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A STATE-WIDE ASSESSMENT OF WATER CLARITY TRENDS IN MICHIGAN LAKES: 1974-2001

By

Laura Christine Bruhn

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ABSTRACT

A STATE-WIDE ASSESSMENT OF WATER CLARITY TRENDS IN MICHIGAN LAKES: 1974-2001

By

Laura Christine Bruhn

The approximately 11,000 inland lakes in the state of Michigan are valued ecosystems yet are susceptible to lake degradation due to anthropogenic stresses. Most data on water quality trends in Michigan have focused on the Great Lakes. There is little information as to how Michigan's inland lakes have changed over time. My first objective was to assess historical water quality trends of 71 inland lakes using volunteer-collected Secchi depth data from Michigan's Cooperative Lakes Monitoring Program (CLMP) with a data span from 1974 to 2001. State-wide, lake clarity in Michigan has been increasing since the 1970s. Of the individual lake trends, 31% are increasing in clarity, 6% are decreasing in clarity, and 63% have no trend. The influence of factors driving the trends such as ecoregions, land use, and non-indigenous species were examined. Ecoregions showed more influence on the clarity of lakes than did land use and the mean Secchi depth was lower for the southern ecoregion section. These analyses did not detect a strong effect of land use on water clarity in lakes across the state. Volunteer monitoring programs an invaluable contribution to water quality information. Results of this study have helped elucidate anthropogenic impacts on inland lakes in Michigan and can assist in setting priorities for statewide lake monitoring.

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Last but not least, I thank my family for their endless support and encouragement during my studies.

PREFACE

Chapter 1 of this thesis provides a background and literature review to the topic. Chapter 2 is written in manuscript form that will be submitted to the journal of the North American Lake Management Society: Lake and Reservoir Management. It is written in the style and format consistent with the journal. The authors are L.C. Bruhn, P.A. Soranno, and J.F. Bartholic. Chapter three includes the future research directions, conclusions, and management implications of the research. Appendix A contains the tables and Appendix B contains the figures referenced in Chapter 2. Appendix C contains results from the sampling frequency analysis. Appendix D contains the metadata reports for the CLMP database that I compiled, which describes in detail the procedures for compiling the data for my analyses. It also lists the description of Excel files and the worksheets within the files. Appendix E contains the summer Secchi depth average (Ave) for each year, for each lake. Appendix E also lists the new key code (NKC), number of samples per summer (n), standard deviation (St.Dev) and standard error (St.Err) for each year.

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CHAPTER 1: INTRODUCTION

Introduction

We depend on water resources for a multitude of uses including irrigation, drinking supply, energy production, recreation, industry, wildlife habitat, and aesthetics. Even though the availability of adequate water quantity and quality are necessities of life-sustaining importance, approximately 40% of the lakes, rivers and estuaries assessed in the United States do not meet basic water quality standards (USEPA, 2000). Rapid land development has resulted in increased pollution loads to our rivers, lakes, wetlands and reservoirs, threatening the value and use of these essential aquatic resources (NRC, 1992).

Water Quality Defined

Biologically and chemically, water quality is defined by a number of factors, and these parameters can generally indicate if a water body is degraded. What type of use of the water body is needed, or what type of assessment that is required, may influence which or how many characteristics are used to determine water quality. Common measurements include chlorophyll, clarity, coliform bacteria, conductivity, dissolved oxygen, hardness, nitrogen (ammonia nitrogen, nitrate, and nitrite), pH, phosphorus, temperature, and total suspended solids (Brooks et al., 1997). It is important to remember that a chemical constituent only becomes a pollutant when it reaches an undesirable level, and that definitions of water quality usually depend on if the water is acceptable for the stakeholder-defined designated use (Lee et al., 1982). Various water quality standards exist, based on many of these parameters, however they vary based on the use. For example drinking water and irrigation water have different standards.

From a regulatory and public awareness perspective, the US Environmental Protection Agency (USEPA) has set two goals that specifically relate to water quality. The first requires safe drinking water: "Every American public water system will provide water that is consistently safe to drink." (USEPA, 1996A). The second goal requires that "America's rivers, lakes, and coastal waters will support healthy communities of fish, plans and other aquatic life, and will support uses such as fishing, swimming, and drinking water supply for people. Wetlands will be protected and rehabilitated to protect wildlife habitat, reduce floods, and improve water quality. Ground waters will be cleaner for drinking and other beneficial uses." (USEPA, 1996A). The USEPA has set five distinct water quality objectives based on these goals and indicators for each, to help determine if these objects are being met.

Point and Non-Point Source Pollution

While anthropogenic uses of our water resources produce benefits to humans such as recreation, housing, and economic growth, they also generate pollution that necessitates watershed management. In recent years in the United States, much effort has been expended in reducing point sources of pollution. Point sources of pollution can be fairly easily identifiable back to a distinct point of origin, such as an industrial outfall or sewage treatment plant. This nature makes point sources relatively easier to monitor or set up control measures than non-point source pollution.

As a result of the effort to reduce and regulate point sources of pollution, non-point source (NPS) pollution has now become the largest threat to water quality (USEPA, 1996B). NPS pollution can be difficult to identify and control because it is diffuse and can originate from urban runoff, construction sites, agricultural land, leaking septic tanks, and atmospheric deposition. In Michigan, at least 86% of impaired (not meeting one or more designated uses) lake acres can be traced back to "inconclusive" pollutant sources, including atmospheric deposition, while point sources of pollutants only contribute approximately 4.4% (MDEQ, 2000). NPS pollution is also often influenced by seasonal land uses or climate changes, as well as significant storm events. Because NPS pollution occurs over such a wide area, and can be transported by variable ways, it is difficult to identify, manage, or regulate.

Due to the challenges of pinpointing sources, the management options for point and NPS pollution are numerous. The following is a general overview that includes examples of structural, vegetative and managerial options. Structural controls of point sources usually consist of a process of pre-treatment, primary, secondary, tertiary, sludge treatment, and waste disposal (Heathcote, 1998). Treatments can target the outfall pollution and/or focus on prevention strategies. Structural controls for urban NPS pollution can include storm sewer screens, porous surfaces, sediment basins, grassed waterways, and for agricultural NPS pollution, terraces, composting, waste lagoons, grassed waterways, and retention ponds (Heathcote, 1998). Vegetative controls for urban and agricultural NPS pollution can include filter strips, constructed wetlands, riparian buffers, cover crops, critical area planting, and crop rotations (Heathcote, 1998). Managerial controls can include proper timing and amount of pesticide and manure applications, drip irrigation, public educational programs, storm drain stenciling, nutrient trading, and erosion control in construction areas (Heathcote, 1998).

Eutrophication and Sedimentation of Lakes

Eutrophication and sedimentation of lakes are two key processes fueled by NPS pollution. Lakes, which have slower turnover and longer retention times than streams, can be more susceptible to degradation. Eutrophication can be a natural successional process, shifting lake waters from higher to lower clarity because increased nutrient levels promote greater plant and algal growth. However, eutrophication due to excessive nutrient levels of phosphorus and nitrogen can be greatly accelerated by human-induced pollution sources, causing harmful ecological effects such as low dissolved oxygen levels, fish kills, widespread algal blooms, and turbid waters (USEPA, 1996A). Algal blooms, because of their visibility, are often what the public first notices and raises in water quality concerns. Nationally, nutrients contribute most to impaired lake acres, 44%; metals are second, and sediments follow as the third most common lake pollutant (USEPA, 2000).

In many lakes, increased inputs of phosphorus have been shown to fuel eutrophication (Schindler, 1977). Yet, the algal productivity of lakes can also respond to both nitrogen and phosphorus inputs. Powers et al. (1972) conducted in-situ field experiments on lakes in Minnesota and Oregon, and all lakes responded positively in algal growth with additional of nitrogen, phosphorus, or the combination of both.

Eutrophication has also been shown to decrease biodiversity. Cichlid fish species diversity was lost in Lake Victoria due to eutrophication because the turbid waters interfered with mating, vision, and sexual selection (Seehausen, et al., 1997). Additionally, in a lake in China, macrozoobenthos species diversity decreased from 1960s levels as the lake became more eutrophic (Gong and Xie, 2001).

Sedimentation of lakes is also a significant problem. In the US, approximately 108 million acres of cropland are excessively eroding, resulting in 1.3 billion tons of erosion (NRCS 2000). The Natural Resource Conservation Service estimates that 60% of sedimentation originates from agricultural lands (NRCS 1997). Sediment loading increases turbidity in waters, thereby clogging fish gills, burying spawning beds, and interfering with fish foraging behavior (Horne and Goldman, 1994). In addition, sediments often transport adsorbed nutrients such as phosphorus, which exacerbate eutrophication when released in the water (Novotny and Olem, 1994).

Land Use and Water Quality of Lakes

Comparatively, lakes consist of a small portion of the landscape; nevertheless they provide many valuable uses. Recreational, industrial, residential, drinking water supplies, ecological habitat, and water storage are some of the ways humans depend on, and value lakes. However, these multitudes of uses often result in lake water quality impairment for either human or wildlife uses (NRC, 1992). Elevated levels of nutrients running off from a lake's watershed are often the cause of excess phytoplankton growth, and turbidity often originates from land uses in the watershed that may be causing accelerated erosion (Davies-Colley et al.,1993). Because of this, we often focus on the human impact of land uses on a lake's water quality, but both anthropogenic land use and natural land types influence water quality. These affects are outlined below.

Anthropogenic Land Use and Water Quality of Lakes

Urban land use

It is well documented that NPS pollution originating from both agricultural and urban land use decreases the quality of water bodies, which receive runoff containing nutrients, sediments, oils, salts, chemicals, pathogens, and other substances harmful to ecosystems (USEPA, 1996A). For example, Blais et al. (2000) determined that two lakes in Alberta became more eutrophic than their pre-1960s eutrophic state, as the land in their watersheds was developed into urban and agriculture. Urbanization creates impervious surfaces that increase the risk of contamination to surface waters due to increased water runoff volume and pollutant loadings. Michigan has a history of losing forested and agricultural land to urban uses. Since the 1950s, Michigan has lost 605,000 forested acres and is projected to lose an additional 1.4 million acres by 2050; urban land use has increased by 895,000 acres since 1950 and is projected to increase by 300,000 acres by the year 2050 (Mauldin et al., 1999). Impervious surfaces like pavement, roads, and rooftops prevent pollutants such as sediments and nutrients from infiltrating and being absorbed by vegetation and soil; instead, they move directly to receiving water bodies. For example, Arnell (1983) measured rainfall and runoff in five urban test watersheds and found greater runoff with increasing imperviousness. Water quality problems from urbanization can even be observed even in areas that are not intensely built up. Suburban residential areas are about 20% impervious, a relatively low level compared to commercial areas at about 85%, but water quality degradation can be detected starting at about 10 to 20% imperviousness (USEPA, 1996A).

Various studies have revealed the effect of urbanization on water quality in lakes. Hasler (1947) surveyed 37 lakes from Austria, England, Finland, Germany, Italy, Sweden, Switzerland, and the United States and found that urban drainage and runoff caused marked changes in the biology of the lakes. Most of these lakes changed from oligotrophic to eutrophic and experienced changes in plankton communities and algal growth resulting from cultural eutrophication (Hasler, 1947). Stemberger and Lazorchak (1994) specifically showed how zooplankton species composition could change in response to water quality conditions. The presence of certain species correlated to disturbance in the lake (fish stocking, agricultural, residential land use, and silvicultural) and could be used as an indicator of disturbance (Stemberger and Lazorchak, 1994).

