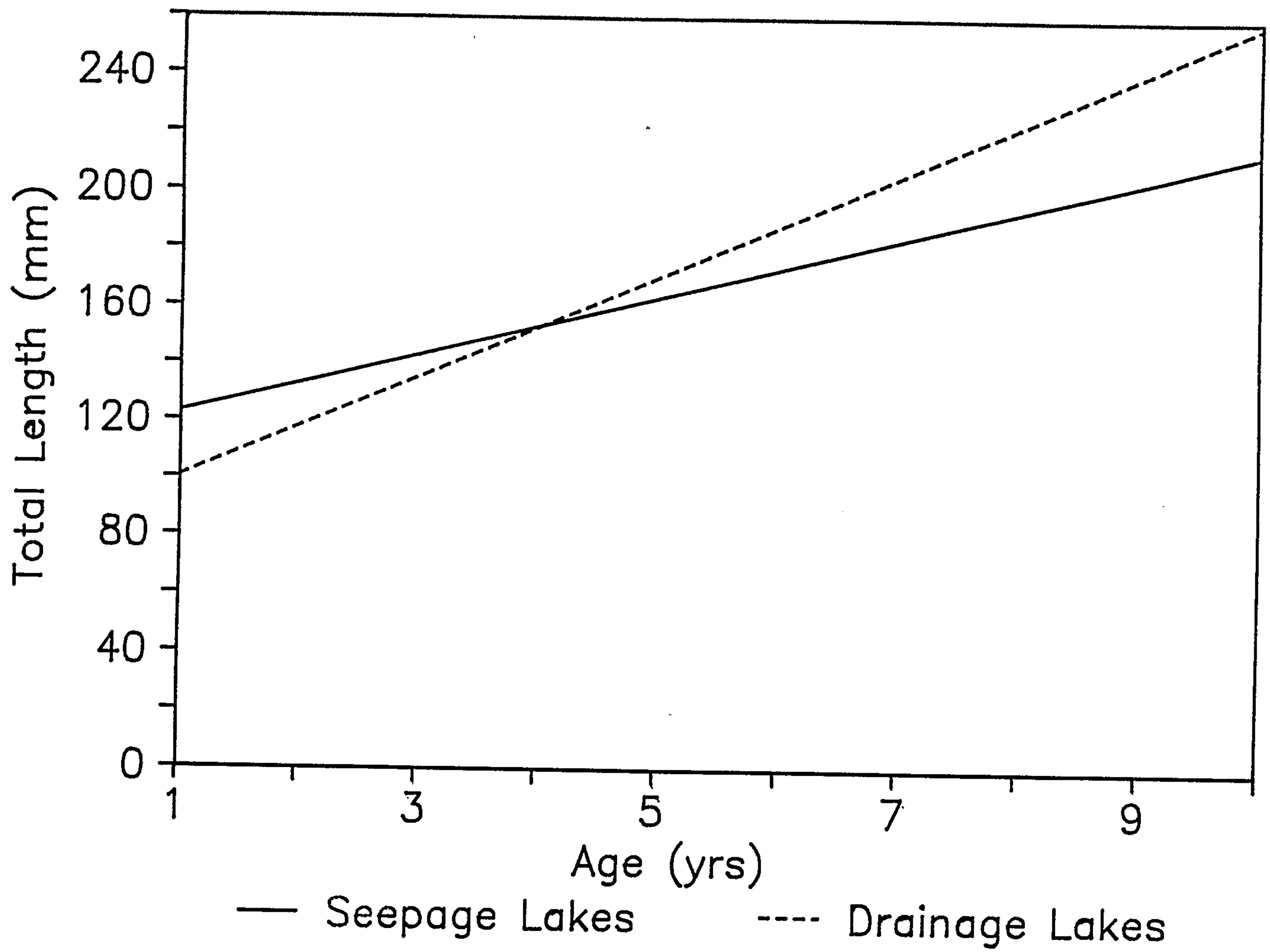

Figure 3-9. Relationship between age and total length for all ages of yellow perch.

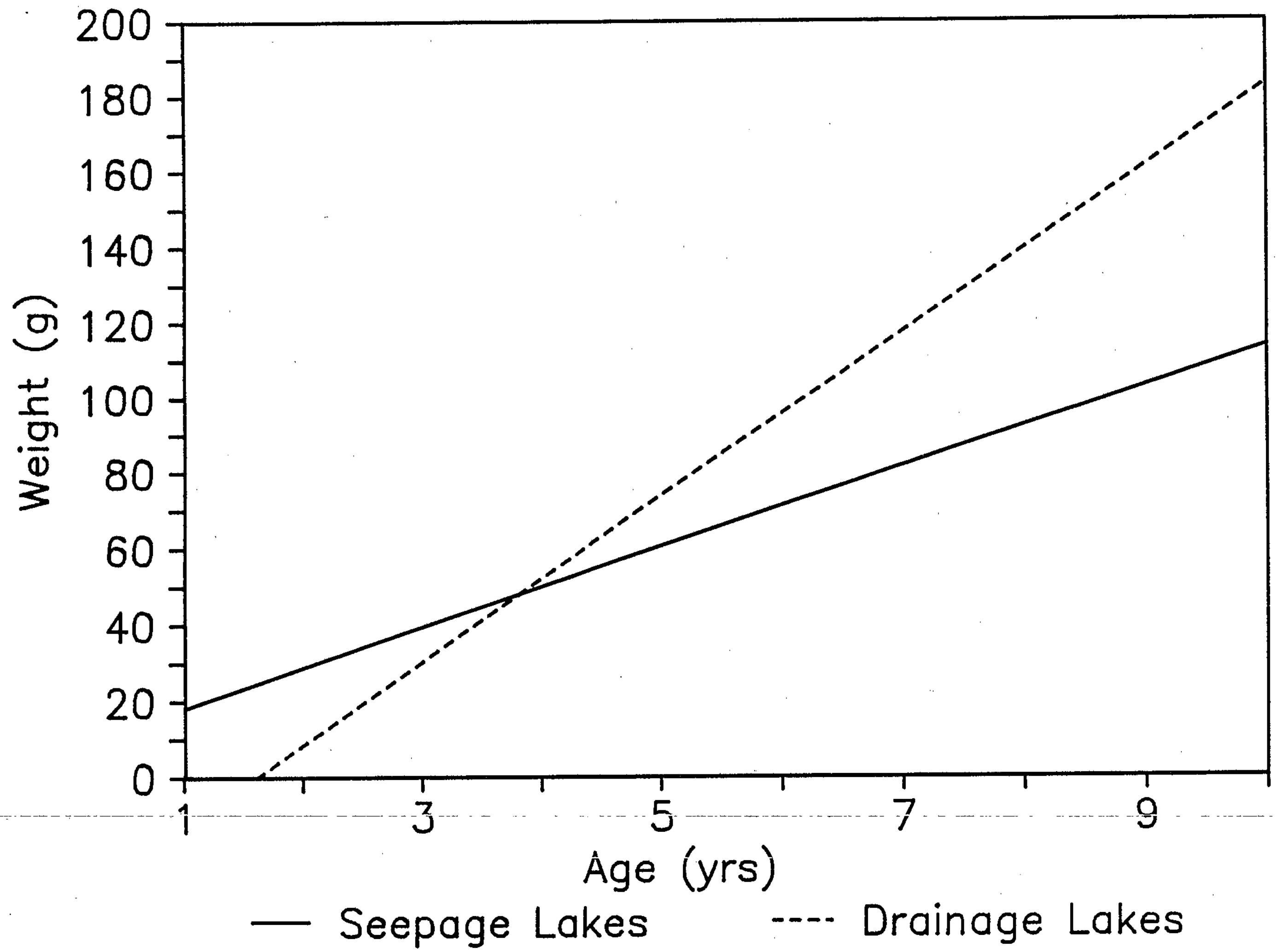

Figure 3-10. Relationship between age and weight for all ages of yellow perch.

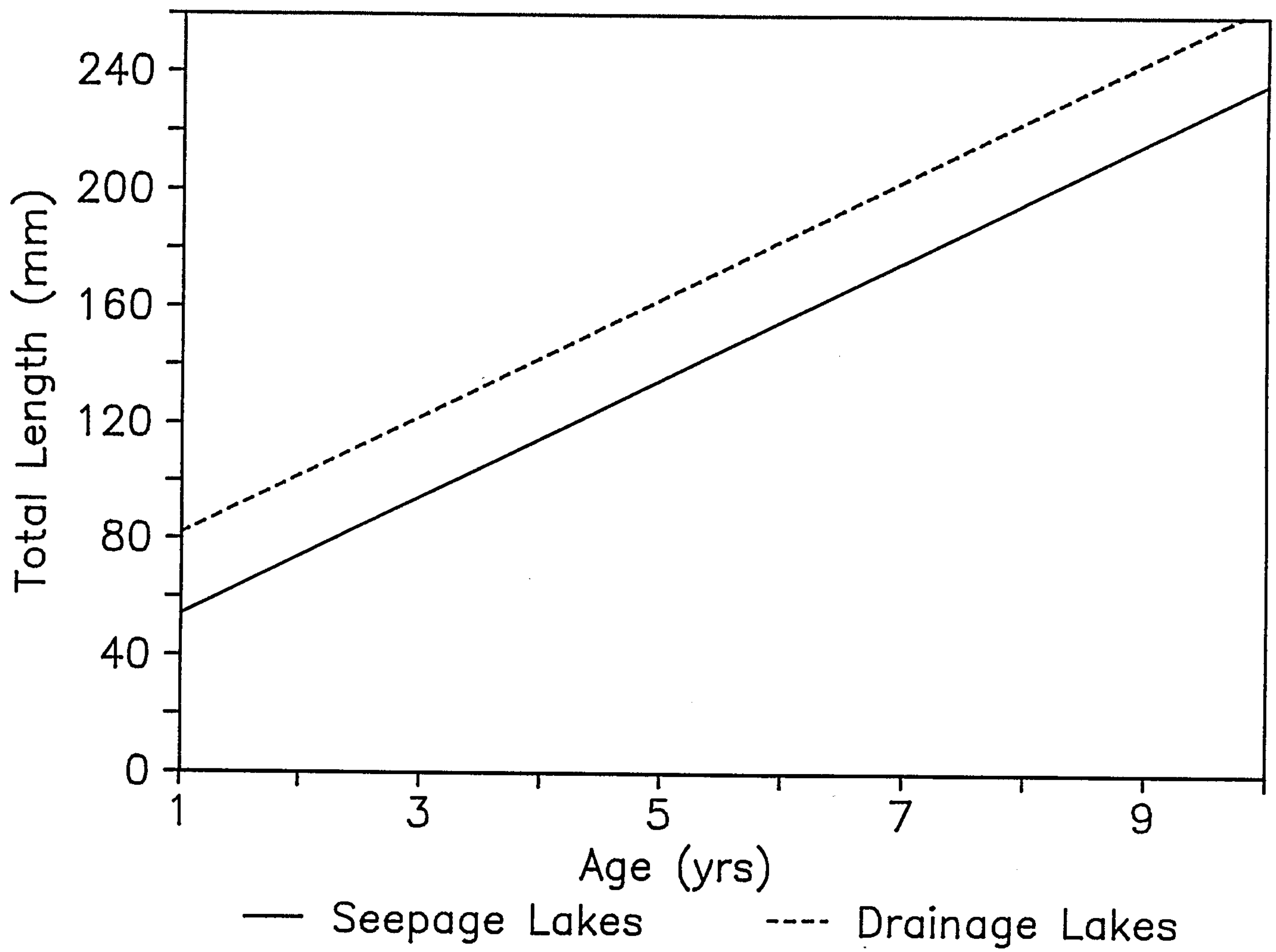

Figure 3-11. Relationship between age and total length for yellow perch age 7 and older.