The intensity or distance of development can dictate the extent of water quality changes. Over the 100-year time span of a paleolimnological study, lakes in watersheds that had changed more than 25% in residential land use increased in specific conductivity, pH, and trophic state, but lakes with less than 20% increase in residential land use did not show water quality changes (Siver et al., 1999). Dillon and Kirchner (1975) found that the export of phosphorus from agricultural and urban land use was at a minimum four times greater than forested land export, and increased depending on the intensity of land use. Hall et al. (1999) found that in a naturally eutrophic lake, land uses were a greater predictor of water quality than climate change, as determined by diatoms and chironomids, but the distance from point sources of pollution impacted the water quality changes.

Improvements in urban management practices can have an impact on water quality. In a paleolimnology study, a reservoir's watershed shifted from primarily agricultural to urban land use, starting in the 1950s, and the sediment core indicated decreased turbidity in the water, probably due to decreased erosion from agricultural activities and improved urban storm water management (Bradbury and Van Betre, 1997). Land development can also be a major source of sedimentation and turbidity to lakes; although sites are relatively small in size,

then can have high erosion rates if not managed properly. Byron and Goldman (1989) showed that the yield of nutrients and sediments from nonpoint sources increases with more erodable soils and disturbance, such as land development, and results in decreased water quality.

Residential land use has also been shown to impact lake bacteriological water quality. Hendry and Toth (1982) found high, but not exceeding contaminant levels of fecal coliform densities along stretches of the shoreline of a lake in Ontario. While the lake as a whole was not effected, the pollution distribution was important because of the swimming uses of the lake along the shoreline (Hendry and Toth, 1982). A study of Higgins Lake, Michigan had a similar spatial distribution of pollution from residential development. Minnerick (2001) found that rapid lakeshore residential development of up to 246% between 1970-1990 did degrade water quality in the shallow shoreline areas, but had not yet affected the whole lake, or the deeper basins.

Agricultural land use

The agriculture industry in the United States is a billion-dollar industry and produces food and fiber produces for the world. However, agricultural land use, be it either cropland, orchards, or animal operations can also transport pollutants to lakes and other water bodies, especially if not managed appropriately. The primary pollutants from agricultural activities are sediments, pesticides, nutrients, and pathogens.

Nitrogen fertilizer use in the United States increased twenty fold and use of phosphorus fertilizer more than tripled in the period 1945-93 (Puckett, 1995). This increased use of nitrogen and phosphorus fertilizers in the last half of the 20th century led to an incredible increase in agricultural productivity but also a substantial increase in potential for contamination of both ground and surface waters by nutrients.

Phosphorus has been shown to primarily travel through surface water runoff from the land, as opposed to nitrogen, which is usually lost through groundwater. Therefore, phosphorus is often the nutrient of greater concern for lakes fed by surface waters. In a study of nutrient dynamics through different land uses, Peterjohn and Correll (1984) found that cropland lost 64% of nitrogen though the harvested crop, 9.2% in surface runoff, and 26% in groundwater flow, compared to phosphorus losses of 84% in harvested crop, 16% in surface runoff and less than 1% in groundwater flow.

Sharpley et al. (1994) discusses how commercial fertilizers and manure leaving agricultural land via runoff contributes to the accelerated eutrophication of freshwaters by phosphorus inputs. For instance, Lake Okeechobee, Florida, transformed into a hypereutrophic state as runoff from cattle operations and vegetable crops transported excess levels of phosphorus and nitrogen (Havens et al., 1995). Agricultural land use can also be a source of sediment NPS pollution. Bradbury and Van Betre (1997) conducted a pollen, diatom, and grain size paleolimnology study to relate the water quality of a reservoir to changing land use in its watershed. From 1912 to 1950, the watershed was primarily

agricultural and the analysis indicated significant sedimentation in the lake (Bradbury and Van Betre, 1997).

Natural Land Use and Water Quality of Lakes

Forested land

Generally, both forested land and wetlands are known to have filtering properties that help remove pollutants before they enter water bodies. The vegetation of forested land can uptake nutrients through trees, ground shrubs and other vegetation. Little research exists on the effects of forested land and lakes. Most research involves the effectiveness of riparian buffer in filtering nutrient and sediment runoff into streams

As an example, Peterjohn and Correll (1984) investigated the transformations of the nutrients from riparian land to surface runoff. Nitrogen retention by the riparian forest was 89%, and retention of phosphorus was 80% (Peterjohn and Correll, 1984). In comparison, nitrogen retention by cropland was only 8%, and of phosphorus, 40% (Peterjohn and Correll, 1984). Lowrance et al. (1984) found similar results when studying a riparian forest's filtering capacity in Georgia. This research concluded that the riparian forest can store nutrients in the soil and vegetation over long periods of time and can prevent nutrients in agricultural runoff from reaching stream channels (Lowrance et al., 1984).

In a paleolimnological study, first looking at the year 1990, lakes in Connecticut had lower pH, specific conductivity and tropic state with increased forest cover (Siver et al., 1999). Over the 100-year time span of the analysis, lakes that had approximately 80% or more forested land in the watershed did not change in water chemistry (Siver et al., 1999). Not all forested land necessarily means undisturbed conditions, however. Watersheds with a history of logging and related soil disturbance can lead to accelerated runoff and nutrient loadings to streams and the lakes that they feed. (Leonard, et al., 1979).

Wetlands

Wetlands are often transition zones between terrestrial and aquatic landscapes, and because of their position on the land, they are often a collection point for runoff. Wetlands are a natural filtering system for runoff, both settling out sediments and up-taking nutrients through vegetation. Therefore, Secchi disk depths can be positively correlated with the extent of wetlands in the watershed (Detenbeck, 1993). However, the ability of wetlands to trap and process nutrients or sediments can depend on retention time. Jansson et al. (1994) found that water retention time was needed to remove nitrogen from runoff waters. Wetlands in regions or times of year where water flow is great may not have enough retention time to remove nutrients and sediments, compared to other regions or times of year.

Wetland waters are often colored with tannins because of low decomposition rates and accumulation of organic matter. When the waters from wetlands reach lakes, this can affect the lake color. Detenbeck et al. (1993) found that the color of lakes increased as the extent of wetlands and seasonally flooded wetlands increased in the lake's watershed. While algal productivity may be low, due to low nutrients and sediments, Secchi depth clarity values may still be low due to the colored waters.

Secchi depth data and land use

Despite evidence of site-specific impacts of land use on lake water quality, on a state-wide scale, or with use of Secchi data, correlations may not be as evident. Even monitoring land use changes over time with Secchi data may not pick up land use influences. Smeltzer et al. (1989) used data from volunteer monitoring to examine water clarity over 11 years in Vermont. They concluded that while Secchi depth had less temporal variability than phosphorus and chlorophyll, monitoring conducted over short time spans may have too much variability to provide early detection from land use change and non point source pollution impacts. Terrell et al. (2000) analyzed Secchi data from 127 Florida lakes over 30 years and despite excluding 13 lakes with known management changes such as point source removal or artificial fertilization, the analysis found no significant change in water clarity. The authors questioned whether even 30 years was enough time to detect land use influences, especially nonpoint source pollution with Secchi data.

CLMP Programs

Management is needed to identify, prevent, and control the sources of cultural eutrophication. Monitoring water conditions, including clarity, is an integral element of management strategies assessing baseline conditions and

tracking changes in lakes. Resources at state agencies often limited and agencies and staff cannot create long-term sampling programs for large numbers of lakes. Therefore, programs that take advantage of citizen volunteers are relatively inexpensive and consequently can be maintained for long periods of time at numerous locations. The USEPA supports lake volunteer monitoring programs and echoes these statements. From the Volunteer Lake Monitoring Handbook Methods Manual, “Volunteer programs have been found to be of enormous value to states, which can gain a baseline of useful information on lakes that might otherwise have gone unmonitored. States also benefit from new partnerships with educated and involved citizens who actively work to protect their lake resources.” (USEPA, 2002B).

These volunteer programs can generate volumes of useful data. For example, Florida's LAKEWATCH program began in 1986, and by 2000, the Florida Department of Environmental Protection estimated that over the past five years, of all the individuals and agencies, only the Department had provided more data on lakes than had the LAKEATCH program (Canfield et al., 2002). Volunteer lake monitoring programs exist in a number of other states. The state of Illinois has a volunteer lake monitoring program in cooperation with the Illinois EPA and local planning and development commissions. The data from Illinois's volunteer monitoring program has resulted in a number of lakes being identified for restoration or protection activities (Sefton et al., 1983). Wisconsin implemented a self-help lake monitoring program in 1986, in cooperation with the University of Wisconsin Extension and the Department of Natural Resources.

Minnesota has a volunteer-based Cooperative Lakes Monitoring Program (CLMP) in cooperation with the Minnesota Pollution Control Agency. Vermont's Lay Monitoring Program , Missouri's Lakes of Missouri Volunteer Program, and Rhode Island's Watershed watch are also examples of volunteer-based lake monitoring programs.

A volunteer program to monitor inland lake water clarity began in Michigan in 1974 as a citizen self-help program. This Cooperative Lakes Monitoring Program (CLMP) works with lake property owners, who measure water clarity levels using Secchi disk depth. More recently, the program also began monitoring phosphorus and chlorophyll. In 1992 this program partnered with the Michigan Lake and Stream Associations, Inc. (ML&SA), and is now a cooperative effort that includes the Michigan Department of Environmental Quality (MDEQ) and Michigan State University's Department of Fisheries and Wildlife.

The Secchi Disk

The Italian scientist P.A. Secchi invented a method to measure water clarity in 1865 when he lowered a bi-colored disk into the ocean and noted the depth at which it disappeared (Tyler, 1968). This method, using what is now called a Secchi disk, is an inexpensive and fairly simple tool to use for collecting lake data. The Secchi depth measures light attenuating particles in the water, such as phytoplankton or inorganic suspended solids, and the Secchi depth is inversely proportional to their concentration in the water column.

The Secchi disk is not a direct measure of water quality parameters such as chlorophyll, coliform bacteria, pH, nitrogen, phosphorus, dissolved oxygen, or temperature. Secchi disk readings are also influenced by natural organic color of the waters (Brezonik, 1978). However, various studies have shown Secchi depth decreases as lakes become eutrophic (Beeton, 1965; Edmondson, 1970) or with nutrient additions (Cruikshank, 1988). When used appropriately, and when aware of its limitations, the Secchi disk is a robust, easily conducted measurements of a lake's clarity, that over time can provide a useful record of seasonal plankton cycles and sediment influxes (Preisendorfer, 1986). Secchi disk measurements can also be used to determine lake trophic state indices (Carlson, 1977).

Thesis Objective

The approximately 11,000 inland lakes in the state of Michigan are ecosystems susceptible to lake degradation due to anthropogenic stresses. Extensive data are available through Michigan's CLMP, however, these data have not been analyzed comprehensively. Therefore there is very little understanding of how Michigan's inland lakes have changed through time. In addition, published literature contains essentially no data or reviews about clarity trends of inland lakes in Michigan. This study will analyze these data to quantify trends and to identify factors contributing to the observed changes in lake water clarity. Specifically, I will examine how water clarity has changed through time since 1974 to 2001. I will also examine whether there are differences in water clarity in lakes in different ecoregions and in lakes with different land use. I will address three main questions in this study:

1. How has the water clarity of Michigan's inland lakes changed from 1974 to present?

2. Do lakes in different ecoregions have different water clarity? Have lakes in different ecoregions exhibited different trends in water clarity through time?

3. Can land use around lakes explain patterns in water clarity across the state?

Research Benefits

Organizing and compiling historical water quality data into a database can prove very useful for uses such as public education and information dissemination programs, identifying sources of pollution, and supporting research. Maas, et al (1991) discusses the challenges of determining water quality within watersheds, and the need for quality, long-term data that can be available to watershed managers. This research will analyze the only long-term monitoring data of inland lakes available in the state of Michigan.

Without knowledge-based, effective policy and Best Management Practices (BMPs) in place, lakes are at greater risk to cultural eutrophication and

sedimentation, resulting in degraded ecosystems, reduction of property values and loss of recreational spending revenue. This study will provide baseline data illustrating water clarity trends for the inland lakes of Michigan in the last ten to thirty years. This analysis will expand our knowledge of water quality trends in Michigan, as well as identify key biophysical factors correlated with increases or decrease in water quality in inland lakes. Results of this study will have three important benefits:

1. To improve our understanding of how lakes respond to changing anthropogenic stresses, which will be widely applicable to other regions, and will be disseminated through publications in the primary literature.

2. To help lake management agencies in Michigan set priorities for statewide lake monitoring.

3. To aid individual communities in Michigan to create watershed management plans for their lake or watershed. This latter effort will be facilitated through integrating our data and results into MSU's Institute of Water Research's interactive, web-based Geographic Information Systems (GIS) tool. This program uses an Internet based GIS system

to compile biophysical information on a sub-watershed level for educational and watershed planning purposes.

The following chapter is the manuscript for is written in manuscript form and will be submitted to the journal of the North American Lake Management Society: Lake and Reservoir Management. It is written in the style and format consistent for the journal.

CHAPTER 2: MANUSCRIPT

Introduction

The approximately 11,000 inland lakes in the state of Michigan are valued ecosystems yet are susceptible to lake degradation due to human-induced stresses such as point and nonpoint source pollution, exotic species invasions, water draw-downs, and shoreline erosion. The total sum of anthropogenic stressors can increase or decrease over time, and water quality will also be expected to change over time. However, most data on water quality trends in Michigan have focused on the Great Lakes. Less information is available on how Michigan's inland lakes have changed over time, or their response to anthropogenic stresses.

Monitoring water conditions such as water clarity is an integral element of management strategies assessing baseline conditions and tracking changes in lakes. Secchi disk depth is an inexpensive and fairly simple tool to use for measuring water clarity data. Although Secchi disk is a rough measure of both water clarity and water quality, when used appropriately, the Secchi disk is a robust, easily collected measure of a lake's clarity that can be effectively used to monitor trends in individual lake water clarity through time. However, resources at state agencies are often limited and agencies and staff cannot create long-term sampling programs for the large numbers of lakes that states like Michigan have. On the other hand, programs that take advantage of citizen volunteers are relatively inexpensive and consequently can be maintained for long periods of

time for a potentially large number of lakes. One program to monitor inland lake water clarity in Michigan began in 1974 as a citizen self-help program (current name: Cooperative Lakes Monitoring Program (CLMP), Michigan Department of Environmental Quality) works with lake property owners, who measure water clarity levels using Secchi disk depth. In 1992 this program partnered with the Michigan Lake and Stream Associations, Inc. (ML&SA), and is now a cooperative effort that includes the Michigan Department of Environmental Quality and Michigan State University's Department of Fisheries and Wildlife.

Citizen volunteer programs like Michigan's CLMP have been used in many states to collect lake data, and several studies have confirmed their validity and accuracy. For example, the Missouri Department of Natural Resources began a citizen lake-monitoring program in 1992, and part of the program included an evaluation of the reliability of volunteer-collected samples. During the 1992-1994 seasons, samples at 19 lakes were collected by citizen volunteers and personnel from the University of Missouri on approximately the same dates (Obrecht et al., 1998). No statistical differences were found between the volunteer data and the University-collected data (Obrecht et al., 1998). In another study, the quality of the volunteer-collected data through the Watershed Watch Program was also tested by staff from University of Rhode Island Cooperative Extension (Herron et al., 1994). The Secchi data collected by volunteers at 21 lakes was as representative of lake water quality as were the Extension staff's measurements (Herron et al., 1994). Finally, at Florida's LAKEWATCH program, Secchi depth samples taken by volunteers at 125 lakes were comparable to those taken by professionals and the mean values were strongly correlated ($r > 0.99$) (Canfield et al., 2002).

One potential source of error with the volunteer's measurements may be change in volunteers over through time. Cruikshank (1988) compared the variability over 6 weeks, between two Secchi depth volunteers, one with eight months experience and one with six years. Of the 20 measurements, there was no significant difference between the Secchi means for the two observers.

Few sources of data on water quality in Michigan lakes that have been consistently collected, except in the CLMP program. Thus, a vast amount of data on Michigan lakes has remained unanalyzed and warrants further study. I address three main questions in this study:

1. How has the water clarity of Michigan's inland lakes changed from 1974 to present?

2. Do lakes in different ecoregions have different water clarity? Have lakes in different ecoregions exhibited different trends in water clarity through time?

3. Can land use around lakes explain patterns in water clarity across the state?

Based on patterns of anthropogenic stresses in Michigan, I expect the following results. I expect to see a number of lakes with decreasing clarity,

especially in urbanized areas due to increasing housing development pressures around lakes. However, due to new local zoning regulations that may limit or strictly regulate shoreline development, or national laws such as the Clean Water Act, a number of lakes may show significant increasing clarity.

One system of organizing the landscape into distinct units for management, comparisons, or conservation is by ecoregions. The ecosystem classification system of ecoregions categorizes the landscape into regions based on biotic and aboitic differences, including geology, soil, climate, vegetation, and animals (Albert, 1995). Other studies, for example, Heiskary et al. (1987), have found significant relationships between water quality and ecoregions, and I expect that these analyses for Michigan's ecoregions will show similar results. I also anticipate finding significant correlations between Secchi depth values and two of the more important land uses for water quality; residential/urban and agricultural land use. To answer the above questions, I compiled CLMP data from 1974-2001 for 71 lakes.

Methods

CLMP Volunteer Secchi Depth Collection

Although there is not complete control over the volunteers' sampling procedures, the MDEQ has developed standard procedures for Secchi depth measurements and volunteers are trained by MDEQ or ML&SA staff yearly. Volunteers collect Secchi depth readings weekly or bi-weekly (every other week) from mid-May through mid-September, although not all volunteers sample this

often. The Secchi depth is taken in the deepest basin of the lake and sometimes at additional stations. Readings are taken on the same day of each week and between 10:00am and 3:00pm to minimize sun angle differences between readings. Secchi data are recorded from an anchored boat and with some distance from the anchor to minimize turbidity created by dropping the anchor. The Secchi disk is lowered on the shaded side of the boat and volunteers are instructed not to wear sunglasses or tinted glasses in order to record more accurate and uniform readings. The Secchi disk is lowered until it disappears, raised until it appears again, and the reading is the average between these two depths.

Lake Selection for Analysis

From 1974 to 1994, most of the CLMP data are in hard copy form on original data sheets or summary sheets. The data have been stored in electronic form since 1995. The data from 1974 to 1995 were transferred into Microsoft Excel. All data are reported in feet, and volunteers are instructed to round readings to the nearest half-foot. Occasionally on the hard copy data, the Secchi depths were recorded to the inch, and for transfer into electronic form, values were rounded to the nearest quarter-foot. Because not all volunteers collect data on the same day of the week, data were recorded in a "week-of" format, using either Saturday or Sunday as the start of the week. On the occasional occurrence that lakes had more than one Secchi depth reading for the week, either the first date or the date closest to the day of week that other samples

were taken was used. The accuracy of data entry was checked twice, at the time of first entry on-screen, and later comparing hard copy to a printout of the entered data.

For these analyses, 71 lakes were selected from those participating in the CLMP program. Criteria for selecting these lakes were as follows: 1) Secchi depth data must have been available for a minimum of nine years 2) One of the nine years must have included the most recent year available, either 2000 or 2001. Nine years was chosen because it was a good cut-off point in the availability of the CLMP data, and it is an effective length of time to measure water quality trends. More years of data are required to detect more subtle shifts in water quality of 10 to 20% (Heiskary et al, 1994). For example, after 10 years of summer Secchi data collection, there is a 78% (weekly sampling) and 75% (biweekly sampling) chance of detecting a minimum of a 20% change in Secchi clarity (Heiskary et al, 1994). The location and characteristics of the 71 selected lakes are listed in Table 1. The selected lakes represent a good geographic dispersion across the lower peninsula of Michigan (Figure 1).

Analysis

Averaging

When lakes had multiple sampling stations, only measurements from the deepest basin were used for analysis. To capture the summer stratified season, only Secchi data from July, August, and September were used in all analyses. This time frame has been used in other studies (Heiskary et al., 1987) and

Stadelmann et al. (2001) found mid-July to mid-September was the best time to measure Secchi depths because lakes behave in the same way and in-lake variability is minimized. Kloiber et al. (2000) also found that Secchi depth transparency variability is relatively small during late summer (July 15-Septermber 15) and varied only about 20% from the mean.

Because the objective of my analyses was to examine annual changes in water clarity, I averaged all summer Secchi depths to calculate one Secchi value per summer. I included data for all years where there was a minimum of three samples over the three month summer period, allowing one missing month of sampling. Stadelmann et al. (2001) found that two measurements during the summer period could estimate the summer Secchi mean clarity with a relative error of 30%. Sixty-eight of 1,183 (5.8%) lake years of CLMP data had a skipped month of sampling, and the majority missed September. Only three lake years had the minimum of three samples and the average number of summer samples per lake year was 11. The data were converted from feet to meters, then for each lake, an annual mean Secchi depth was determined by averaging the summer data points.

Statistics

The data were normally distributed, and there was no seasonality because of the annual averaging. I used linear regressions and t-tests to analyze the data. Other studies have used regressions to examine water quality trends. For example, Francis et al. (1994) used regressions for their 30-year study on the

clarity trends of lake Pontchartrain. Also, Schindler et al. (1996) used regressions of 20-year datasets to determine the effect of climate change on lakes in northwestern Ontario. Finally, Byron and Goldman (1989) used regressions to evaluate the relationship between nutrient and sediment concentrations in runoff water and land disturbance.

For all analyses, a p-value of 0.1 or less was considered significant. The objective of these analyses was to examine general trends, not test hypotheses, therefore the 0.1 level was used. Even if the stricter 0.05 level was used, my basic conclusions remain the same since the majority of the results are still significant at the 0.05 level. The 0.1 level has also been used in similar trend analyses using volunteer-collected Secchi depth data (Heiskary and Lindbloom, 1993).

Time trends

To determine the presence of water clarity time trends for each of the 71 lakes, I regressed the annual Secchi depth means against year using Systat 9.0 (SPSS, 1998). I calculated trends for different datasets: 1) Data with all frequencies of sampling: one sample per month, two samples per month, and three or more samples per month 2) Only data from years that had a minimum of two samples or more per month. Table 2 (Appendix C) shows the data span of each lake and the number of years of data with each scenario. After the initial screening, one lake dropped below the minimum number of 9 years (Painter lake), and was only included in the ecoregion analysis.

I calculated a state-wide Secchi depth average of all lakes in approximately five year intervals (1974-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2001). To not bias the trend with the larger number of lakes sampled in more recent years, only the lakes (n=31) with Secchi data from each time interval were used (Figure 2). Because of the relatively short data span, it was more informative to look at change through time across 5-year intervals instead of decades. Also, only two lakes consistently had data every year, and only nine started sampling in 1974. The 5-year intervals allowed me to capture more of the lakes in a state-wide analysis. These lakes were fairly evenly distributed between ecoregion section six and seven, 55% and 45%, respectively, and there was at least one lake in each subsection. These lakes all had fairly high residential land use in the 100 m buffer, but otherwise land use was varied. For each lake, the average of the annual means for each time period was calculated. Then the average across all lakes for each time period was calculated. I then regressed the means from both scenarios against time.

The present-day state-wide Secchi depth average was calculated from the 1996-2001 Secchi depth means from all 71 lakes. To determine the trophic status of lakes, I used the following criteria: a Secchi depth of less than 2.5 meters is eutrophic, from 2.5 to 4.0 mesotrophic, and greater than 4.0 oligotrophic (Forsberg and Ryding, 1980).