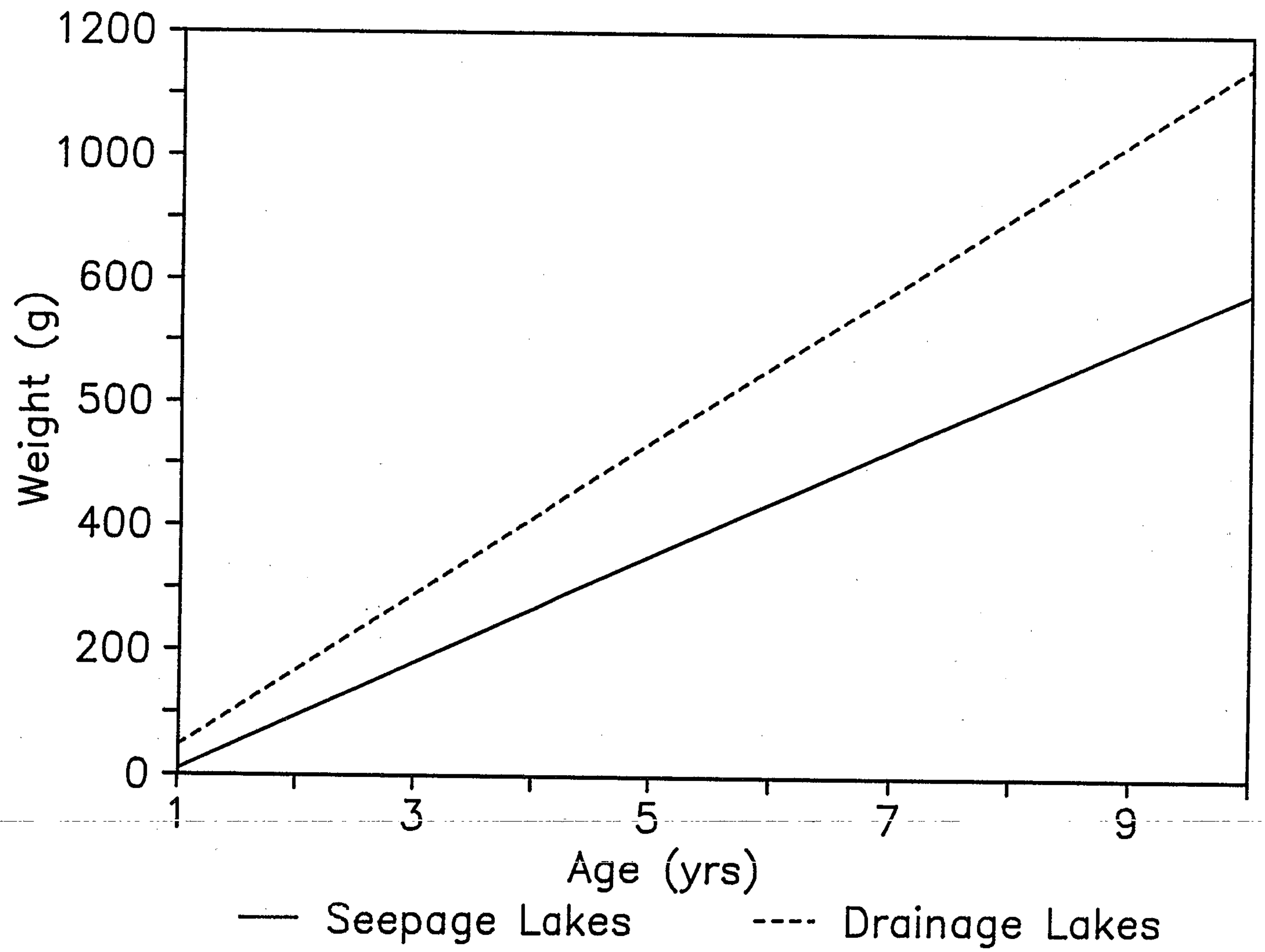

Figure 3-12. Relationship between age and weight for all ages of largemouth bass.

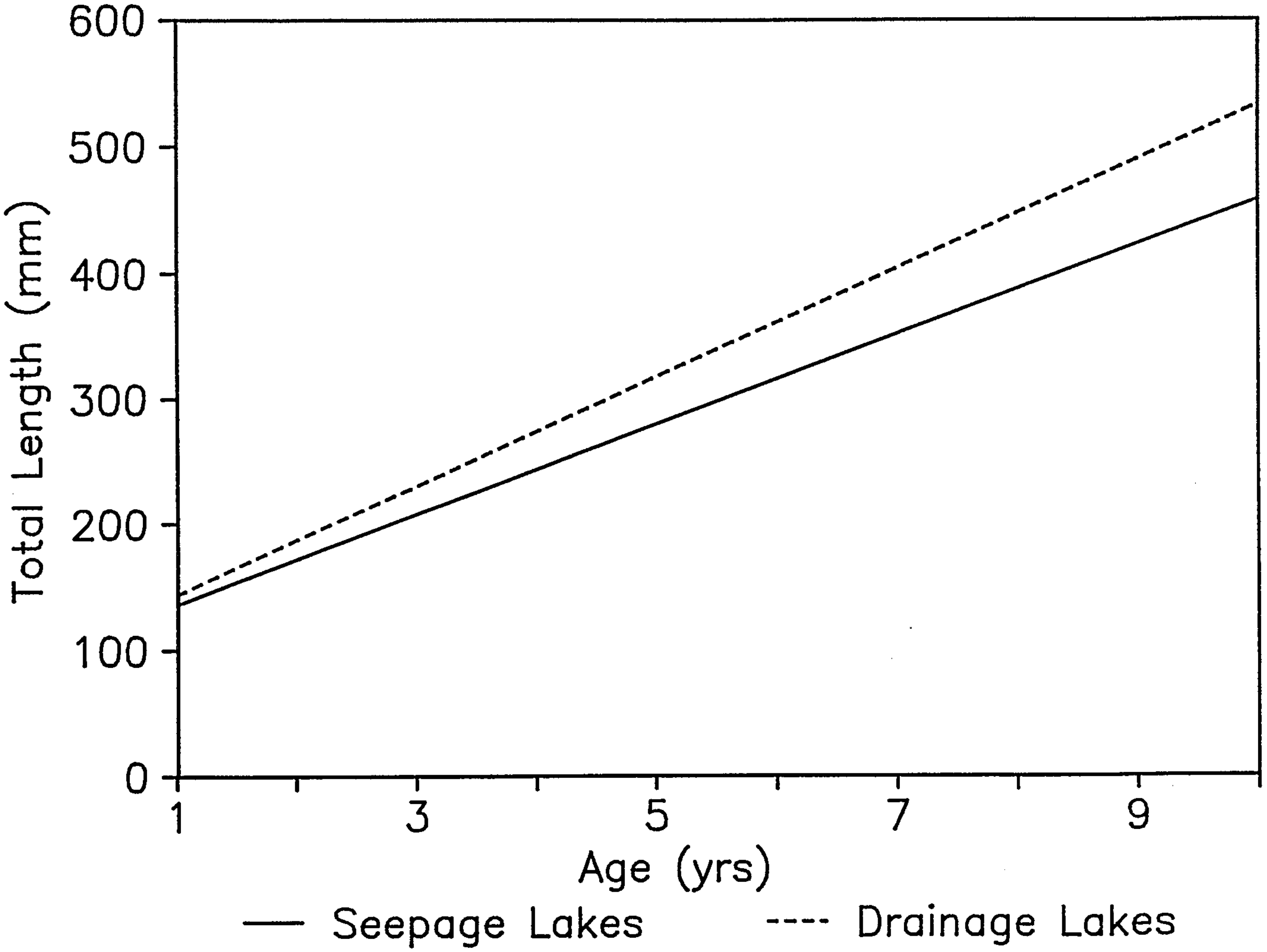

Figure 3-13. Relationship between age and total length for all ages of largemouth bass.

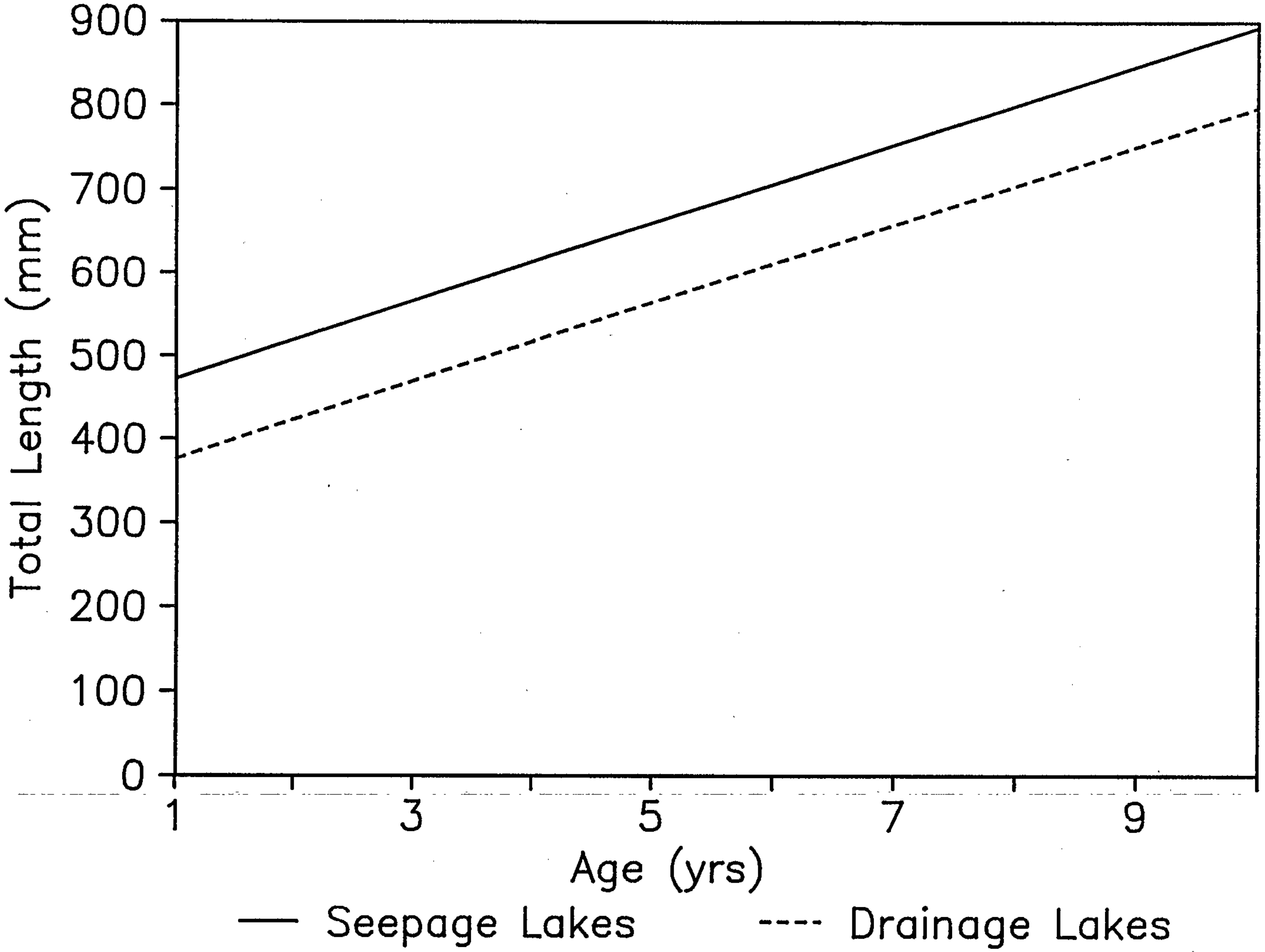

Figure 3-14. Relationship between age and total length for all ages of northern pike.