Ecoregions

A commonly used ecoregion delineation is Omernik's (1987) ecoregions. Omernik defines ecoregions by land surface characteristics, soils, potential natural vegetation, and land use. In my analyses I sought to first detect the presence of water quality trends, and secondly, the effects of land use and ecoregion on them. Because Omernik's ecoregions includes land use, the two analyses would be confounded. Therefore, I used Albert's (1995) ecoregion delineations at the section and subsection level (Figure 1). Albert uses essentially the same criteria (vegetation, physiography, climate and bedrock geology), but omits land use in the delineation.

The current Secchi depth means for the state's ecoregion sections and subsections were calculated from the 1996-2001 Secchi depth means from all 71 lakes. This time interval was used to minimize the effect of time trends on the calculations. For the subsection analysis, ecoregions 7.1, 7.5, and 7.6 were dropped due to low sample size. I ran an analysis of variance on the subsection data, using Fisher's Least-Significant-Difference test, and a t-test on the section data. These means were also translated to trophic state based on Forsberg and Ryding's (1980) criteria. Using the results from the individual lake trend analysis, I analyzed lakes with increasing or decreasing trends by ecoregion section.

Land Use

The land use information was obtained from Michigan Resource Information System (MIRIS) data (MDNR, 1999). Land use information for MIRIS was obtained from aerial photos from 1978-1979, and a compilation of data from regional planning commissions. The land use/cover data were classified using level I classes in the Anderson Classification scheme (Anderson et al. 1976), which includes: urban, agriculture, non-forested vegetation (i.e., grasses and shrubs), forest, water, and wetlands. Because the urban category is primarily made up of residential land use/cover near lakes, I used the term 'residential' for this land use/cover. The minimum resolution of the MIRIS land use/cover data is approximately 1 ha.

Because land use information for MIRIS was from 1978, I only included annual Secchi means within a ten-year span of these data (1974-1983). For each lake that had data during this time period, I calculated the average of the annual means for the time period. To determine the effect of land use on Secchi depths, I plotted these means against the percent land use within both a 100 and 500 m buffer around each lake. The land use categories selected for analyses were: residential, agriculture, residential combined with agriculture, forest and wetlands. I regressed Secchi means against all land use categories.

To determine if there were differences in land use between the ecoregion sections, I calculated the average percent land use types for the two ecoregion sections (six and seven) for each of the land use classifications and buffer distances. I ran a t-test on these data to compare the two sections.

Results

Time trends

For the individual lake trend analysis using all sampling frequencies, I found 26 lakes with significant ($P \leq 0.1$) trends in water clarity. Of the 26 significant trends, 22 were increasing in clarity and 4 decreasing. Table 3 lists the lakes with significant trends. The results of the analyses using the datasets of alternate sampling frequencies is discussed in Appendix C. For the state-wide Secchi depth trend, the 31 lakes showed a significant ($P = 0.056$) increasing clarity trend (Figure 2).

The current state-wide trophic status calculated from the 1996-2001 Secchi depth means from all 71 lakes shows the majority (52%) are mesotrophic; 28% are oligotrophic and 20% are eutrophic (Figure 3). The current trophic state of the individual lakes calculated from the 1996-2001 Secchi depth means are shown in Table 1.

Ecoregions

The current Secchi depth mean for ecoregion section six (southern Michigan) is 3.1m, and for ecoregion section seven (northern Michigan), 4.1m (Figure 4). The t-test showed a significant difference between these means ($P = 0.003$). For the ecoregion subsection means, Fisher's Least-Significant-Difference test showed a significant difference ($P < 0.1$) between the means of

7.2 and 6.2, 6.3; between 7.3 and 6.1, 6.2, 6.3; between 7.4 and 6.2, 6.3 (Figure 5).

The number of eutrophic, mesotrophic, and oligotrophic lakes were grouped by ecoregion subsection and are illustrated in Figure 6a-c. Ecoregion section six has more (11) eutrophic lakes than section seven (2). Ecoregion section six has slightly more (18) mesotrophic lakes than section seven (16), and ecoregion section six has less (7) oligotrophic lakes than section seven (12).

Using results from the individual lake trend analysis, lakes with increasing or decreasing trends were grouped by ecoregion section six or seven (Figure 7). For the significant trends ($P \leq 0.1$), both ecoregions had more lakes with increasing water clarity than decreasing. In ecoregion 6, 21% of lakes are decreasing in clarity and 79% of lakes are increasing in clarity. In ecoregion 7, 8% of lakes are decreasing in clarity and 92% of lakes are increasing in clarity.

Land use

Comparing land use differences between the ecoregion sections, the significant differences ($P \leq 0.1$) were: agricultural land 100 m buffer ($P = 0.003$) and 500 m buffer ($P = 0.023$), and forest land 100 m buffer ($P = 0.055$) and 500 m buffer ($P = 0.091$) (Table 4). Agricultural land use area was higher in section six compared to seven, 2.7% versus 0.3% in the 100 m buffer and 18.8% versus 9.0% in the 500 m buffer. In contrast, forest land was higher in section seven compared to six, 26.0% versus 16.4% in the 100 m buffer and 47.3% versus

37.4% in the 500 m buffer. All other differences between ecoregion sections were not significant.

When individual land use categories were plotted against Secchi depths, only two categories were significant (Figures 8a and 9e). Residential land use in the 100 m buffer showed a positive relationship with Secchi depth ($P = 0.07$) (Figure 8a) and wetlands in the 500 m buffer showed a negative relationship ($P = 0.004$) (Figure 9e). When the two outliers were removed in the Residential land use in the 100 m buffer regression, the positive relationship was even stronger ($P = 0.03$, $R^2 = 0.091$). Residential land use in the 500 m buffer, the combined residential and agriculture land use for both buffer sizes, and forest land use in the 500 m buffer showed positive relationships with Secchi depth, but none were significant. Agricultural land use in both the 100 and 500 m buffers, forest in 100 m buffer, and wetlands in the 100 m buffer all showed negative relationships with Secchi depth, but none were significant.

Discussion

Changes in the water clarity of Michigan's inland lakes from 1974 to present.

It is apparent from the individual lake trends, as well as the state-wide analysis that in general, the clarity of Michigan's lakes in the lower peninsula has been increasing since 1974. State-wide, there is a significant increasing trend, and the majority of the significant individual lake trends were increasing in clarity. Trend analyses in Minnesota have shown similar patterns in water clarity. Heiskary and Lindbloom (1993) studied volunteer-collected Secchi depth data

from 152 lakes with 8 or more years of data, ending in 1992. Twenty nine percent of lakes showed significant increase in clarity, 8% significant decrease, and 63% had no trend. Terrell et al. (2000) analyzed volunteer and agency-collected Secchi data from 127 Florida lakes over 30 years and found no significant change in clarity. However, the analysis excluded 13 lakes with known management changes such as point source removal or artificial fertilization.

The reasons for increasing clarity in Michigan may be many, including improved management practices around lakes to control polluted runoff, influences of laws and regulations such as the Clean Water Act, removal of phosphorus from soap products, switches from septic to sewer systems in residences surrounding lakes, improved urban storm water management, changes in fish communities, and the presence of zebra mussels (*Dreissena polymorpha*). For example, the Federal Water Pollution Control Act was amended in 1977 and became known as the Clean Water Act. The Act gave the Environmental Protection Agency the power to reduce pollutant discharges into waterways through regulatory and non-regulatory tools. The Act also financed construction of wastewater treatment facilities and management of polluted runoff. In addition to the Clean Water Act, various cost-sharing programs with landowners that started emerging in the late 1980 and 1990s may have helped reduced polluted runoff and improved the clarity of waters. Examples of these include the National Resources Conservation Service's Environmental Quality

Incentives Program (EQIP) and the Farm Service's Conservation Reserve Program (CRP).

Most of the individual lakes water clarity trends are slight, with lakes remaining within their trophic state. The average significant trend magnitude was approximately ½ to 1 m. However, a few lakes had more dramatic shifts of approximately 2 meters. St. Joseph county's Klinger and Pleasant lakes have shifted from eutrophic in the late 1970s and early 1980s to almost oligotrophic currently. A similar situation exists for Benzie county's Big Platte lake, shifting from almost eutrophic in the mid-1970s to almost oligotrophic currently. In contrast, Oakland county's lake Sherwood has shifted from almost oligotrophic in the early 1980s, to eutrophic currently (Figure 10a).

I investigated some of the lakes with the more dramatic clarity shifts to help determine what may be some influencing factors on the change. For Lake Sherwood, the land along the shoreline of Oakland county's Lake Sherwood has been highly developed. By the late 1970s, about 80% of the homes had already been built along the shoreline, but there has been an increase in subdivision growth and a number of development activities around the lake in recent years (Klemmer, pers. comm.). Three to four years ago a school construction project approximately ¼ mile from the lake resulted in sediment runoff to the lake, the developer was sued and the lake needed to be dredged (Till, pers. comm.). Many of the homeowners use fertilizers on their lawns and the lake is also treated for weeds, but they are not harvested (Till, pers. comm). All the original homes were on septic systems, but new subdivisions now must be hooked up to

a sewer system (Klemmer, pers. comm.). In addition, older homes must be hooked up to a sewer systems if there is a septic tank failure or an addition built to the home (Klemmer, pers. comm.). Currently there is no comprehensive testing for septic tank failures of homes around the lake, but Oakland county will be starting a program to test all tanks over the next five years (Till, pers. comm.).

In contrast, Benzie county's Big Platte lake has increased in water clarity substantially (Figure 10b). Upstream from Platte lake, along the Platte River, is the Michigan Department of Natural Resource's (DNR) Platte river fish hatchery. In 1986 the Platte Lake Improvement Association filed a lawsuit against the DNR to reduce water and phosphorus discharges. In March of 2000, a consent agreement was finally signed that provides a phosphorus concentration limit in Platte lake, discharge limitations, and a six to seven year phase-down plan for phosphorus (GLAO, 2000). Even before the consent agreement was signed, the hatchery began reducing its phosphorus discharges to less than 10% of its early peak levels by modified sewage procedures and changes in fish food (BFC, 2001). It is likely that these reductions in phosphorus loads to the lake helped reduce phytoplankton populations and therefore increased clarity levels in the lake.

A 1972-1996 Secchi depth trend analysis on Narragansett Bay in Rhode Island showed a significant increase in clarity (Borkman and Smayda, 1998). The Bay also responded to management changes; the greatest increase in clarity occurred during a 10-year period when discharges of total suspended solids from wastewater treatment plants decreased 75% (Borkman and Smayda, 1998).

St. Joseph county's Klinger and Pleasant lakes have shifted from eutrophic in the late 1970s and early 1980s to almost oligotrophic currently (Figure 10c,d). The water level in Pleasant lake never varies in the lake more than three inches, and the lake has greater than normal flushing than other lakes nearby, as it is fed by a spring in the west and outflows to a creek on the east side (Kaiser, pers. comm.). Additionally, minimal farmland exists around the lake (0.9% in the 100 m buffer and 5.4% in the 500 m buffer), so there is probably little influence from agricultural runoff and manure from a nearby confined hog farm is trucked away from the area (Kaiser, pers. comm.). The homes around the lake are on septic systems, but in the late 1960s and early 1970s, a housing developer raised the lake levels 1 ½ feet, and the low septic systems were flooded and abandoned (Kaiser, pers. comm.). Since then, new septic systems have been placed farther away from the lake's shoreline (Kaiser, pers. comm.).

The following information about Klinger lake was obtained by speaking with the CLMP volunteer sampler (McBride, pers. comm.) and it may explain the increase in clarity. In 1972, a sewer system was installed for the homes around Klinger lake (McBride, pers. comm.). It is likely that there was some time lag until the clarity of the lake responded, dependent on the flushing rate of the lake. In 1996 zebra mussels were spotted in the lake (McBride, pers. comm.; Michigan Sea Grant, 2001). The exotic species Eurasian milfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*) are also beginning to invade via the two lakes ahead of Klinger in a chain of three (McBride, pers. comm.). As with Pleasant lake, minimal farmland exists around the lake (2.3% in the 100 m buffer

and 0.0% in the 500 m buffer). The lake also has a number of artesian wells flowing into it (McBride, pers. comm.), and it is also fairly deep compared to other lakes in the state, with a maximum depth of 21.9 meters and average depth 6.4 meters.

To investigate the influence of zebra mussels on the increasing clarity of Michigan's inland lakes, the Sea Grant (2001) database of zebra mussel monitoring was compared to the lakes in the CLMP program. This database records which lakes have been monitored for zebra mussels and what year they were first detected. Zebra mussels are an exotic species, originating in Europe and were first discovered in North America, in Lake St. Clair in 1988 (Herbert, et al., 1991). Zebra mussels feed primarily on algae and are capable of filtering about one liter of water per day (Reeders el al., 1989).

Of the lakes with significant increases in clarity, 42% contained zebra mussels. Zebra mussels were also present in 4% of the lakes with significant decreases in clarity. The 1996-2001 mean Secchi depth for all lakes with zebra mussels was 4.0 meters, and for those without, 3.4 meters (Figure 11). A t-test showed this difference was significant ($P = 0.091$). Of the lakes with significant trends, there was one spotting in 1992, but presence in other lakes was not detected until 1995 or later. To clarify if there was a difference between these two groups of lakes before zebra mussel infestation, the average Secchi depths were compared for the time period 1974-1990. The mean Secchi depth for all lakes with zebra mussels was 3.7 meters, and for those without, 3.1 meters (Figure 12). A t-test showed this difference was not significant ($P = 0.11$),

although it is only marginally non-significant. Thus, although statistically, the two lake groups historically have 'similar' Secchi depths before zebra mussel invasion, there may be some biological differences in lakes that have been invaded by zebra mussels. Additionally, the difference between the mean Secchi depth of the lakes 20 lakes with zebra mussels, before and after infestation was not significant. Finally, not every lake in the CLMP program has been tested for zebra mussel presence. The infestation of zebra mussels into Michigan's inland lakes in recent years may have some influence on the increasing clarity trends, but it is difficult to attribute the observed differences solely to zebra mussels.

The influence of ecoregions on the water clarity of Michigan's inland lakes.

The significant differences in Secchi depth between ecoregion sections and subsections (Figures 4 and 5) suggests that management strategies should take into account a lake's ecoregion in the process of setting water quality goals or standards. The highly significant difference was between ecoregion sections, and the fact that the subsection differences were only between 7s and 6s indicates that ecoregion section seems to explain more than subsection.

Ecoregions may be a way to guide management strategies, as they illustrate regional differences in lake water quality characteristics. For example, Heiskary et al. (1987) found great variation in total phosphorus concentrations in Minnesota's lakes when categorized by ecoregions. Additionally, natural resource managers in Minnesota have created a model in which ecoregions are used to predict runoff, precipitation, evaporation, stream phosphorus

concentration and atmospheric phosphorus deposition (Wilson and Walker, 1989). This program allows screening for lakes that may have unnaturally high phosphorus levels due to their ecoregions, morphometry and hydrology (Wilson and Walker, 1989).

Restoration or protection goals may vary by ecoregion and on average, the southern portion of Michigan's lower peninsula has lower water clarity than the northern portion. This lower clarity is further illustrated by the larger number (11) of eutrophic lakes in section six than in section seven (2) and the larger number of oligotrophic lakes in section seven (12) than in six (7). This may be due to the physical properties inherent to the ecoregion. For example, the southern zone is primarily composed of silt and clay loams, while the northern lower peninsula is primarily sands (Albert, 1995). Silty soils have greater erosion potential than sandy soils, and lakes could be more susceptible to sedimentation-induced clarity decreases in the southern ecoregion. In addition, differences in land use between the ecoregions may help explain differences in water quality (see below). For example, ecoregion section six further shows its vulnerability to decreasing water clarity in the individual lake trend analysis (Figure 7). Ecoregion six has more lakes with decreasing clarity and fewer lakes with increasing clarity than ecoregion seven. These results suggest that anthropogenic stressors may be greater in section six and land use is likely a causal factor

Correlations of land use to ecoregions and the influence of land use on the water clarity of Michigan's inland lakes.

Comparing land use differences between the ecoregion sections, the significant differences were agricultural and forest land in both buffer sizes. Agricultural land use is greater in southern Michigan and forested land is greater in northern Michigan. This may explain the greater mean clarity of lakes in northern Michigan, since agricultural land is known to be an origin of nonpoint source pollution to water bodies (Sharpley et al., 1994; Carpenter et al., 1998). However, in the relationship between Secchi depth and agricultural land in the 100 m and 500 m buffer distances are not significant (Figures 8b and 9b). It may be that the range and percentage of agricultural area in both buffer distances is too minimal to detect a significant relationship. In the 100 m buffer, agriculture land use comprises 2.7% for ecoregion six and 0.3% for ecoregion seven, and in the 500 m buffer, 18.8% for ecoregion six and 9.0% for ecoregion seven (Table 4). This dataset also may be too coarse or may need to be combined with other water quality measurements to pick up significant correlations with land use. This is further illustrated in that forested land shows significant differences between ecoregion, but no significant trend comparing Secchi depth to forested land, where we might expect to see a positive relationship.

Residential land use in the 100 m buffer showed a significant positive relationship with Secchi depth and the 500 m buffer showed a non-significant, but positive relationship. This result is surprising, but it may be that clearer lakes are favored for housing developments and residences. Interestingly, residential land use is very similar around lakes regardless of ecoregion, suggesting development is occurring around lakes throughout the state of Michigan. As was shown by the ecoregion and land use analysis, the higher density of residential use is within the 100 m buffer around the lake (Table 4). Residential land use area in the 100 m buffer is 65% for six and 59% for seven, compared to 21% and 23% in the 500 m buffer. High-quality water is important to people, and degraded water bodies can affect property values. Several studies have illustrated the negative economic consequences of cultural eutrophication of lakes and other water bodies. For example, a study in Maine showed the detrimental impact of poor water quality on lakeside property values, as market prices dropped 10-20% with a one-meter reduction in clarity (Bouchard, 1995). Water quality had a significant influence on home values along the shores of Chesapeake Bay (Leggett and Bockstael, 2000), and home values along Lake Champaign, Vermont were lower compared to homes by a less polluted lake (Young, 1984). Smith et al. (1995) found people's perception of clarity in lakes was strongly related to site suitability, and 90% of survey respondents reported water suitable for bathing at a Secchi depth of approximately 2.75 m.

In an effort to separate the effects of ecoregion from land use on lake clarity, I regressed Secchi means against the percent land use, for both the 100 and 500 m buffers in each of the ecoregion sections. Of the significant trends ($P \leq 0.1$), three supported the previous positive relationship of Secchi depth with residential land use: ecoregion six residential land use in the 100 m buffer, ecoregion seven residential land use in 500 m buffer, and ecoregion six

residential + agricultural land use in the 100 m buffer (Figures 13a-c). The most significant relationships (P = 0.03) were negative correlations with Secchi depth and wetlands in ecoregion seven's 100 and 500 m buffer (Figures 14a-b). It also supports the significant negative correlation between all lakes and wetlands in the 500 m buffer. The negative relationships of both distances of wetland buffers with Secchi depth may be due to runoff from wetlands that contain tannins and dead organic material that may color the water and lead to decreased clarity (Wetzel, 2001). Forested land in ecoregion six's 500 m buffer showed a negative relationship with Secchi depth. This seems somewhat unusual, but it could be do to logging activities that could be disturbing the soil. All other tests were not significant.

The fact that few land uses versus Secchi depth relationships were significant again may indicate that this dataset also may be too coarse or may need to be combined with other water quality measurements to pick up significant correlations with land use. Even on the significant relationships, the R^2 values were fairly small. It is crucial to note that these land use analyses were very broad-scale and additional future research is needed to help quantify the effect of land use on lakes.

Conclusions

State-wide, lake clarity in Michigan has been increasing since the 1970s. Of the individual lake trends, 31% are increasing in clarity, 6% are decreasing in clarity, and 63% have no trend. Although further monitoring is needed, the

observed increase in water clarity may be due to zebra mussels, better watershed management practices, or local and national regulations. I was not able to determine the underlying causes in these analyses.

The highly significant difference between ecoregion sections indicates that section seems to explain more than subsection. The mean Secchi depth was lower for southern Michigan (ecoregion section six). It was easier to pick up differences in lake clarity through ecoregion influences than land use directly and ecoregions may be a way to guide management strategies, since they indicate regional differences in lake water quality characteristics.

Although land use and changes in management on an individual lake scale may explain the greater trophic shifts in clarity in some of the lakes, these analyses did not detect a strong effect of land use on water clarity in lakes across the state. This dataset may be too coarse or may need to be combined with other water quality measurements to pick up significant correlations with land use. It is also important to remember that Secchi depth is only one component of water quality and that Secchi readings cannot directly indicate other water quality characteristics that would be harmful to humans or the lake ecosystem, such as the presence of harmful chemicals or pathogens.

Volunteer monitoring programs provide an invaluable contribution to water quality information, as they provide people-power for agencies that cannot spend the time or money to send staff to numerous lakes to collect data. These data not only help us determine trends, but also set baseline conditions. Smeltzer's et al. (1989) study used a model to determine that 10 years of Secchi depth data

should be able to detect a future 10% degradation in water clarity. This conclusion is important in that 10 years of monitoring data from programs like Michigan's CLMP can set baseline information, from which to detect future changes. Smeltzer el al. (1989) also concluded that the temporal variability for phosphorus and chlorophyll was too large to detect non point source pollution influences over short times (less than 10 years), and the Secchi depth was a better monitoring tool to use. At the same time, while we use these volunteer-collected Secchi data, it is also essential to continue the training and checking of volunteers to ensure they are being as consistent as possible and are following procedures.

It is important to both apply the CLMP data to understand the water quality status and changes of Michigan's lakes, and to close the feedback loop by disseminating the information to the volunteers and the general public. One possibility of distribution could be to store the data on a website where it could easily be accessed by the public. Also, as identified by these analyses, it would be beneficial to include the lakes exhibiting significant trends in state monitoring programs. More comprehensive monitoring of these lakes, along with additional information through case studies can help natural resource managers determine what factors may be driving trends in water quality.

CHAPTER 3: CONCLUSIONS

Future Research

No lakes in the upper peninsula of Michigan, nor the northeast tip of the lower peninsula met the selection criteria for the analyses in this study. The Tip of the Mitt monitoring group, in the northeast area of Michigan conducts an active program of lake monitoring, separate from the CLMP and it would be useful to add their data into these analyses. For a more comprehensive water quality analysis, the phosphorus and chlorophyll data could be added into analyses once the sampling has been ongoing for a longer time.

The case studies on individual lakes revealed specific information on activities around the lakes. Additional research could continue to clarify the relationships between Secchi disk clarity and lake characteristics. The investigations could include shape and depth of lakes, lake geological origin, primary source and rate of water recharge, flooding versus drought years, presence of zebra mussels, residential land use density, use of septic tanks versus sewers, residential landscaping, frequency of algae treatments, local lake management or ordinances, and any unique land uses in the lake's watershed.