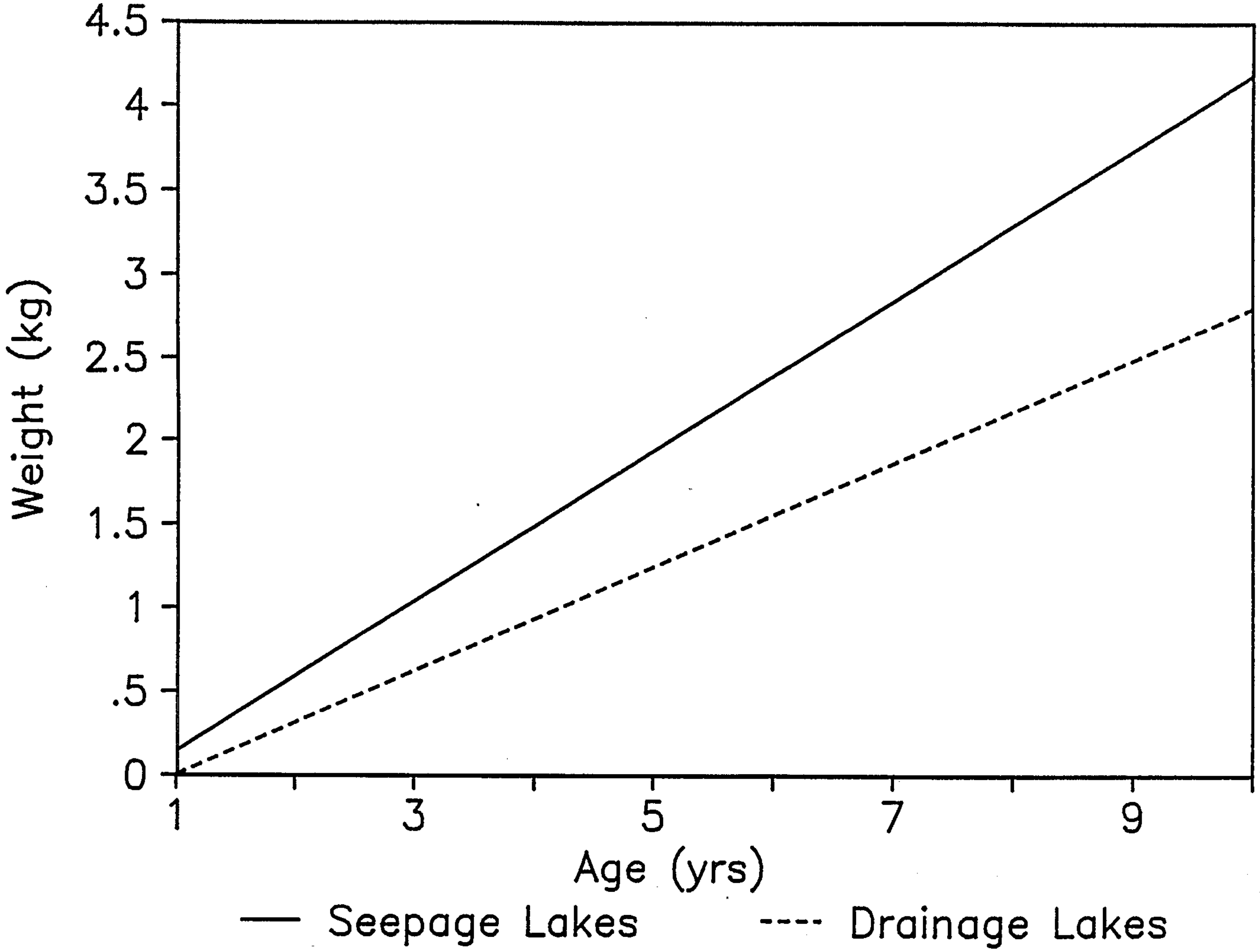

Figure 3-15. Relationship between age and weight for all ages of northern pike.

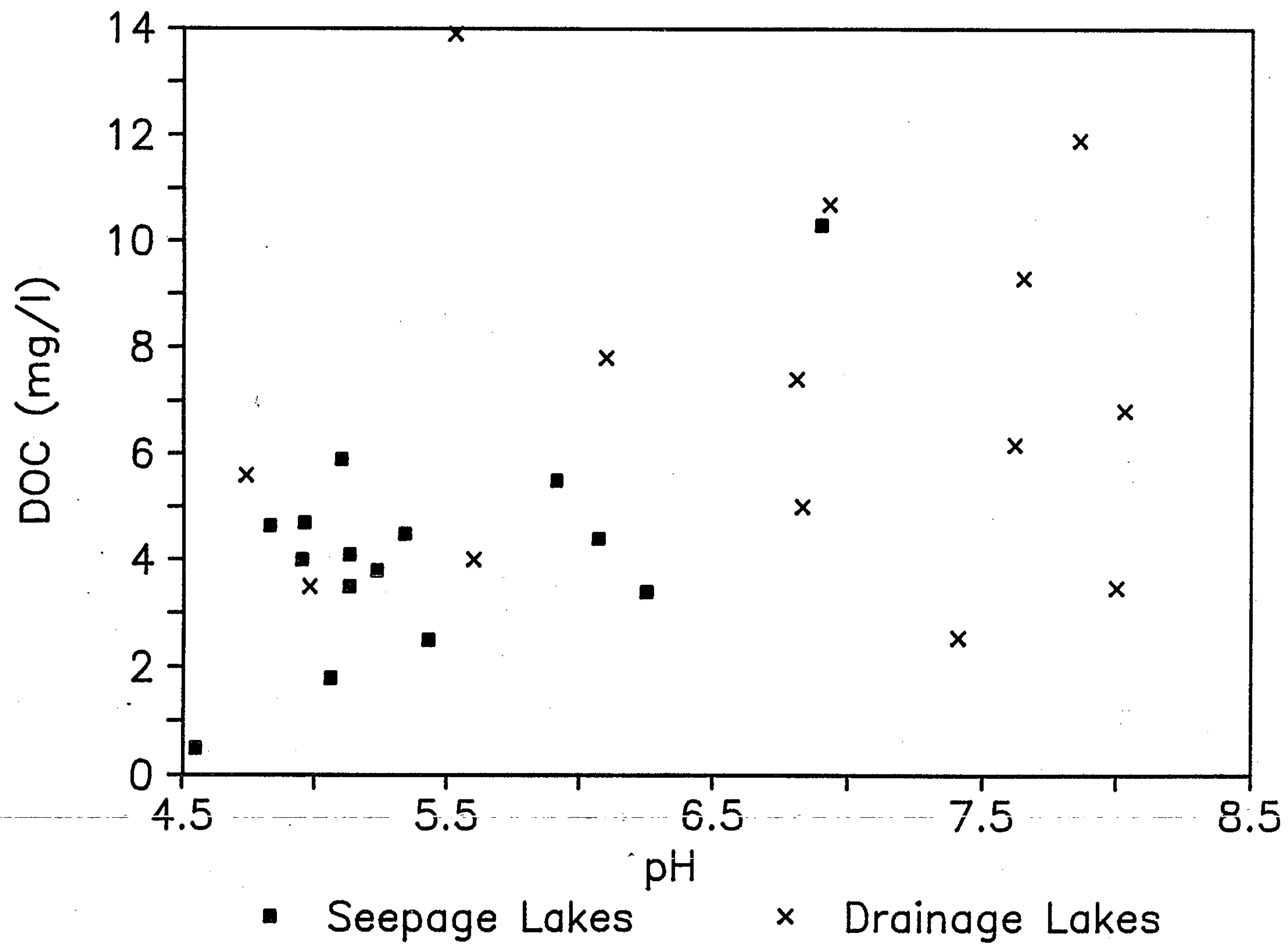

Figure 3-16. Plot of pH versus DOC for lakes with mercury values for yellow perch ages 2-4.

4. DISCUSSION

It is apparent from the foregoing results that a high percentage of game fish, which are the species most likely to be consumed by humans, exceed various health guidelines for mercury. The severity and extent of the mercury contamination problem depends upon whether the FDA action level of 1.0 ppm methyl mercury is used or the more conservative figure of 0.5 ppm adopted by several states, Canada, and the WHO. Furthermore, an additional perspective for Subregion 2B may be obtained by comparing the mercury levels in fish, and the number of lakes affected, to these same factors in other geographical areas. Finally, some examination of the relationship between fish mercury levels and lake acidity factors is possible for this subregion.

4.1 RELATIONSHIP OF SUBREGION 2B MERCURY LEVELS TO OTHER GEOGRAPHIC AREAS

Subregion 2B lakes sampled for ELS-II had fish that exceeded 0.5 ppm Hg in 24 of 38 lakes (38 = number of lakes with fish analyzed for mercury). This represents 65% of the lakes in the survey with game fish. However the percentage of all game fish analyzed for mercury that exceeded 0.5 and 1.0 ppm was lower at 17% and 3%, respectively. While these percentages are relatively low, they largely reflect samples of fish in size classes that may not be heavily sought by anglers (e.g., Table 3-8). However, it is reasonable to assume that a fairly high percentage of larger and older fish have levels exceeding the guidelines (see Table 3-12).

Based on the probability sampling frame for the ELS-I and ELS-II surveys, data collected on fish mercury levels for the 49 ELS-II lakes can be extrapolated to estimate fish mercury characteristics for Subregion 2B as a whole. Regional estimates are provided for the total number and area of lakes in which fish mercury levels exceed 0.5 and 1.0 ppm (Table 4-1). Similar estimates are provided for yellow perch and other game fish combined. A more detailed explanation of the techniques employed in these regional expansions is provided by Cusimano et al (1988). Results of these estimates show that nearly 54% of all lakes in this subregion and nearly 82% of the surface area of all lakes have one

Table 4-1. Population Estimates (Subregion 2B) of Lakes with Fish Mercury Levels Exceeding 0.5 and 1.0 ppm Hg, Based on Direct Estimation From the Sample of 49 ELS-II Lakes

	Number of Lakes			Percentage of Lakes	
	Sample	Population	(±95% CL)	Number	Area
Regional Assessment of Fish Mercury Content					
ELS-II target population	49	639.5			
Lakes with measurements of fish mercury	38	547.2	(32.8)	85.6	96.1
≥ 1 fish with > 0.5 ppm	24	344.9	(36.8)	53.9	81.7
≥ 1 fish with > 1.0 ppm	10	116.8	(32.4)	18.3	13.7
Yellow Perch Mercury Content					
Yellow perch caught	31	446.3	(33.6)		
≥ 1 yellow perch with > 0.5 ppm	18	192.7	(33.9)	43.2	70.7
≥ 1 yellow perch with > 1.0 ppm	7	59.2	(25.0)	13.3	2.5
Other Game Fish Mercury Content					
Other fish caught	22	456.8	(44.6)		
Measurements of fish mercury for other game fish species	17	413.6	(51.8)		
≥ 1 fish with > 0.5 ppm	10	241.4	(58.9)	58.4	84.1
≥ 1 fish with > 1.0 ppm	3	178.4	(113.1)	43.1	38.8

or more fish exceeding the 0.5 ppm Hg state health advisory. Over 18% of all lakes are estimated to have one or more fish exceeding 1.0 ppm Hg. However, game fish other than yellow perch (walleye, northern pike, and largemouth bass) are estimated to have at least one fish over the 1.0 ppm action level in 43% of the 457 lakes in which they occur.

A report on mercury in fish (pike) from Swedish lakes (Hakanson et al., 1988) indicated that 250 to 300 lakes in Sweden were "blacklisted" because they were known to contain fish that exceeded the 1.0 ppm Hg Swedish guidelines. However, using statistical techniques to extrapolate to all Swedish lakes over 0.01 km^2 (10 ha), the authors estimated that 11.3% of the approximately 83,200 lakes exceeded the 1.0 ppm guidelines. Moreover, if the WHO action level of 0.5 ppm was invoked, over 50% of all Swedish lakes ($>$10 hectares) would exceed the standard.

In North America, although the muscle tissue of some fish has been found to contain more than 1.0 ppm of mercury, widespread bioaccumulation of mercury in fish in excess of the FDA action level has not been reported. The sparse data regarding the mercury content of fish taken from waters with low acid neutralizing capacity (ANC) indicate that:

1. 8% of all fish collected from 23 low-ANC lakes in northeastern Minnesota were reported by Helwig and Heiskary (1985) to have mercury levels in excess of the 1.0 ppm FDA action level,
2. approximately 20-30 low-ANC lakes in Wisconsin have consumption advisories due to fish mercury levels (J. Weiner, U.S. Fish and Wildlife Service, La Crosse, WI - personal communication to S.P. Gloss), and
3. although Sloan and Schofield (1983) reported levels of mercury in fish to be higher in low-ANC lakes than in higher ANC lakes in the northeastern United States, reported mercury levels in fish sampled there typically do not exceed the 1.0 ppm action level (Bloomfield et al., 1980; Akielaszek and Haines, 1981).

There are no published data on mercury levels in fish taken from low-ANC waters in the southeast, including Florida, or in fish taken from low-ANC waters in the western United States. The most extensive data on mercury concentrations in fish come from analysis of 70,000 to 80,000 fish taken from approximately 1,500 predominantly low-ANC lakes, out of a total of 250,000 lakes, in Ontario, Canada. Approximately 7% of the fish analyzed contained more than 0.5 ppm mercury--the standard set by the Canadian government as the limit for human consumption. A smaller percentage of piscivorous (fish-eating) fish taken from low-ANC lakes contained more than 1.0 ppm mercury. These data have prompted the Province of Ontario to place restrictions on the harvesting and/or consumption of some sizes and species of fish in three-quarters of the approximately 1,500 lakes sampled.

Although the data from different geographic areas do not lend themselves to strict quantitative comparisons, it appears that Subregion 2B lakes are demonstrating fish mercury levels similar to those of other areas with low-ANC (acid-sensitive) waters in North America. In addition, the proportion of lakes affected is high, especially for large game fish. However, based upon projections by Hakanson et al. (1980), the contamination in Subregion 2B may not be as severe as that in Sweden.