Although land use and changes in management on an individual lake scale seemed to explain the greater trophic shifts in clarity in some of the lakes, these analyses did not detect a strong effect of land use on water clarity in lakes across the state. It is crucial to note that these land use analyses were very broad-scale and additional future research is needed to help quantify the effect of

land use on lakes. Interesting future analyses could investigate additional individual lake land uses on a detailed, smaller scale, as well as compare the 1978 land use to changes currently. A more current, comprehensive, state-wide land use dataset is needed for Michigan to assist in both additional regional and local analyses.

Opportunities also exist to combine these CLMP Secchi depth data with new technologies for determining water clarity. For example, there are current research efforts in Minnesota, Wisconsin, and Michigan to quantify Secchi depth transparency from remotely sensed data, using Land sat satellite imagery (Olmanson et al., 2000; Kloiber et al., 2000; Nelson et al., under review). The data compiled here can be used to supplement and compare with satellite-based monitoring programs to determine the status and trends of water clarity of the state's lakes. Ground-based data can also be used to determine the appropriate sampling time frame for satellite data collection.

For these analyses, it was easier to pick up differences in lake clarity through ecoregion influences than land use directly. Ecoregions can be a way to guide management strategies, since they indicate regional differences in lake water quality characteristics. The natural landscapes of the United States are quite varied and unique and it is unreasonable to apply the specific results of this Great Lakes region lakes analysis broadly. However, the strength of the ecoregion predicting capabilities has opportunities for further research and applications on a broader national scale. Interesting future research could compare the impacts of ecoregions on varied aquatic ecosystems and further

identify key biophysical factors correlated with increases or decreases in water quality. Ecoregion analyses can assist in identifying regions that are potentially more susceptible to degradation based on their biophysical characteristics.

Conclusions

Protecting the water quality of lakes is imperative, since degraded water bodies can restrict human contact with the water, harm fish, invertebrates, vegetation, and alter biodiversity. Secchi disk monitoring can help determine and track certain aspects of water quality. State-wide, lake clarity in Michigan has been increasing since the 1970s. Of the individual lake trends, 31% are increasing in clarity, 6% are decreasing in clarity, and 63% have no trend.

While much still remains unknown, of the trends, increasing clarity is the dominant direction, and in this aspect, lakes may be improving in water quality. It is interesting to compare Michigan's 303(d) list of impaired (not meeting one or more designated uses) lakes and reservoirs to the CLMP database. Of the 71 lakes I analyzed, eight are on the list, out of a total of 102 (USEPA, 2002A). The impairments of these eight lakes are metals, fish consumption advisory, and pesticides (USEPA, 2002A). None are listed for phosphorus or turbidity, the water quality parameters that are measured by Secchi readings. State-wide, Michigan may be reducing these sources of pollution. However, it is key to remember that Secchi depth is only one component of water quality and that Secchi readings cannot directly indicate other water quality characteristics that

could be harmful to humans or the lake ecosystem, such as the presence of harmful chemicals or pathogens, or the above mentioned. .

These increases in clarity may be the result of some real impacts from better watershed management practices and local and national regulations. Point source pollution control from programs like the National Pollutant Discharge Elimination System (NPDES) certainly has had a role in improvements to surface water quality. Another program of the Clean Water Act, section 319 grants have also had a significant part in reducing NPS pollution. Established in 1987, states, territories and tribes and apply for grants for many types of NPS pollution reduction programs. Additionally, in 1977 the State of Michigan implemented a 0.5% phosphorus limit in laundry detergents that may have also had an impact on improving clarity (MDEQ, 2002). In addition to these regulatory and management impacts on reduced pollution to lakes, zebra mussels or other invading exotics may have a real impact on the increasing clarity trends. While it seems beneficial to have the water cleared by these invaders, the impact on the native ecosystem is harmful or still unknown, and zebra mussels should not be relied upon to "clean up" pollution problems that are still occurring from land uses.

Management Implications

Results of this study have helped elucidate anthropogenic impacts on inland lakes and determine baseline conditions and can help communities in Michigan create watershed management plans for their lake. The watershed

management approach is growing in popularity as a method to protect and monitor the quality of our water resources. Whereas some approaches pinpoint a specific pollutant source, or do not take into account the entire water ecosystem, watershed management integrates human, community, biological, chemical, physical, legal, and policy considerations of the land and water. The USEPA (2002C) defines a watershed management approach as "…a coordinated framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined areas, taking into consideration both ground and surface water flow." The USEPA began encouraging a watershed approach to management during the mid-1990s. The holistic and ecosystem-based nature, of the watershed approach, is aimed to be more effective than the political boundary-based management.

From monitoring programs such as the CLMP, or other programs, watershed or lake organizations can have better information to aid in identification and prioritization of significant contributing sources of pollution or baseline water quality status. With knowledge of current and changing water quality conditions, management choices or studies can be better tailored to the needs of the lake. For example, if the lake is showing increasing clarity, the presence of zebra mussels, or other water quality parameters could be tested to see what other pollution problems may exist. If a lake is showing decreasing clarity, management options could include encouraging sewer installation, testing for septic failures, soil erosion control, timing and reduction of fertilizer use, or

use of vegetative buffer strips or native plant landscaping. Even without the presence of any trends, it is always crucial to promote best management practices for residential and agricultural land use. Monitoring program like the CLMP can provide better advice on the baseline or changing conditions of these lakes to help sustain their value to state and local communities.

Volunteer monitoring programs an invaluable contribution to water quality information, as they provide people-power for agencies that cannot spend the time or money to send staff to numerous lakes to collect data. Using volunteers to monitor lakes is not only an efficient method, but also is an opportunity to educate the public about the resource. When citizens are involved in taking care of their resource, it certainly brings greater awareness, cooperation, and buy-in to management activities. Even in states where lakes are not a major component of the landscape, with proper training and administrative support, volunteer programs can be used to monitor other biological resources such as rivers, wildlife communities, beaches, and wetlands.

Volunteer monitoring programs promote self-reliance and empowerment for lake management decision-making. Lake associations or watershed groups can not only work on their own goals for the lake, but can also help identify targets for protection and restoration for inclusion in state-run programs. Monitoring programs like Michigan's CLMP can integrate existing water quality information with the tools and plans needed to protect, maintain, and restore water resources.

APPENDIX A: TABLES

Table 1. Characteristics of the 71 selected lakes.

County	Lake Name	New Key Code	Surface Area (ha)	Max Depth (m)	Ave. Depth (m)	Trophic Classification (1996-2001)	Eco-region
Alcona	Vaughn	1-29	45	19.8	6.5	Mesotrophic	7.2
Allegan	Hutchins	3-178	154	10.4	3.2	Eutrophic	6.3
Allegan & Van Buren	Eagle	3-60	83	17.1	6.5	Oligotrophic	6.3
Alpena	Beaver	4-1	280	23.5	8.5	Mesotrophic	7.6
Barry	Barlow	8-586	73	18.6		Mesotrophic	6.2
Barry	Payne	8-604	46	13.1	4.9	Mesotrophic	6.2
Benzie	Big Platte	10-39	1025	27.4	8.2	Mesotrophic	7.4
Benzie	Crystal	10-42	3994	48.8	17.5	Oligotrophic	7.4
Berrien	Little Paw Paw	11-2	41	9.1		Eutrophic	6.3
Branch	Coldwater	12-90	640	28.0	5.6	Mesotrophic	6.2
Branch	Long	12-86	50	13.7		Eutrophic	6.2
Cass	Christiana	14-400-GRP	72	12.2	6.3	Eutrophic	6.2
Cass	Dewey	14-88	91	15.2		Eutrophic	6.2
Cass	Donnell	14-224	100	19.2	7.6	Mesotrophic	6.2
Cass	Indiana	14-394	33	21		Mesotrophic	6.2
Cass	Juno	14-400-GRP	88	11.3		Eutrophic	6.2
Cass	Painter	14-400-GRP	42	8.2		Eutrophic	6.2
Cass	Twin Lakes-North	14-75	26	16.5	5.2	Mesotrophic	6.2
Clare	Crooked	18-69	107	22.3	4.9	Mesotrophic	7.2
Clare	George	18-125	52	7.6	2.8	Mesotrophic	7.2
Clare	Shingle	18-124	107	22.9		Mesotrophic	7.2
Crawford	Margrethe	20-44	778	19.8	4.7	Mesotrophic	7.2
Genesee	Byram	25-54	54	18.3		Mesotrophic	6.4
Genesee	Fenton	25-35	351	27.4	6.2	Oligotrophic	6.4
Grand Traverse	Arbutus	28-84	153	13.4	3.7	Oligotrophic	7.2
Grand Traverse	Duck	28-124	787	27.4	7.3	Mesotrophic	7.3
Grand Traverse	Long	28-214	1178	24.4	7.9	Oligotrophic	7.3
Grand Traverse	Spider	28-81	180	9.8	2.8	Oligotrophic	7.2
Iosco	Long	35-96	197	18.9	5.0	Mesotrophic	7.1
Iosco	Van Etten	35-219	570	10.1	4.6	Eutrophic	7.1
Jackson	Clear	38-32	52			Mesotrophic	6.1

County	Lake Name	New Key Code	Surface Area (ha)	Max Depth (m)	Ave. Depth (m)	Trophic Classification (1996-2001)	Eco-region
Jackson	Vineyard	38-503	219	12.8	4.2	Mesotrophic	6.1
Kalkaska	Cub	40-106	23	7.0	2.9	Oligotrophic	7.2
Kent	Camp	41-516	55	15.2	0.0	Oligotrophic	6.4
Lake	Harper	43-254	34	18.0	5.5	Oligotrophic	7.3
Leelanau	Glen	45-9	1969	39.6	21.8	Oligotrophic	7.4
Leelanau	Leelanau-North	45-3	1194	36.9	12.4	Mesotrophic	7.5
Leelanau	Little Glen	45-9	565	4.0	1.8	Eutrophic	7.4
Lenawee	Devils	46-45	531	19.2	4.3	Mesotrophic	6.1
Livingston	Coon	47-204	39			Eutrophic	6.1
Livingston	Zukey	47-97	60	10.7		Eutrophic	6.1
Manistee	Bear	51-132	758	6.1	3.8	Mesotrophic	7.4
Mason	Blue	53-131	27	18.3		Oligotrophic	7.3
Mason	Ford	53-135	74	22.9	10.8	Oligotrophic	7.4
Mason	Hackert	53-101	49	15.8	2.0	Mesotrophic	7.4
Mecosta	Blue	54-53	93	15.2	0.0	Oligotrophic	7.2
Mecosta	Horsehead	54-136	179	12.8	0.0	Mesotrophic	7.2
Mecosta	Mecosta	54-54	126	11.3	3.2	Mesotrophic	7.2
Mecosta	Round	54-51	64	13.7	4.8	Mesotrophic	7.2
Mecosta	School Section	54-57	49	10.1	3.1	Oligotrophic	7.2
Missaukee	Sapphire	57-70	100	2.4	1.2	Eutrophic	7.2
Montcalm	Baldwin	59-99	25	10.7	1.8	Mesotrophic	6.4
Montmorency	Avalon	60-162	156	22.6	10.6	Oligotrophic	7.6
Montmorency	West Twin	60-19	528	9.1	2.2	Mesotrophic	7.2
Newaygo	Bills	62-75	81	27.4	5.7	Mesotrophic	6.4
Newaygo	Emerald	62-82	31	15		Mesotrophic	7.3
Newaygo	Sylvan	62-81	41	19.2		Mesotrophic	7.3
Oakland	Lakeville	63-1650	174	20.1	3.0	Mesotrophic	6.1
Oakland	Sherwood	63-252	99	6.1		Eutrophic	6.1
Oakland	Taylor	63-1025	15	18.3		Oligotrophic	6.1
Oakland	Walled	63-16	261			Oligotrophic	6.1
Oakland	White	63-575	210	9.8	3.3	Oligotrophic	6.1
Ottawa	Crockery	70-164	42	16.5	7.5	Eutrophic	6.3
Roscommon	Higgins	72-117	4122	41.1	15.8	Oligotrophic	7.2
Shiawassee	Leisure	n/a	94			Oligotrophic	6.4
St. Joseph	Clear	78-93	261	9.4	3.6	Mesotrophic	6.2
St. Joseph & Cass	Corey	14-159	242	24.4	7.7	Mesotrophic	6.2
St. Joseph	Klinger	78-171	338	21.9	6.4	Mesotrophic	6.2
St. Joseph	Pleasant	78-94	104	16.2	5.9	Mesotrophic	6.2
Van Buren	Lake of the Woods	80-288	122	9.1	4.5	Mesotrophic	6.2
Wexford	Stone Ledge	83-17	34	6.1		Mesotrophic	7.2

Table 3. Lakes with significant trends.

County	Lake Name	Yrs. Of Data	Yrs. Data Span	Trend	P-value	R^2
Branch	Long	25	77-01	-	0.091	0.119
Livingston	Coon	18	74-01	-	0.094	0.165
Manistee	Bear	24	77-01	-	0.044	0.172
Oakland	Sherwood	21	80-00	-	0.001	0.44
Alcona	Vaughn	10	75-01	+	0.034	0.447
Barry	Payne	11	90-00	+	0.04	0.39
Benzie	Big Platte	23	77-01	+	0.001	0.415
Berrien	Little Paw Paw	10	92-01	+	0.026	0.482
Cass	Dewey	25	74-00	+	0.022	0.207
Cass	Twin Lakes- North	10	92-01	+	0.024	0.491
Grand Traverse	Long	15	79-01	+	0.104	0.19
Iosco	Long	28	74-01	+	0.003	0.296
Jackson	Vineyard	21	77-01	+	0.039	0.206
Kalkaska	Cub	9	93-01	+	0.015	0.592
Leelanau	Lake Leelanau- North	25	77-01	+	0.001	0.396
Livingston	Zukey	13	80-01	+	0.017	0.416
Mason	Blue	14	88-01	+	0.006	0.48
Mecosta	Blue	19	81-01	+	< 0.001	0.543
Mecosta	Horsehead	21	81-01	+	0.002	0.419
Mecosta	Mecosta	18	81-01	+	0.032	0.257
Mecosta	School Section	11	90-00	+	0.001	0.729
Montcalm	Baldwin	23	77-01	+	< 0.001	0.613
Oakland	Lakeville	19	76-01	+	0.091	0.159
St. Joseph	Klinger	17	82-01	+	< 0.001	0.729
St. Joseph	Pleasant	22	78-01	+	< 0.001	0.823
Van Buren	Lake of the Woods	21	81-01	+	0.087	0.146

Table 4. Percent land use types in ecoregion sections

Buffer size (m)	Land use type	Ecoregion 6 %	Ecoregion 7 %	P-value
100	Residential	64.8	59.4	0.282
100	Agricultural	2.7	0.3	0.003
100	Residential + Agriculture	67.5	59.6	0.116
100	Forest	16.4	25.9	0.055
100	Wetlands	4.8	7.1	0.244
500	Residential	21.0	23.3	0.601
500	Agricultural	18.8	8.9	0.023
500	Residential + Agriculture	39.8	32.2	0.140
500	Forest	37.4	47.3	0.091
500	Wetlands	10	7.3	0.216

APPENDIX B: FIGURES

Figure 1. Ecoregions with selected lakes.

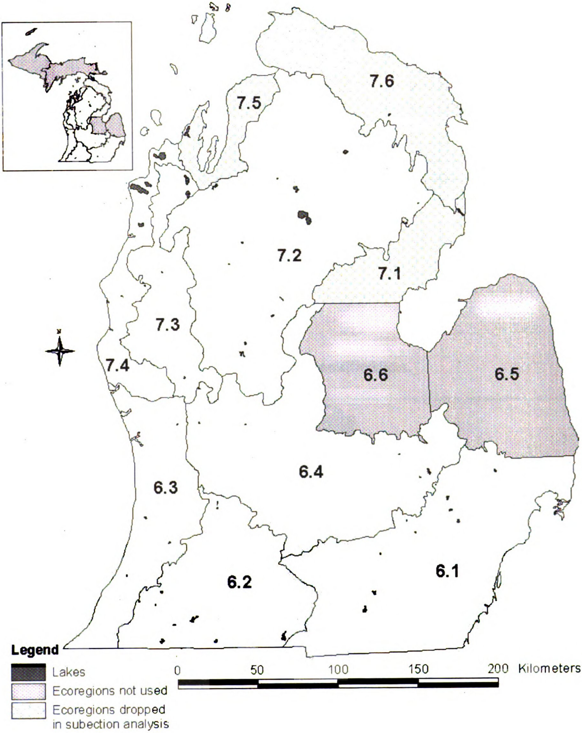


Figure 2. State-wide Secchi depth trend.

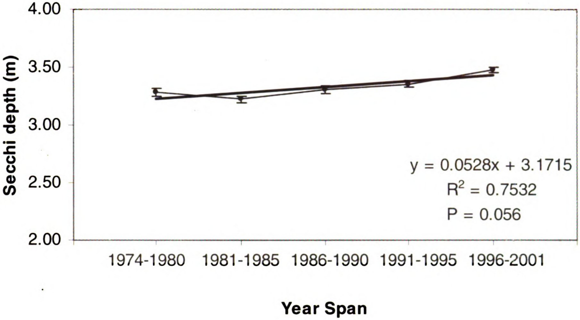


Figure 3. State-wide 1996-2001 trophic classification.

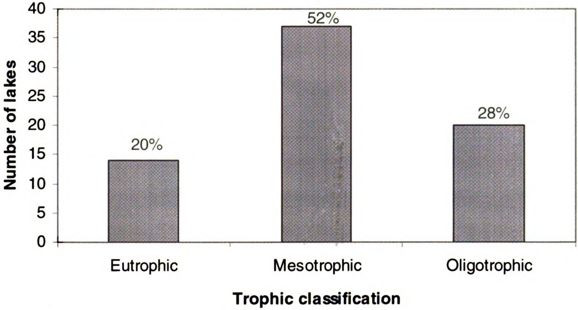


Figure 4. Ecoregion section Secchi depth average 1996-2001.

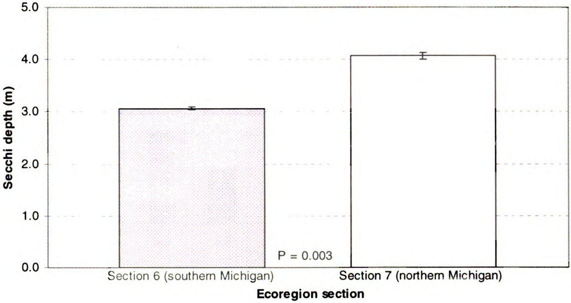


Figure 5. Ecoregion subsection Secchi depth average 1996-2001.

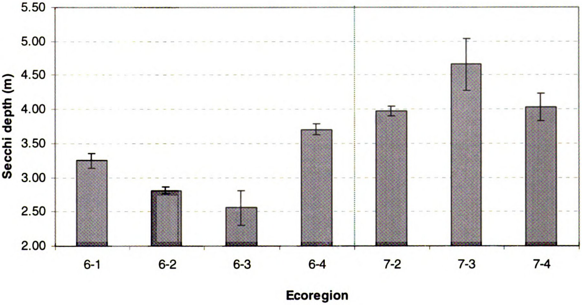


Figure 6. 1996-2001 trophic classification by ecoregion subsection.

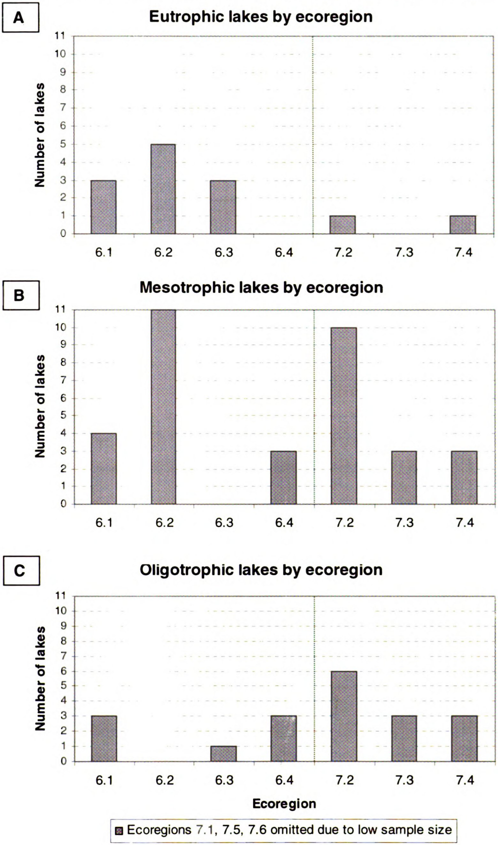


Figure 7. Significant lake clarity trends by ecoregion.

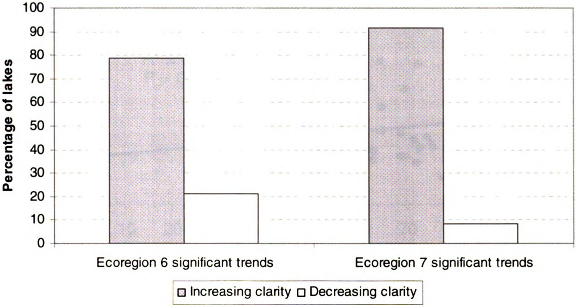
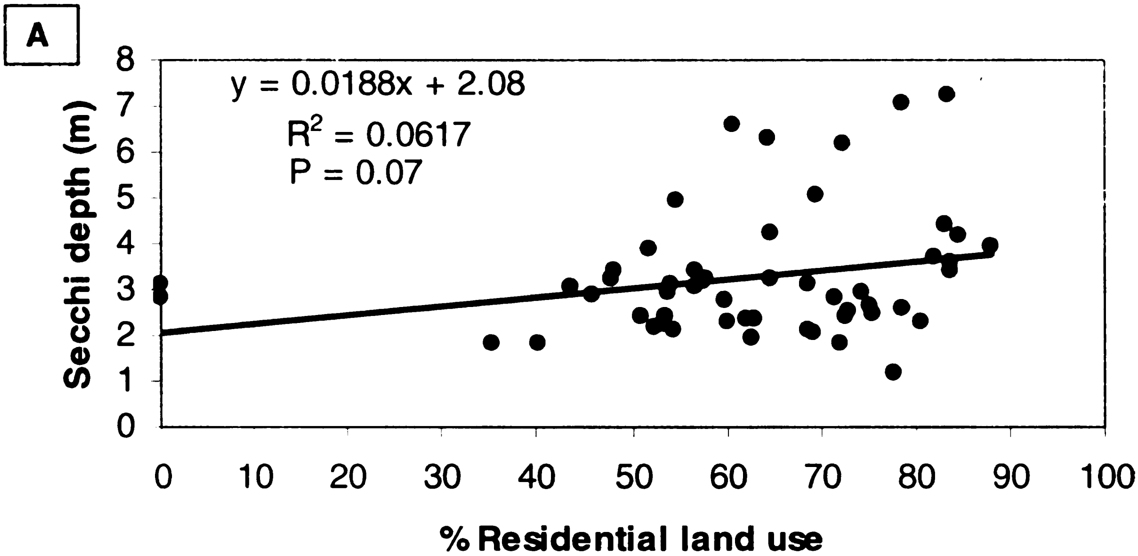
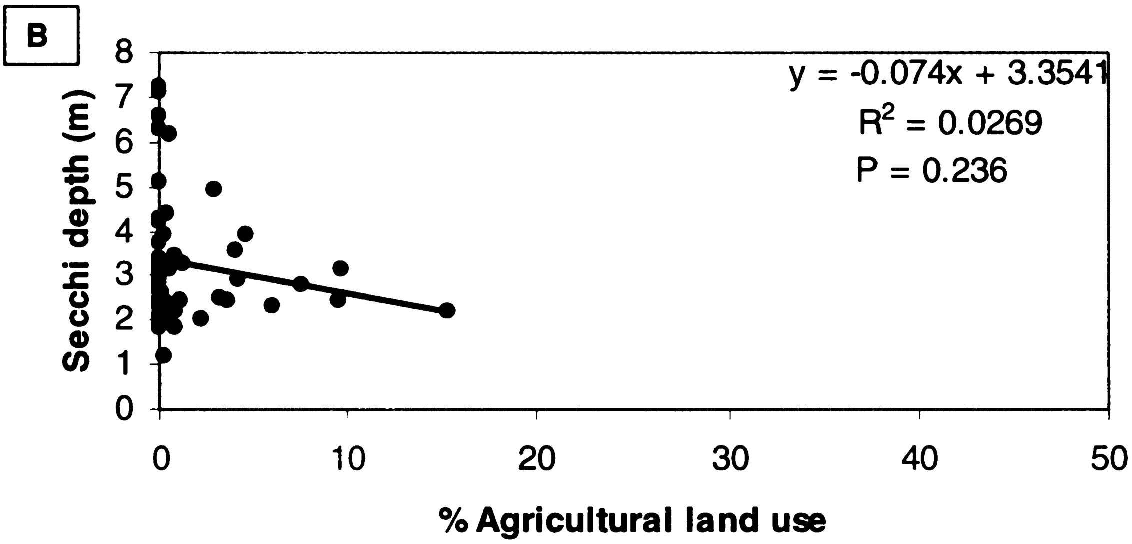