4.2 APPARENT FACTORS AFFECTING MERCURY ACCUMULATION IN SUBREGION 2B LAKES

Results obtained in this study concerning the influence of fish size and age on mercury concentration are consistent with those of other recent studies (Lathrop et al., 1985; Helwig and Heiskary, 1985; Akielaszek and Haines, 1981). A positive correlation was observed between mercury concentration and fish length, weight, and age in all game species. Simple linear regressions describing the relationships among these variables were also statistically significant. However, there were large differences in the correlation coefficients obtained for these relationships between seepage and drainage lakes in yellow perch. Greater variability in the mercury concentrations at all lengths was observed in the seepage lakes, and the maximum observed concentrations were greatest in the drainage lakes. Additionally, the largest yellow perch in the older age classes were obtained from drainage lakes. However, the highest mercury levels in yellow perch ages 2-4 were in seepage lakes, where younger perch apparently are larger than perch of a similar age in drainage lakes. The observed differences in mercury concentrations between lake types may therefore be related to factors affecting growth as well as differences in water quality factors that affect the availability of mercury.

This study also indicated differences in mercury concentrations among species. In particular, mercury concentrations in white sucker in each age class were lower than those measured in all other species. These differences do not appear to be related to lake differences. The mean concentration of mercury in age-3, -6, and -7 yellow perch, for example, was statistically greater than in white sucker in the 12 lakes in which they were both captured. Since mercury concentrations were lower in all age classes, these differences cannot be explained by differences in duration of exposure. Moreover, large differences in mercury concentrations were not observed among different age classes of white sucker. Differences in growth rate also do not appear to explain the differences in mercury concentrations between white sucker and other species. The indirect evidence available indicates that the observed differences between white sucker and the other species could be due to differences in food, chemical characteristics of benthic and pelagic environments, or uptake and elimination rates.

The correlations between fish mercury and water quality variables found in our study are compared with the results of similar studies (Helwig and Heiskary, 1985; Lathrop et al., 1987; McMurtry et al., 1989) in Table 4-2. Each study involved the statistical analysis of water quality and fish mercury data from a large number of lakes. The geographical regions, fish species, and statistical approaches varied between studies.

Most of these studies indicate a fairly consistent negative correlation between fish mercury and pH, as well as between mercury and other indicators of lake acidification such as ANC, calcium, conductivity, and aluminum. The pH and ANC correlations were most consistent, the ANC, calcium, conductivity and aluminum correlations were less consistent. Our results were mixed, with significant negative correlations between mercury and pH in both seepage and drainage lakes, but with a significant negative correlation between mercury and ANC only for seepage lakes. Calcium, aluminum, and conductivity were not significantly correlated with mercury in either lake type, but aluminum had a significant, albeit weak, positive correlation when all lakes were grouped together (Table 3-13).

Table 4-2. Comparison of Correlations Between Water Quality and Fish Mercury Among Several Studies

	Present study		Other studies			
Location	UP Michigan	UP Michigan	NE Minnesota[1]	Wisconsin[2]	Ontario[3]	Ontario[3]
Lake type	Drainage	Seepage	Mostly drainage	Unspecified	Unspecified	Unspecified
Fish species	Yellow perch	Yellow perch	Northern pike walleye	Walleye	Lake trout	Smallmouth bass
Water quality correlations						
pH	–	–	–	–	0	–
ANC	0	–	–	–	0	–
Ca	0	0	–	–	0	–
conductivity	0	0	0	–	0	–
Al	0	0	+	n	+	0
total P	0	0	0	–	n	n
DOC	0	–	n	n	+	+
color	0	+	+	0	+	0
SO_4	0	+	n	n	–	–

[1] Helwig and Heiskary, 1985
[2] Lathrop et al., 1987
[3] McMurtry et al., 1989

– = negative correlation
+ = positive correlation
0 = no significant correlation
n = not measured

Several studies have indicated a positive correlation between fish mercury and aluminum concentrations in water. In our study, a positive correlation was found only when all lakes were grouped together. Helwig and Heiskary (1985) also found good correlations for northern pike and walleye in drainage lakes. McMurtry et al. (1989) found a positive correlation between mercury and aluminum for lake trout, but found no significant correlation for smallmouth bass.

Negative correlations have been noted between fish mercury and total phosphorus or other measures of lake productivity such as chlorophyll a (Lathrop et al., 1989; Helwig and Heiskary, 1985). Our results also showed significant negative correlations for total phosphorus in seepage lakes and all lakes together.

One of the most interesting results of this study was the relationship between DOC and mercury. Dissolved organic carbon and mercury concentrations were not correlated in drainage lakes, but a consistent and statistically significant negative correlation was observed between mercury and DOC in seepage lakes. The role that DOC may have in influencing observed mercury concentrations is indicated in Figure 3-2, which shows the relationship between pH and mercury in yellow perch ages 2-4. The wide variability in the relationship at the lower pH range can be explained by DOC concentrations in the lakes. At low DOC concentrations, mercury concentrations in fish were relatively high, and the lower mercury concentrations occurred in lakes with higher DOC concentrations. The observed negative relationship between DOC and mercury may be due to mercury complexation with organics that reduces either the bioavailability of mercury or its uptake across gill membranes.

Several other studies noted the opposite effect--an increase in fish mercury with increasing DOC or color (Helwig and Heiskary, 1985; Suns et al., 1987; McMurtry et al., 1989). The proposed mechanisms have included increased methylation rates with increasing DOC (particularly at low DOC ranges) (McMurtry et al., 1989), increased mercury release from the sediments due to humic substances (Saar and Weber, 1982), and concentration of mercury in precipitation by terrestrial organic matter in the watershed (Gorham et al., 1984). The above studies were not restricted to seepage lakes, and in one case, drainage lakes were emphasized (Helwig and Heiskary, 1985).

Among other significant chemical variables, the most obvious were the positive and negative correlations between mercury levels and sulfate and silica, respectively, in seepage lakes. Physical variables showed correlations only in drainage lakes for yellow perch ages 2-4 and only in seepage lakes for yellow perch age 7 and older.

Numerous statistical relationships exist between mercury levels and water chemistry variables; however, a survey study provides no basis from which to imply causal mechanisms. For example, several multiple regression models that predict mercury levels in fish have high correlation coefficients, but their variables may or may not be implicated in actual causes for increased or decreased mercury levels in fish. The variables identified in multiple regression models are not always the same as those that have the highest coefficients in simple correlation matrices. Overall, the most consistent variables related to the mercury levels found in fish were those describing fish size (total length, weight, age). Therefore, the principal benefit of this study is that it begins to quantify the mercury problem in one subregion of the ELS and suggests some possible lake characteristics that may warrant further investigation as to their possible cause and effect relationships with mercury accumulation in fish.

4.3 HUMAN HEALTH CONSIDERATIONS AND RECOMMENDATIONS FOR ADDITIONAL RESEARCH

Given our current knowledge about the processes controlling mercury uptake and accumulation in low ANC lakes, as well as our lack of information about the extent and severity of the problem, it is not possible to quantitatively infer the importance of acidic deposition to observed mercury levels in fish from low ANC lakes. It is possible that acidification makes some contribution to increased mobilization, methylation, and bioaccumulation of mercury in fish from certain lakes. However, it seems apparent that many natural processes or other anthropogenic activities may also cause bioaccumulation of mercury to levels that may represent a human health hazard.

The major uncertainty in defining the extent and severity of the mercury problem in the United States is the lack of systematic survey data that would allow some type of extrapolation to the entire lake resource. Although some individual states are gradually increasing their databases on mercury levels in fish, there is not a coordinated effort to develop the necessary information on a regional or national scale. Similarly, the data on harvest and consumption rates of fish species and sizes are probably not sufficient to assess current health risks. However, risk to an individual consumer could be estimated (and has been; NAS, 1978) for various consumption scenarios, even without comprehensive mercury contamination data.

Additional research needed to reduce the current uncertainty about the quantitative relationships between acidic deposition, bioaccumulation of mercury in fish, and human health risks includes: (1) systematic surveys designed to identify the extent and severity of mercury bioaccumulation in fish taken from lakes in regions potentially affected by acidic deposition, (2) studies designed to identify and quantify the factors affecting bioaccumulation, and (3) studies designed to quantify the consumption by humans of fish from low-ANC waters and the demography of angler populations.

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6. APPENDIX

Appendix. Individual data for fish mercury analysis subregion 2B.

SPECIES	LAKE ID	LAKE NAME	HYDRO TYPE	AGE	TL (MM)	WT (GMS)	Hg (PPM)
BROOK TROUT	2B1-061	GOPHER LAKE	S	3	361	800	0.2300
BROOK TROUT	2B1-061	GOPHER LAKE	S	3	245	200	0.0200
BROOK TROUT	2B1-061	GOPHER LAKE	S	4	397	760	0.3400
BROOK TROUT	2B1-061	GOPHER LAKE	S	4	358	650	0.0600
BROOK TROUT	2B1-061	GOPHER LAKE	S	6	451	1251	0.3700
BROOK TROUT	2B1-061	GOPHER LAKE	S	6	457	1400	0.2700
BROOK TROUT	2B1-061	GOPHER LAKE	S	7	508	1775	0.3600
BROOK TROUT	2B3-007	ISLAND LAKE	D	1	215	100	0.0300
BROOK TROUT	2B3-007	ISLAND LAKE	D	1	190	85	0.0200
BROOK TROUT	2B3-007	ISLAND LAKE	D	1	188	60	0.0200
BROOK TROUT	2B3-007	ISLAND LAKE	D	1	195	80	0.0300
BROOK TROUT	2B3-007	ISLAND LAKE	D	1	211	110	0.0200
BROOK TROUT	2B3-007	ISLAND LAKE	D	1	272	240	0.0200
BROOK TROUT	2B3-007	ISLAND LAKE	D	2	276	245	0.0400
BROOK TROUT	2B3-007	ISLAND LAKE	D	2	274	285	0.1200
BROOK TROUT	2B3-007	ISLAND LAKE	D	2	270	210	0.0400
[illegible] TROUT	2B3-007	ISLAND LAKE	D	1	246	144	0.1400
BROOK TROUT	2B3-031	TWIN LAKES	D	1	233	106	0.1500
BROOK TROUT	2B3-031	TWIN LAKES	D	1	221	87	0.1500
BROOK TROUT	2B3-031	TWIN LAKES	D	1	240	129	0.1300
BROOK TROUT	2B3-031	TWIN LAKES	D	1	217	92	0.1500
BROOK TROUT	2B3-031	TWIN LAKES	D	1	209	72	0.1400
BROOK TROUT	2B3-031	TWIN LAKES	D	1	211	73	0.1100
BROOK TROUT	2B3-031	TWIN LAKES	D	2	367	470	0.2900
BROOK TROUT	2B3-031	TWIN LAKES	D	2	383	550	0.2700
BROOK TROUT	2B3-055	(NO NAME)	D	*	211	109	0.1800
BROOK TROUT	2B3-055	(NO NAME)	D	*	179	61	0.2600
BROOK TROUT	2B3-055	(NO NAME)	D	2	349	560	0.2000
LARGEMOUTH BASS	2B1-016	DEEP LAKE	D	3	220	127	0.2200
LARGEMOUTH BASS	2B1-016	DEEP LAKE	D	3	217	132	0.2700
LARGEMOUTH BASS	2B1-016	DEEP LAKE	D	3	234	169	0.1500
LARGEMOUTH BASS	2B1-016	DEEP LAKE	D	3	222	135	0.2600
LARGEMOUTH BASS	2B1-016	DEEP LAKE	D	6	307	380	0.2900
LARGEMOUTH BASS	2B1-022	TWIN LAKES (EASTERN)	S	4	207	113	0.2500
LARGEMOUTH BASS	2B1-022	TWIN LAKES (EASTERN)	S	4	220	129	0.3500
LARGEMOUTH BASS	2B1-022	TWIN LAKES (EASTERN)	S	4	211	120	0.4400
LARGEMOUTH BASS	2B1-022	TWIN LAKES (EASTERN)	S	5	240	183	0.2700
LARGEMOUTH BASS	2B1-022	TWIN LAKES (EASTERN)	S	5	255	203	0.5300
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	117	23	0.1600
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	118	21	0.2100
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	92	10	0.1900
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	90	10	0.2000
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	108	17	0.2500
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	90	10	0.1700
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	90	11	0.1800
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	92	11	0.1900
LARGEMOUTH BASS	2B1-061	GOPHER LAKE	S	0	116	23	0.3200
LARGEMOUTH BASS	2B2-061	(NO NAME)	D	3	276	300	0.7300

LARGEMOUTH BASS	2B2-061	(NO NAME)	D	4	320	550	0.6900
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	1	88	7	0.1100
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	1	78	6	0.0800
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	2	205	109	0.1600
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	3	203	104	0.2400
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	3	180	67	0.1600
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	3	183	84	0.1800
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	4	314	370	0.5300
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	5	303	410	0.2800
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	5	310	410	0.4300
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	5	261	240	0.2000
LARGEMOUTH BASS	2B2-075	RICHARDSON LAKE	S	8	379	800	0.4200
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	261	200	0.1300
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	263	232	0.1400
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	267	240	0.1400
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	297	350	0.1900
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	275	278	0.1100
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	271	257	0.1600
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	4	297	350	0.1100
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	5	318	400	0.3400
LARGEMOUTH BASS	2B3-027	CASEY LAKE	S	5	304	373	0.1300
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	4	273	270	0.8100
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	4	269	225	0.7700
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	4	275	270	0.7200
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	4	268	230	0.7300
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	4	257	210	0.5900
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	6	330	430	0.8800
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	6	351	530	0.7300
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	7	370	640	1.0000
LARGEMOUTH BASS	2B3-030	ISLAND LAKE	S	8	334	480	0.8300
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	3	241	200	0.2300
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	4	292	395	0.3900
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	4	333	520	0.4400
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	4	296	350	0.5400
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	4	296	380	0.3300
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	4	304	400	0.4800
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	5	302	370	0.6000
LARGEMOUTH BASS	2B3-031	TWIN LAKES	D	6	319	440	0.7300
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	0	108	14	0.1300
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	0	81	6	0.0700
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	0	83	8	0.0900
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	0	94	10	0.0600
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	0	81	6	0.1100
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	1	114	18	0.1200
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	1	216	139	0.3000
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	1	102	13	0.1300
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	1	150	42	0.3500
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	1	102	13	0.1400
LARGEMOUTH BASS	2B3-037	RUMBLE LAKE	D	9	446	1620	0.6400
LARGEMOUTH BASS	2B3-071	OSTRANDER LAKE	S	5	330	320	0.2100
LARGEMOUTH BASS	2B3-071	OSTRANDER LAKE	S	7	356	550	0.3600
LARGEMOUTH BASS	2B3-071	OSTRANDER LAKE	S	10	431	1060	0.5500
NORTHERN PIKE	2B1-022	TWIN LAKES (EASTERN)	S	*	620	1515	0.4100
NORTHERN PIKE	2B1-022	TWIN LAKES (EASTERN)	S	5	634	1650	0.5900

NORTHERN PIKE	2B1-022	TWIN LAKES (EASTERN)	S	8	850	4300	1.1200
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	2	496	920	0.4100
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	2	598	900	0.3700
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	3	587	1280	0.5900
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	3	656	1800	0.4700
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	3	556	1140	0.5500
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	4	655	1950	0.6300
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	4	705	2110	0.6100
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	4	608	1620	0.8600
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	5	591	1480	0.7900
NORTHERN PIKE	2B3-009	GRAND SABLE LAKE	D	6	578	1220	0.4400
NORTHERN PIKE	2B3-012	ROUND LAKE	D	3	576	980	0.8800
NORTHERN PIKE	2B3-012	ROUND LAKE	D	3	466	515	1.0300
NORTHERN PIKE	2B3-012	ROUND LAKE	D	3	485	610	1.0700
NORTHERN PIKE	2B3-012	ROUND LAKE	D	3	424	450	0.7400
NORTHERN PIKE	2B3-012	ROUND LAKE	D	4	520	760	0.8800
NORTHERN PIKE	2B3-012	ROUND LAKE	D	5	578	840	1.6400
NORTHERN PIKE	2B3-012	ROUND LAKE	D	5	533	830	0.7400
NORTHERN PIKE	2B3-023	BONE LAKE	D	2	267	117	0.2900
NORTHERN PIKE	2B3-023	BONE LAKE	D	2	296	135	0.1300
NORTHERN PIKE	2B3-023	BONE LAKE	D	2	367	250	0.1100
NORTHERN PIKE	2B3-023	BONE LAKE	D	2	396	320	0.2000
NORTHERN PIKE	2B3-023	BONE LAKE	D	2	369	260	0.1600
NORTHERN PIKE	2B3-023	BONE LAKE	D	3	446	460	0.2700
NORTHERN PIKE	2B3-023	BONE LAKE	D	3	410	340	0.2000
NORTHERN PIKE	2B3-023	BONE LAKE	D	3	451	480	0.2000
NORTHERN PIKE	2B3-023	BONE LAKE	D	3	356	260	0.1000
NORTHERN PIKE	2B3-023	BONE LAKE	D	4	566	1080	0.2800
NORTHERN PIKE	2B3-023	BONE LAKE	D	5	464	500	0.2900
NORTHERN PIKE	2B3-023	BONE LAKE	D	5	540	900	0.4700
NORTHERN PIKE	2B3-023	BONE LAKE	D	5	620	1340	0.3000
NORTHERN PIKE	2B3-023	BONE LAKE	D	5	437	400	0.3300
NORTHERN PIKE	2B3-023	BONE LAKE	D	5	469	540	0.2600
NORTHERN PIKE	2B3-023	BONE LAKE	D	5	504	660	0.3100
NORTHERN PIKE	2B3-023	BONE LAKE	D	7	625	1390	0.4000
NORTHERN PIKE	2B3-023	BONE LAKE	D	8	525	800	0.3500
NORTHERN PIKE	2B3-023	BONE LAKE	D	8	610	1100	0.4300
NORTHERN PIKE	2B3-023	BONE LAKE	D	10	924	5440	1.0700
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	*	389	304	0.2300
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	1	289	118	0.0800
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	2	349	260	0.1700
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	2	325	191	0.0700
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	3	369	285	0.2400
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	4	467	590	0.1100
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	4	415	350	0.1200
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	5	398	380	0.3000
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	5	430	409	0.3500
NORTHERN PIKE	2B3-028	CATARACT BASIN	R	6	552	878	0.1500
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	2	384	285	0.2500
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	2	370	245	0.1100
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	2	393	324	0.3300
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	3	403	324	0.2300
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	3	473	420	0.4400
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	3	425	450	0.3400

NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	3	390	296	0.2800
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	4	410	357	0.2300
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	4	493	550	0.4600
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	4	526	740	0.4200
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	4	414	365	0.2300
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	5	490	680	0.2900
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	5	436	460	0.2900
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	5	478	524	0.3900
NORTHERN PIKE	2B3-034	KLONDIKE LAKE	D	5	470	500	0.2400
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	2	551	1000	0.2700
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	2	486	620	0.3500
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	2	535	850	0.2200
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	3	620	1450	0.5300
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	3	565	1150	0.5400
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	5	723	2200	0.5000
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	6	610	1200	0.7800
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	6	610	1280	0.6400
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	7	659	1300	0.7500
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	7	686	1800	0.9900
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	7	650	1477	0.9000
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	7	721	1150	0.6800
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	7	675	1740	0.7900
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	8	927	5000	0.9300
NORTHERN PIKE	2B3-037	RUMBLE LAKE	D	8	659	1620	0.5900
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	2	506	790	0.2000
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	3	555	1130	0.1700
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	3	581	1260	0.1700
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	3	549	950	0.1900
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	3	536	950	0.1700
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	4	577	1250	0.1800
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	S	5	734	2400	0.4000
NORTHERN PIKE	2B3-071	OSTRANDER LAKE	R	7	466	545	0.2900
SMALL MOUTH BASS	2B3-009	GRAND SABLE LAKE	D	4	256	260	0.3900
SMALL MOUTH BASS	2B3-009	GRAND SABLE LAKE	D	4	297	380	0.3800
SMALL MOUTH BASS	2B3-028	CATARACT BASIN	R	4	268	250	0.2300
SMALL MOUTH BASS	2B3-028	CATARACT BASIN	R	4	335	520	0.1900
WALLEYE	2B3-023	BONE LAKE	D	1	196	65	0.1100
WALLEYE	2B3-023	BONE LAKE	D	2	321	280	0.2000
WALLEYE	2B3-023	BONE LAKE	D	3	368	420	0.1900
WALLEYE	2B3-023	BONE LAKE	D	4	409	680	0.3600
WALLEYE	2B3-023	BONE LAKE	D	4	404	540	0.2600
WALLEYE	2B3-023	BONE LAKE	D	4	415	600	0.2800
WALLEYE	2B3-023	BONE LAKE	D	8	431	660	0.4200
WALLEYE	2B3-023	BONE LAKE	D	8	560	1380	0.4200
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	3	330	440	0.0400
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	3	308	320	0.0022
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	3	295	300	0.0022
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	5	341	460	0.0400
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	5	312	320	0.0100
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	5	342	480	0.0400
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	5	298	280	0.0600
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	5	331	380	0.0300
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	6	287	250	0.0600
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	6	362	560	0.0400

WHITE SUCKER	2B2-004	WRIGHT LAKE	S	6	340	420	0.0800
WHITE SUCKER	2B2-004	WRIGHT LAKE	S	7	393	660	0.0400
WHITE SUCKER	2B2-024	(NO NAME)	S	2	174	39	0.2400
WHITE SUCKER	2B2-024	(NO NAME)	S	2	169	44	0.1400
WHITE SUCKER	2B2-024	(NO NAME)	S	2	174	40	0.2300
WHITE SUCKER	2B2-024	(NO NAME)	S	2	173	44	0.1000
WHITE SUCKER	2B2-024	(NO NAME)	S	3	172	43	0.2500
WHITE SUCKER	2B2-024	(NO NAME)	S	6	359	420	0.0500
WHITE SUCKER	2B2-024	(NO NAME)	S	6	410	725	0.0300
WHITE SUCKER	2B2-024	(NO NAME)	S	6	255	130	0.1100
WHITE SUCKER	2B2-024	(NO NAME)	S	7	370	450	0.0100
WHITE SUCKER	2B2-024	(NO NAME)	S	7	317	255	0.0400
WHITE SUCKER	2B2-024	(NO NAME)	S	7	322	240	0.0800
WHITE SUCKER	2B2-024	(NO NAME)	S	8	344	360	0.0300
WHITE SUCKER	2B2-061	(NO NAME)	D	3	240	138	0.1400
WHITE SUCKER	2B2-061	(NO NAME)	D	3	210	82	0.1200
WHITE SUCKER	2B2-061	(NO NAME)	D	4	279	175	0.4900
WHITE SUCKER	2B2-061	(NO NAME)	D	4	285	200	0.2800
WHITE SUCKER	2B2-061	(NO NAME)	D	4	196	77	0.1900
WHITE SUCKER	2B2-061	(NO NAME)	D	6	426	650	0.1500
WHITE SUCKER	2B2-061	(NO NAME)	D	6	350	400	0.3900
WHITE SUCKER	2B2-061	(NO NAME)	D	6	360	475	0.2700
WHITE SUCKER	2B2-061	(NO NAME)	D	7	287	204	0.1000
WHITE SUCKER	2B2-061	(NO NAME)	D	7	349	300	0.3800
WHITE SUCKER	2B2-061	(NO NAME)	D	9	388	485	0.4900
WHITE SUCKER	2B2-061	(NO NAME)	D	9	385	527	0.5900
WHITE SUCKER	2B2-082	(NO NAME)	D	5	326	360	0.1000
WHITE SUCKER	2B2-082	(NO NAME)	D	7	333	400	0.1200
WHITE SUCKER	2B2-082	(NO NAME)	D	7	398	620	0.3200
WHITE SUCKER	2B2-082	(NO NAME)	D	8	361	460	0.2700
WHITE SUCKER	2B2-082	(NO NAME)	D	8	343	440	0.2000
WHITE SUCKER	2B2-082	(NO NAME)	D	8	352	480	0.1000
WHITE SUCKER	2B3-009	GRAND SABLE LAKE	D	1	146	31	0.0800
WHITE SUCKER	2B3-009	GRAND SABLE LAKE	D	2	228	131	0.0600
WHITE SUCKER	2B3-009	GRAND SABLE LAKE	D	3	315	321	0.0700
WHITE SUCKER	2B3-009	GRAND SABLE LAKE	D	3	232	121	0.0500
WHITE SUCKER	2B3-009	GRAND SABLE LAKE	D	3	234	128	0.0400
WHITE SUCKER	2B3-012	ROUND LAKE	D	1	101	10	0.0800
WHITE SUCKER	2B3-012	ROUND LAKE	D	1	107	12	0.0900
WHITE SUCKER	2B3-020	BUTO LAKE	D	5	351	390	0.0500
WHITE SUCKER	2B3-020	BUTO LAKE	D	5	335	400	0.0600
WHITE SUCKER	2B3-020	BUTO LAKE	D	6	316	320	0.0700
WHITE SUCKER	2B3-020	BUTO LAKE	D	6	375	460	0.0900
WHITE SUCKER	2B3-020	BUTO LAKE	D	6	365	460	0.0600
WHITE SUCKER	2B3-020	BUTO LAKE	D	6	362	440	0.0900
WHITE SUCKER	2B3-020	BUTO LAKE	D	7	356	440	0.0700
WHITE SUCKER	2B3-020	BUTO LAKE	D	7	356	440	0.0400
WHITE SUCKER	2B3-020	BUTO LAKE	D	8	366	460	0.0600
WHITE SUCKER	2B3-020	BUTO LAKE	D	8	359	450	0.0900
WHITE SUCKER	2B3-023	BONE LAKE	D	3	336	490	0.1000
WHITE SUCKER	2B3-023	BONE LAKE	D	3	322	340	0.0300
WHITE SUCKER	2B3-023	BONE LAKE	D	3	395	690	0.0500
WHITE SUCKER	2B3-023	BONE LAKE	D	3	311	310	0.0500

WHITE SUCKER	2B3-023	BONE LAKE	D	3	311	310	0.0500
WHITE SUCKER	2B3-023	BONE LAKE	D	6	496	1100	0.4000
WHITE SUCKER	2B3-023	BONE LAKE	D	6	516	1300	0.3600
WHITE SUCKER	2B3-023	BONE LAKE	D	6	349	440	0.0500
WHITE SUCKER	2B3-023	BONE LAKE	D	6	380	540	0.0900
WHITE SUCKER	2B3-023	BONE LAKE	D	6	451	1000	0.1500
WHITE SUCKER	2B3-023	BONE LAKE	D	6	419	720	0.0500
WHITE SUCKER	2B3-028	CATARACT BASIN	R	*	344	660	0.0500
WHITE SUCKER	2B3-028	CATARACT BASIN	R	3	410	943	0.0700
WHITE SUCKER	2B3-028	CATARACT BASIN	R	3	342	600	0.0600
WHITE SUCKER	2B3-028	CATARACT BASIN	R	3	306	348	0.0200
WHITE SUCKER	2B3-028	CATARACT BASIN	R	3	502	1261	0.3900
WHITE SUCKER	2B3-028	CATARACT BASIN	R	4	390	824	0.0800
WHITE SUCKER	2B3-028	CATARACT BASIN	R	5	320	372	0.0400
WHITE SUCKER	2B3-028	CATARACT BASIN	R	6	419	800	0.1600
WHITE SUCKER	2B3-028	CATARACT BASIN	R	6	573	1840	0.4400
WHITE SUCKER	2B3-028	CATARACT BASIN	R	6	503	1380	0.3100
WHITE SUCKER	2B3-028	CATARACT BASIN	R	6	505	1360	0.4500
WHITE SUCKER	2B3-028	CATARACT BASIN	R	7	484	1100	0.5600
WHITE SUCKER	2B3-028	CATARACT BASIN	R	7	429	820	0.1800
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	247	170	0.0300
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	374	570	0.1500
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	234	150	0.0600
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	367	530	0.0700
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	257	190	0.0500
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	338	400	0.0700
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	223	120	0.0500
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	246	170	0.0200
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	326	420	0.0500
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	220	120	0.0100
WHITE SUCKER	2B3-031	TWIN LAKES	D	3	320	380	0.0600
WHITE SUCKER	2B3-031	TWIN LAKES	D	6	362	515	0.0900
WHITE SUCKER	2B3-031	TWIN LAKES	D	6	351	520	0.0700
WHITE SUCKER	2B3-031	TWIN LAKES	D	6	259	200	0.0010
WHITE SUCKER	2B3-031	TWIN LAKES	D	7	380	620	0.2100
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	2	261	213	0.0300
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	3	371	560	0.0400
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	3	255	160	0.0200
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	3	332	440	0.0400
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	3	320	378	0.0100
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	4	320	360	0.0400
WHITE SUCKER	2B3-037	RUMBLE LAKE	D	4	345	460	0.0300
WHITE SUCKER	2B3-055	(NO NAME)	D	*	243	132	0.0400
WHITE SUCKER	2B3-055	(NO NAME)	D	1	120	15	0.0300
WHITE SUCKER	2B3-055	(NO NAME)	D	3	250	152	0.0900
WHITE SUCKER	2B3-055	(NO NAME)	D	3	243	142	0.0200
WHITE SUCKER	2B3-055	(NO NAME)	D	3	237	141	0.0500
WHITE SUCKER	2B3-055	(NO NAME)	D	3	182	58	0.0100
WHITE SUCKER	2B3-057	TWIN LAKE	D	4	337	290	0.0200
WHITE SUCKER	2B3-057	TWIN LAKE	D	7	371	570	0.0800
YELLOW PERCH	2B1-035	LAKE NITA	S	1	139	37	0.0002
YELLOW PERCH	2B1-035	LAKE NITA	S	1	138	35	0.1600
YELLOW PERCH	2B1-035	LAKE NITA	S	1	142	41	0.0002
YELLOW PERCH	2B1-035	LAKE NITA	S	1	143	36	0.0004

YELLOW PERCH	2B1-035	LAKE NITA	S	1	126	24	0.1500
YELLOW PERCH	2B1-035	LAKE NITA	S	1	144	38	0.1200
YELLOW PERCH	2B1-035	LAKE NITA	S	1	140	32	0.2000
YELLOW PERCH	2B1-035	LAKE NITA	S	1	144	38	0.0018
YELLOW PERCH	2B1-035	LAKE NITA	S	1	146	38	0.1000
YELLOW PERCH	2B1-035	LAKE NITA	S	1	141	35	0.0900
YELLOW PERCH	2B1-035	LAKE NITA	S	1	135	29	0.2000
YELLOW PERCH	2B1-035	LAKE NITA	S	1	145	37	0.1100
YELLOW PERCH	2B1-035	LAKE NITA	S	2	201	124	0.0000
YELLOW PERCH	2B1-035	LAKE NITA	S	2	195	97	0.0012
YELLOW PERCH	2B1-035	LAKE NITA	S	2	191	108	0.1530
YELLOW PERCH	2B1-035	LAKE NITA	S	2	229	160	0.0600
YELLOW PERCH	2B1-035	LAKE NITA	S	2	191	88	0.0001
YELLOW PERCH	2B1-035	LAKE NITA	S	2	240	200	0.4900
YELLOW PERCH	2B1-035	LAKE NITA	S	2	242	220	0.4200
YELLOW PERCH	2B1-035	LAKE NITA	S	2	231	134	0.6000
YELLOW PERCH	2B1-035	LAKE NITA	S	2	240	160	0.3200
YELLOW PERCH	2B1-035	LAKE NITA	S	3	286	380	0.6300
YELLOW PERCH	2B1-035	LAKE NITA	S	4	296	460	0.0500
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	2	135	22	0.5900
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	2	115	16	0.5600
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	2	117	16	0.2500
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	2	118	15	0.5800
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	2	120	14	0.5400
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	2	116	13	0.7200
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	4	116	16	0.4500
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	4	112	14	0.4200
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	5	182	53	0.6600
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	7	312	409	2.3600
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	7	180	62	1.0100
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	7	203	98	0.7500
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	8	241	151	1.0000
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	8	292	331	1.1900
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	9	335	434	2.2500
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	9	275	249	1.4200
YELLOW PERCH	2B1-039	WEST BRANCH LAKES (SW)	D	11	278	216	1.8900
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	1	88	6	0.3300
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	1	85	6	0.1900
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	2	92	8	0.1800
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	2	90	7	0.2000
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	2	115	13	0.2500
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	2	91	8	0.2000
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	3	117	18	0.3100
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	3	111	14	0.3900
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	3	115	12	0.2000
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	3	118	14	0.2200
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	3	115	13	0.3200
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	3	109	11	0.0900
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	4	113	13	0.2100
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	4	111	14	0.3400
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	5	166	37	0.3400
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	6	238	173	0.9400
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	7	166	33	0.0700
YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	7	165	46	0.0800

YELLOW PERCH	2B1-040	WEST BRANCH LAKES (SE)	D	11	348	470	1.9400
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	2	111	13	0.3800
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	2	107	11	0.4500
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	3	110	13	0.5000
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	3	111	11	0.6700
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	4	105	10	0.5800
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	5	180	54	0.1200
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	5	105	10	0.8400
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	6	133	20	0.1600
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	6	130	18	0.1300
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	6	119	13	0.5000
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	6	103	9	0.7100
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	6	110	11	0.9700
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	7	168	41	0.6300
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	7	166	41	0.5500
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	7	110	12	0.2400
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	8	257	174	1.0800
YELLOW PERCH	2B1-041	TRIANGLE LAKE	S	9	290	285	1.2800
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	123	17	0.2900
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	123	18	0.1200
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	83	6	0.2900
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	82	5	0.4200
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	85	5	0.3300
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	80	5	0.3400
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	124	19	0.2500
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	84	5	0.3900
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	1	123	18	0.2000
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	2	170	54	0.3100
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	2	171	49	0.3100
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	2	175	56	0.4100
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	2	125	18	0.2300
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	2	170	52	0.4000
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	3	241	174	0.5400
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	3	208	94	0.3200
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	3	176	57	0.3800
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	3	175	57	0.4900
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	3	224	129	0.4100
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	4	200	82	0.5400
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	4	246	181	0.7600
YELLOW PERCH	2B1-047	JOHNSON LAKE	S	5	263	224	0.6600
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	123	20	0.2800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	131	25	0.2800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	122	22	0.3800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	121	21	0.3200
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	121	22	0.2900
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	122	22	0.2800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	119	21	0.3200
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	130	24	0.2900
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	131	25	0.2300
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	130	25	0.2600
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	118	19	0.2700
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	130	25	0.2600
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	123	24	0.3100
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	129	22	0.2900

YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	123	22	0.2800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	123	21	0.0600
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	123	21	0.0500
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	122	23	0.2700
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	130	26	0.3600
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	130	25	0.2000
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	1	116	17	0.2800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	3	176	47	0.2600
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	3	176	53	0.4000
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	3	149	34	0.0700
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	3	150	33	0.4200
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	3	150	33	0.1000
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	4	188	56	0.3800
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	4	172	42	0.3700
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	151	33	0.5000
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	185	57	0.1300
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	149	31	0.5200
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	129	24	0.3100
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	150	35	0.5100
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	171	40	0.2400
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	196	75	0.1700
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	151	31	0.5100
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	5	150	34	0.4100
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	6	173	58	0.0900
YELLOW PERCH	2B1-052	PECK AND RYE LAKE	S	8	180	64	0.2900
YELLOW PERCH	2B1-064	MALLARD LAKE	S	0	89	7	0.2500
YELLOW PERCH	2B1-064	MALLARD LAKE	S	1	114	12	0.1900
YELLOW PERCH	2B1-064	MALLARD LAKE	S	1	123	19	0.3000
YELLOW PERCH	2B1-064	MALLARD LAKE	S	1	125	19	0.4000
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	123	20	0.4600
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	132	23	0.3200
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	120	18	0.5700
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	156	39	0.4000
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	130	22	0.0800
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	164	48	0.1100
YELLOW PERCH	2B1-064	MALLARD LAKE	S	2	150	34	0.0400
YELLOW PERCH	2B1-064	MALLARD LAKE	S	3	191	55	0.4500
YELLOW PERCH	2B1-064	MALLARD LAKE	S	3	148	32	0.2330
YELLOW PERCH	2B1-064	MALLARD LAKE	S	3	172	54	0.5300
YELLOW PERCH	2B1-064	MALLARD LAKE	S	3	150	35	0.2100
YELLOW PERCH	2B1-064	MALLARD LAKE	S	4	195	84	0.3400
YELLOW PERCH	2B1-064	MALLARD LAKE	S	4	187	65	0.4400
YELLOW PERCH	2B1-064	MALLARD LAKE	S	5	150	36	0.2600
YELLOW PERCH	2B1-064	MALLARD LAKE	S	6	185	56	0.5200
YELLOW PERCH	2B1-064	MALLARD LAKE	S	6	185	58	0.7700
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	1	95	8	0.1900
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	1	98	10	0.0700
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	1	100	10	0.1500
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	1	100	10	0.1700
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	2	115	15	0.4000
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	2	116	15	0.1100
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	117	14	0.2700
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	119	16	0.4000
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	155	38	0.2000

YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	127	20	0.1300
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	98	9	0.2900
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	115	14	0.1100
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	127	20	0.0700
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	3	125	20	0.1900
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	7	146	29	0.6900
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	7	141	33	0.2700
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	7	146	35	0.5100
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	7	161	43	0.1800
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	8	158	42	0.2800
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	8	171	52	0.4100
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	8	201	73	0.8100
YELLOW PERCH	2B2-007	TOIVOLA LAKES (WEST)	S	9	176	53	0.3600
YELLOW PERCH	2B2-038	OTTER LAKE	D	1	105	12	0.0800
YELLOW PERCH	2B2-038	OTTER LAKE	D	1	117	14	0.1000
YELLOW PERCH	2B2-038	OTTER LAKE	D	2	123	19	0.1300
YELLOW PERCH	2B2-038	OTTER LAKE	D	3	127	21	0.1700
YELLOW PERCH	2B2-038	OTTER LAKE	D	3	123	18	0.2900
YELLOW PERCH	2B2-038	OTTER LAKE	D	4	117	18	0.0300
YELLOW PERCH	2B2-038	OTTER LAKE	D	4	142	25	0.2500
YELLOW PERCH	2B2-038	OTTER LAKE	D	4	182	66	0.0200
YELLOW PERCH	2B2-038	OTTER LAKE	D	4	159	35	0.2400
YELLOW PERCH	2B2-038	OTTER LAKE	D	4	125	21	0.1500
YELLOW PERCH	2B2-038	OTTER LAKE	D	5	180	56	0.2900
YELLOW PERCH	2B2-038	OTTER LAKE	D	5	153	29	0.4800
YELLOW PERCH	2B2-038	OTTER LAKE	D	5	197	74	0.7500
YELLOW PERCH	2B2-038	OTTER LAKE	D	6	150	31	0.3600
YELLOW PERCH	2B2-038	OTTER LAKE	D	7	179	57	0.3100
YELLOW PERCH	2B2-038	OTTER LAKE	D	7	233	122	0.6200
YELLOW PERCH	2B2-038	OTTER LAKE	D	8	191	72	0.5400
YELLOW PERCH	2B2-038	OTTER LAKE	D	9	219	111	0.8300
YELLOW PERCH	2B2-038	OTTER LAKE	D	9	262	205	1.1600
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	4	141	26	0.6000
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	4	113	13	0.4200
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	4	143	27	0.0600
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	4	151	30	0.1100
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	5	155	42	0.6300
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	5	162	48	0.1800
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	5	161	46	0.2200
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	6	175	53	0.3600
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	6	180	61	0.3100
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	6	160	44	0.1300
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	6	162	43	0.4200
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	6	175	51	0.1500
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	7	175	55	0.0500
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	7	170	52	0.0400
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	7	185	57	0.2800
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	7	180	66	0.0900
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	7	239	146	0.8000
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	7	189	63	0.0300
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	8	155	39	0.2000
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	8	182	60	0.0200
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	9	240	160	0.8600
YELLOW PERCH	2B2-044	QUINLAN LAKE	S	9	295	300	0.0900

YELLOW PERCH	2B2-044	QUINLAN LAKE	S	9	291	300	0.0900
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	1	114	15	0.0008
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	3	108	13	0.0400
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	3	112	13	0.0700
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	3	109	14	0.0900
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	4	114	14	0.0400
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	4	110	14	0.1100
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	5	153	39	0.0400
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	5	170	54	0.0500
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	5	184	61	0.1700
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	186	68	0.0200
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	156	41	0.0200
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	157	47	0.0200
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	153	40	0.0300
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	158	40	0.0600
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	165	44	0.0600
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	6	166	47	0.0001
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	7	153	37	0.0400
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	7	152	36	0.0900
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	7	176	61	0.0300
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	7	164	49	0.0300
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	7	173	49	0.0400
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	7	180	66	0.0100
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	8	171	59	0.0200
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	9	172	53	0.0500
YELLOW PERCH	2B2-049	CRANBERRY LAKE	S	11	170	53	0.0400
YELLOW PERCH	2B2-061	(NO NAME)	D	*	253	183	1.5800
YELLOW PERCH	2B2-061	(NO NAME)	D	*	285	262	1.1900
YELLOW PERCH	2B2-061	(NO NAME)	D	2	83	5	0.3100
YELLOW PERCH	2B2-061	(NO NAME)	D	2	87	6	0.3800
YELLOW PERCH	2B2-061	(NO NAME)	D	2	97	8	0.4400
YELLOW PERCH	2B2-061	(NO NAME)	D	3	122	17	0.2000
YELLOW PERCH	2B2-061	(NO NAME)	D	3	113	13	0.1900
YELLOW PERCH	2B2-061	(NO NAME)	D	4	126	18	0.3000
YELLOW PERCH	2B2-061	(NO NAME)	D	4	180	49	0.2300
YELLOW PERCH	2B2-061	(NO NAME)	D	5	102	10	0.0500
YELLOW PERCH	2B2-061	(NO NAME)	D	6	147	28	0.2700
YELLOW PERCH	2B2-061	(NO NAME)	D	6	166	39	0.1700
YELLOW PERCH	2B2-061	(NO NAME)	D	7	237	126	1.0700
YELLOW PERCH	2B2-061	(NO NAME)	D	8	201	71	0.6800
YELLOW PERCH	2B2-061	(NO NAME)	D	8	257	138	1.0200
YELLOW PERCH	2B2-061	(NO NAME)	D	8	234	120	0.8600
YELLOW PERCH	2B2-061	(NO NAME)	D	9	220	99	0.2900
YELLOW PERCH	2B2-061	(NO NAME)	D	9	222	103	0.8300
YELLOW PERCH	2B2-061	(NO NAME)	D	10	302	366	1.2600
YELLOW PERCH	2B2-061	(NO NAME)	D	10	259	194	0.6300
YELLOW PERCH	2B2-061	(NO NAME)	D	10	284	225	1.3100
YELLOW PERCH	2B2-061	(NO NAME)	D	10	296	268	1.5000
YELLOW PERCH	2B2-061	(NO NAME)	D	10	280	262	0.7900
YELLOW PERCH	2B2-061	(NO NAME)	D	10	256	148	1.3600
YELLOW PERCH	2B2-061	(NO NAME)	D	10	195	70	0.7900
YELLOW PERCH	2B2-061	(NO NAME)	D	11	273	232	1.7900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	2	108	10	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	2	114	13	0.1700

YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	2	107	10	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	2	111	10	0.1700
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	2	112	12	0.1500
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	113	12	0.2100
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	115	13	0.1100
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	115	15	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	129	22	0.1500
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	122	15	0.1900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	110	13	0.1900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	121	17	0.1000
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	115	14	0.1300
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	112	14	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	111	12	0.0700
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	120	16	0.1000
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	128	20	0.1100
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	121	15	0.1300
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	122	19	0.0700
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	111	13	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	115	15	0.1300
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	125	19	0.0900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	3	121	17	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	121	17	0.1200
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	118	16	0.0900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	131	21	0.1300
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	120	17	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	106	12	0.0800
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	121	16	0.1500
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	130	21	0.1700
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	118	14	0.1600
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	125	19	0.1400
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	135	24	0.0900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	127	18	0.1500
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	4	171	44	0.2000
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	5	162	39	0.1800
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	5	129	18	0.0900
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	5	187	63	0.4100
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	6	194	80	0.3400
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	6	215	103	0.5200
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	7	175	72	0.3000
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	7	190	82	0.3200
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	7	201	76	0.3800
YELLOW PERCH	2B2-075	RICHARDSON LAKE	S	8	240	133	0.5300
YELLOW PERCH	2B2-079	PINE LAKE	S	*	124	21	0.0800
YELLOW PERCH	2B2-079	PINE LAKE	S	1	121	19	0.0900
YELLOW PERCH	2B2-079	PINE LAKE	S	1	120	19	0.0800
YELLOW PERCH	2B2-079	PINE LAKE	S	1	112	15	0.1100
YELLOW PERCH	2B2-079	PINE LAKE	S	1	122	20	0.0600
YELLOW PERCH	2B2-079	PINE LAKE	S	2	127	22	0.1200
YELLOW PERCH	2B2-079	PINE LAKE	S	4	150	34	0.1600
YELLOW PERCH	2B2-079	PINE LAKE	S	4	172	54	0.1400
YELLOW PERCH	2B2-079	PINE LAKE	S	4	158	35	0.3700
YELLOW PERCH	2B2-079	PINE LAKE	S	5	165	47	0.1900
YELLOW PERCH	2B2-079	PINE LAKE	S	5	161	38	0.1700
YELLOW PERCH	2B2-079	PINE LAKE	S	5	167	51	0.3500

YELLOW PERCH	2B2-079	PINE LAKE	S	5	168	42	0.2100
YELLOW PERCH	2B2-079	PINE LAKE	S	5	158	35	0.3400
YELLOW PERCH	2B2-079	PINE LAKE	S	5	163	40	0.1400
YELLOW PERCH	2B2-079	PINE LAKE	S	5	167	45	0.1700
YELLOW PERCH	2B2-079	PINE LAKE	S	6	170	56	0.2400
YELLOW PERCH	2B2-079	PINE LAKE	S	9	211	86	0.4900
YELLOW PERCH	2B2-079	PINE LAKE	S	11	324	520	0.6700
YELLOW PERCH	2B2-082	(NO NAME)	D	4	147	29	0.1500
YELLOW PERCH	2B2-082	(NO NAME)	D	4	135	23	0.1000
YELLOW PERCH	2B2-082	(NO NAME)	D	4	168	45	0.2300
YELLOW PERCH	2B2-082	(NO NAME)	D	4	168	40	0.2700
YELLOW PERCH	2B2-082	(NO NAME)	D	5	174	46	0.3300
YELLOW PERCH	2B2-082	(NO NAME)	D	5	183	55	0.2300
YELLOW PERCH	2B2-082	(NO NAME)	D	6	185	56	0.2600
YELLOW PERCH	2B2-082	(NO NAME)	D	8	167	47	0.4900
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	1	150	30	0.3000
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	1	113	13	0.1900
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	1	116	14	0.1700
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	1	110	13	0.2400
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	1	112	13	0.1000
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	2	154	34	0.2500
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	2	150	29	0.3100
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	4	155	33	0.3500
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	4	181	75	0.4600
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	4	152	32	0.3300
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	4	180	61	0.4100
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	5	187	62	0.3300
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	6	181	40	0.4300
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	7	214	109	0.3400
YELLOW PERCH	2B2-090	ELEVENMILE LAKE	S	9	314	380	0.2900
YELLOW PERCH	2B2-098	DELENE LAKE	S	2	103	11	0.0500
YELLOW PERCH	2B2-098	DELENE LAKE	S	2	96	8	0.0900
YELLOW PERCH	2B2-098	DELENE LAKE	S	2	109	10	0.0600
YELLOW PERCH	2B2-098	DELENE LAKE	S	2	112	17	0.0300
YELLOW PERCH	2B2-098	DELENE LAKE	S	2	115	11	0.0400
YELLOW PERCH	2B2-100	HERBERT LAKE	S	1	130	21	0.1900
YELLOW PERCH	2B2-100	HERBERT LAKE	S	1	110	15	0.2000
YELLOW PERCH	2B2-100	HERBERT LAKE	S	1	120	17	0.1500
YELLOW PERCH	2B2-100	HERBERT LAKE	S	1	117	19	0.1400
YELLOW PERCH	2B2-100	HERBERT LAKE	S	2	135	26	0.2000
YELLOW PERCH	2B2-100	HERBERT LAKE	S	2	135	27	0.1500
YELLOW PERCH	2B2-100	HERBERT LAKE	S	2	165	45	0.2800
YELLOW PERCH	2B2-100	HERBERT LAKE	S	2	165	44	0.3000
YELLOW PERCH	2B2-100	HERBERT LAKE	S	2	140	28	0.2300
YELLOW PERCH	2B2-100	HERBERT LAKE	S	2	128	24	0.1800
YELLOW PERCH	2B2-100	HERBERT LAKE	S	3	168	46	0.1730
YELLOW PERCH	2B2-100	HERBERT LAKE	S	3	183	65	0.3400
YELLOW PERCH	2B2-100	HERBERT LAKE	S	3	188	70	0.3200
YELLOW PERCH	2B2-100	HERBERT LAKE	S	4	196	75	0.2300
YELLOW PERCH	2B2-100	HERBERT LAKE	S	4	198	88	0.3600
YELLOW PERCH	2B2-100	HERBERT LAKE	S	5	205	88	0.4100
YELLOW PERCH	2B2-100	HERBERT LAKE	S	5	190	73	0.1300
YELLOW PERCH	2B2-100	HERBERT LAKE	S	6	207	99	0.0200
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	1	116	16	0.0900

YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	1	126	17	0.1000
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	1	118	17	0.1000
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	1	114	15	0.1400
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	2	161	48	0.2400
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	2	112	14	0.1000
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	2	119	17	0.1300
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	2	163	42	0.2000
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	2	122	17	0.1500
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	3	161	48	0.1600
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	5	166	53	0.2600
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	5	166	47	0.2900
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	5	168	55	0.1900
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	5	165	44	0.0900
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	6	168	45	0.5300
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	6	200	87	0.1400
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	6	189	71	0.1000
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	6	180	58	0.3900
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	7	207	88	0.4600
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	7	196	84	0.4300
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	8	241	124	0.0600
YELLOW PERCH	2B3-009	GRAND SABLE LAKE	D	9	181	63	0.4300
YELLOW PERCH	2B3-012	ROUND LAKE	D	1	99	8	0.2500
YELLOW PERCH	2B3-012	ROUND LAKE	D	1	104	10	0.1600
YELLOW PERCH	2B3-012	ROUND LAKE	D	1	109	12	0.1100
YELLOW PERCH	2B3-012	ROUND LAKE	D	2	126	20	0.1800
YELLOW PERCH	2B3-012	ROUND LAKE	D	2	140	27	0.1600
YELLOW PERCH	2B3-012	ROUND LAKE	D	2	144	30	0.1900
YELLOW PERCH	2B3-012	ROUND LAKE	D	2	134	23	0.1100
YELLOW PERCH	2B3-012	ROUND LAKE	D	2	127	20	0.1800
YELLOW PERCH	2B3-012	ROUND LAKE	D	3	120	17	0.1200
YELLOW PERCH	2B3-012	ROUND LAKE	D	3	116	15	0.1600
YELLOW PERCH	2B3-012	ROUND LAKE	D	5	131	22	0.0300
YELLOW PERCH	2B3-012	ROUND LAKE	D	7	252	190	0.4600
YELLOW PERCH	2B3-013	FOX LAKE	C	2	111	12	0.1700
YELLOW PERCH	2B3-013	FOX LAKE	C	3	113	14	0.2100
YELLOW PERCH	2B3-013	FOX LAKE	C	3	110	13	0.2000
YELLOW PERCH	2B3-013	FOX LAKE	C	3	115	12	0.1500
YELLOW PERCH	2B3-013	FOX LAKE	C	3	110	14	0.2500
YELLOW PERCH	2B3-013	FOX LAKE	C	3	120	15	0.4700
YELLOW PERCH	2B3-013	FOX LAKE	C	4	137	22	0.2400
YELLOW PERCH	2B3-013	FOX LAKE	C	4	135	20	0.4100
YELLOW PERCH	2B3-013	FOX LAKE	C	4	143	26	0.2500
YELLOW PERCH	2B3-013	FOX LAKE	C	4	135	22	0.3300
YELLOW PERCH	2B3-013	FOX LAKE	C	7	192	73	0.6800
YELLOW PERCH	2B3-013	FOX LAKE	C	8	173	46	0.0100
YELLOW PERCH	2B3-013	FOX LAKE	C	8	217	105	0.210
YELLOW PERCH	2B3-013	FOX LAKE	C	11	309	410	1.220
YELLOW PERCH	2B3-020	BUTO LAKE	D	2	120	14	0.220
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	116	16	0.230
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	122	19	0.110
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	113	14	0.290
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	172	49	0.260
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	121	15	0.260
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	113	14	0.210

YELLOW PERCH	2B3-020	BUTO LAKE	D	3	132	20	0.2900
YELLOW PERCH	2B3-020	BUTO LAKE	D	3	126	19	0.1700
YELLOW PERCH	2B3-020	BUTO LAKE	D	5	156	40	0.1800
YELLOW PERCH	2B3-020	BUTO LAKE	D	5	168	42	0.2400
YELLOW PERCH	2B3-020	BUTO LAKE	D	12	326	400	1.4100
YELLOW PERCH	2B3-023	BONE LAKE	D	1	92	10	0.0100
YELLOW PERCH	2B3-023	BONE LAKE	D	1	91	10	0.0001
YELLOW PERCH	2B3-023	BONE LAKE	D	2	109	16	0.0100
YELLOW PERCH	2B3-023	BONE LAKE	D	2	106	13	0.0200
YELLOW PERCH	2B3-023	BONE LAKE	D	2	111	15	0.0200
YELLOW PERCH	2B3-023	BONE LAKE	D	2	114	18	0.0100
YELLOW PERCH	2B3-023	BONE LAKE	D	3	127	25	0.0200
YELLOW PERCH	2B3-023	BONE LAKE	D	4	197	100	0.1400
YELLOW PERCH	2B3-023	BONE LAKE	D	5	172	57	0.0800
YELLOW PERCH	2B3-023	BONE LAKE	D	5	174	50	0.0800
YELLOW PERCH	2B3-023	BONE LAKE	D	5	216	140	0.1400
YELLOW PERCH	2B3-023	BONE LAKE	D	6	175	58	0.2000
YELLOW PERCH	2B3-023	BONE LAKE	D	6	188	81	0.0500
YELLOW PERCH	2B3-023	BONE LAKE	D	6	171	69	0.0600
YELLOW PERCH	2B3-023	BONE LAKE	D	7	220	120	0.3300
YELLOW PERCH	2B3-023	BONE LAKE	D	7	215	105	0.0600
YELLOW PERCH	2B3-023	BONE LAKE	D	7	242	160	0.1600
YELLOW PERCH	2B3-023	BONE LAKE	D	9	211	93	0.1000
YELLOW PERCH	2B3-023	BONE LAKE	D	9	267	250	0.1900
YELLOW PERCH	2B3-023	BONE LAKE	D	9	260	200	0.3000
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	146	40	0.0500
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	145	40	0.0500
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	165	66	0.0300
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	155	54	0.0600
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	153	39	0.0500
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	145	41	0.0500
YELLOW PERCH	2B3-028	CATARACT BASIN	R	3	142	38	0.0400
YELLOW PERCH	2B3-028	CATARACT BASIN	R	4	146	41	0.0670
YELLOW PERCH	2B3-028	CATARACT BASIN	R	5	220	163	0.1300
YELLOW PERCH	2B3-028	CATARACT BASIN	R	5	176	86	0.1000
YELLOW PERCH	2B3-028	CATARACT BASIN	R	5	219	173	0.1300
YELLOW PERCH	2B3-028	CATARACT BASIN	R	5	175	81	0.0800
YELLOW PERCH	2B3-028	CATARACT BASIN	R	7	195	126	0.0600
YELLOW PERCH	2B3-028	CATARACT BASIN	R	8	261	299	0.2500
YELLOW PERCH	2B3-028	CATARACT BASIN	R	9	285	327	0.2200
YELLOW PERCH	2B3-028	CATARACT BASIN	R	9	281	335	0.1800
YELLOW PERCH	2B3-028	CATARACT BASIN	R	11	272	350	0.2400
YELLOW PERCH	2B3-028	CATARACT BASIN	R	11	276	340	0.2300
YELLOW PERCH	2B3-030	ISLAND LAKE	S	2	106	9	0.4000
YELLOW PERCH	2B3-030	ISLAND LAKE	S	3	107	13	0.2500
YELLOW PERCH	2B3-030	ISLAND LAKE	S	3	112	13	0.3500
YELLOW PERCH	2B3-030	ISLAND LAKE	S	3	129	18	0.3100
YELLOW PERCH	2B3-030	ISLAND LAKE	S	4	110	12	0.2200
YELLOW PERCH	2B3-030	ISLAND LAKE	S	4	120	18	0.3400
YELLOW PERCH	2B3-030	ISLAND LAKE	S	4	124	23	0.4700
YELLOW PERCH	2B3-030	ISLAND LAKE	S	6	158	38	0.4700
YELLOW PERCH	2B3-030	ISLAND LAKE	S	8	182	65	0.8500
YELLOW PERCH	2B3-030	ISLAND LAKE	S	8	176	59	0.5100
YELLOW PERCH	2B3-031	TWIN LAKES	D	2	106	10	0.1600

YELLOW PERCH	2B3-031	TWIN LAKES	D	2	120	14	0.2000
YELLOW PERCH	2B3-031	TWIN LAKES	D	2	120	15	0.1700
YELLOW PERCH	2B3-031	TWIN LAKES	D	3	105	10	0.2400
YELLOW PERCH	2B3-031	TWIN LAKES	D	3	112	11	0.2300
YELLOW PERCH	2B3-031	TWIN LAKES	D	4	177	51	0.5100
YELLOW PERCH	2B3-031	TWIN LAKES	D	5	146	25	0.1600
YELLOW PERCH	2B3-031	TWIN LAKES	D	6	157	49	0.2500
YELLOW PERCH	2B3-031	TWIN LAKES	D	6	192	57	0.5200
YELLOW PERCH	2B3-031	TWIN LAKES	D	6	165	45	0.3100
YELLOW PERCH	2B3-031	TWIN LAKES	D	7	166	47	0.4400
YELLOW PERCH	2B3-031	TWIN LAKES	D	7	216	103	0.3300
YELLOW PERCH	2B3-031	TWIN LAKES	D	8	180	58	0.6600
YELLOW PERCH	2B3-031	TWIN LAKES	D	9	230	132	0.2300
YELLOW PERCH	2B3-034	KLONDIKE LAKE	D	4	165	46	0.1000
YELLOW PERCH	2B3-034	KLONDIKE LAKE	D	7	251	203	0.2600
YELLOW PERCH	2B3-034	KLONDIKE LAKE	D	8	169	46	0.1000
YELLOW PERCH	2B3-034	KLONDIKE LAKE	D	9	267	221	0.3300
YELLOW PERCH	2B3-034	KLONDIKE LAKE	D	11	220	108	0.4000
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	*	110	13	0.0100
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	2	106	12	0.0600
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	2	101	11	0.0700
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	3	121	16	0.0800
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	3	115	15	0.0600
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	3	109	14	0.0100
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	3	117	16	0.2000
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	3	119	16	0.0800
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	3	113	12	0.0300
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	4	125	19	0.0200
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	5	110	13	0.1000
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	6	228	134	0.1500
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	6	125	18	0.0700
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	8	198	77	0.3300
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	8	161	43	0.2600
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	8	232	121	0.4400
YELLOW PERCH	2B3-037	RUMBLE LAKE	D	10	217	108	0.2700
YELLOW PERCH	2B3-055	(NO NAME)	D	2	149	35	0.1500
YELLOW PERCH	2B3-055	(NO NAME)	D	2	150	35	0.1500
YELLOW PERCH	2B3-055	(NO NAME)	D	2	146	39	0.0500
YELLOW PERCH	2B3-055	(NO NAME)	D	2	145	34	0.1800
YELLOW PERCH	2B3-055	(NO NAME)	D	2	155	43	0.1300
YELLOW PERCH	2B3-055	(NO NAME)	D	3	237	184	0.2600
YELLOW PERCH	2B3-055	(NO NAME)	D	3	206	103	0.3300
YELLOW PERCH	2B3-055	(NO NAME)	D	3	178	60	0.3100
YELLOW PERCH	2B3-055	(NO NAME)	D	3	204	118	0.2900
YELLOW PERCH	2B3-055	(NO NAME)	D	3	195	96	0.2200
YELLOW PERCH	2B3-055	(NO NAME)	D	4	211	112	0.3500
YELLOW PERCH	2B3-055	(NO NAME)	D	4	209	117	0.3200
YELLOW PERCH	2B3-055	(NO NAME)	D	4	202	111	0.2500
YELLOW PERCH	2B3-055	(NO NAME)	D	4	195	99	0.2800
YELLOW PERCH	2B3-057	TWIN LAKE	D	3	170	50	0.0600
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	2	115	11	0.0900
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	2	129	18	0.0100
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	118	11	0.2900
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	115	13	0.0200

YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	118	12	0.1000
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	114	13	0.0500
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	116	10	0.0200
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	116	11	0.0900
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	3	109	9	0.0200
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	4	125	13	0.1200
YELLOW PERCH	2B3-071	OSTRANDER LAKE	S	10	196	74	0.1900

* Denotes a missing value.

TL - total length

WT - weight

S - seepage

D - drainage

R - reservoir

*U.S. GOVERNMENT PRINTING OFFICE: 1991-548-187/25603