Figure 8. Land use versus Secchi depth: 100 m buffers.





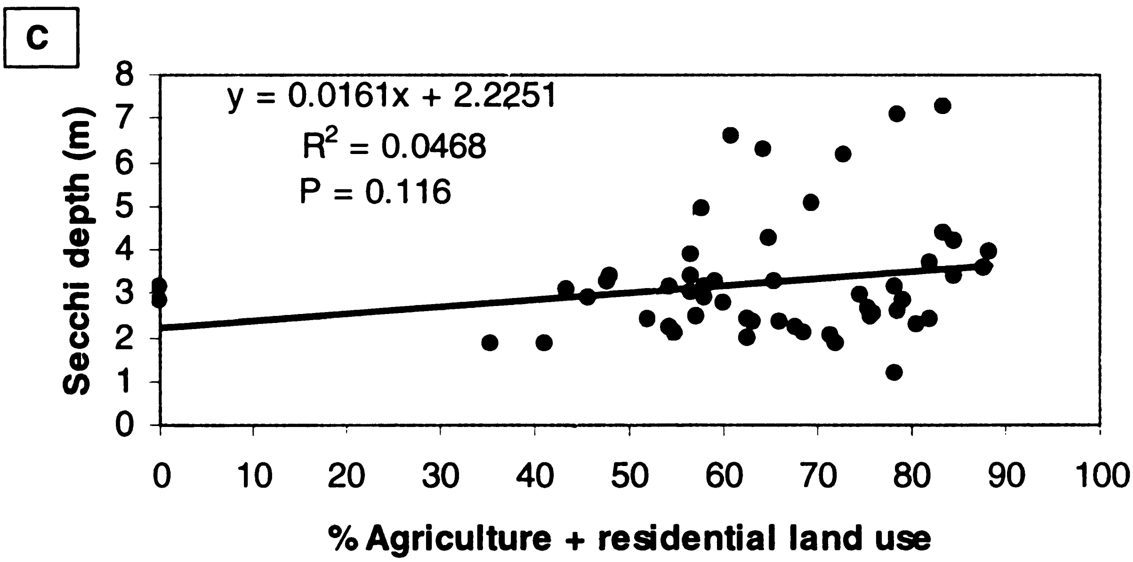
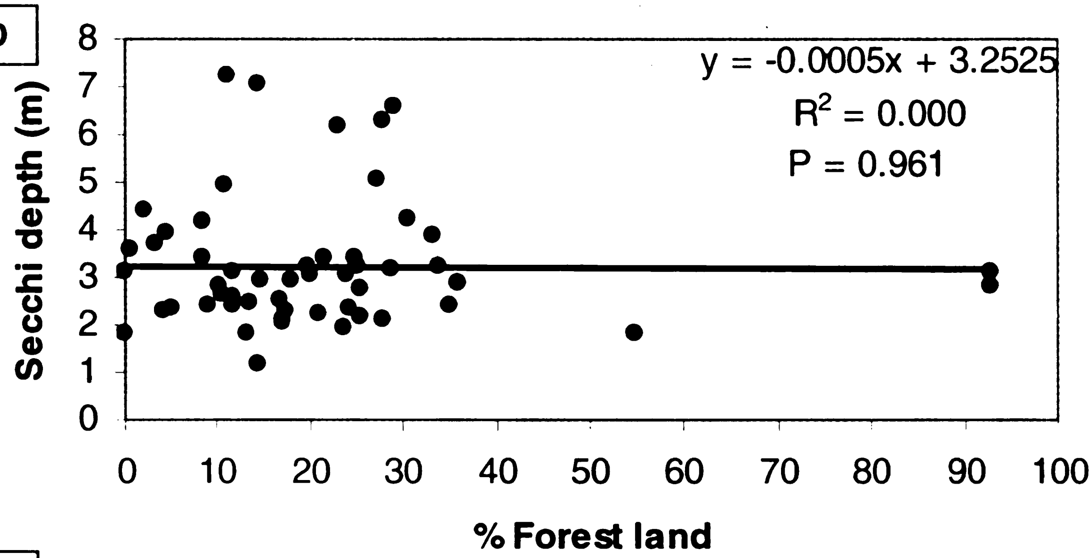


Figure 8 (cont'd.). Land use versus Secchi depth: 100 m buffers.

D



E

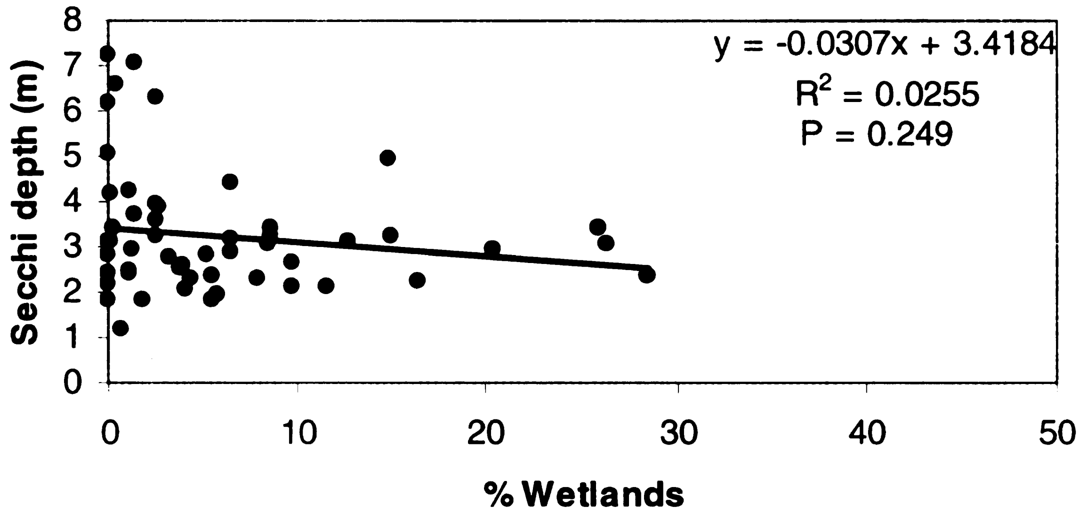


Figure 9. Land use versus Secchi depth: 500 m buffers.

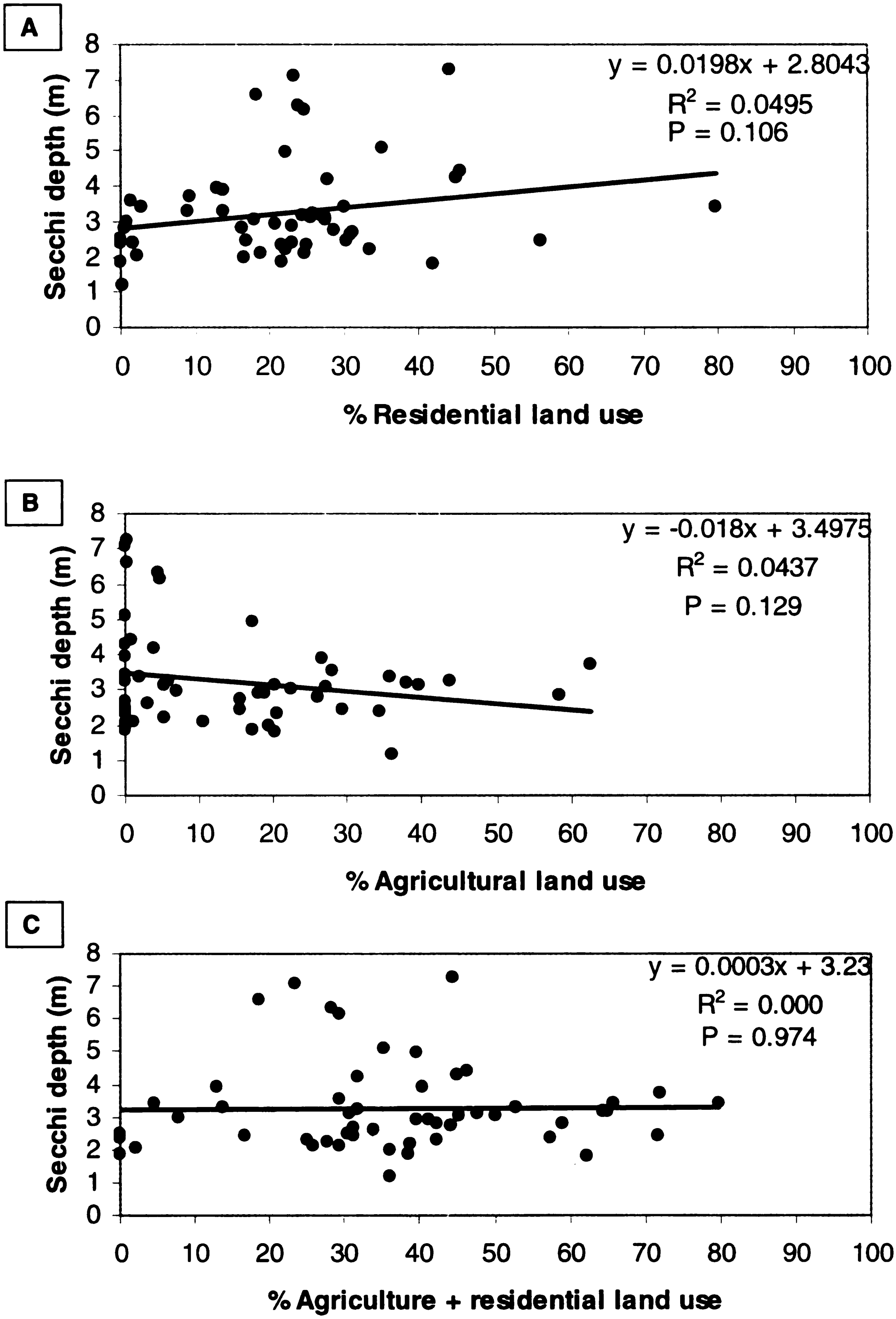
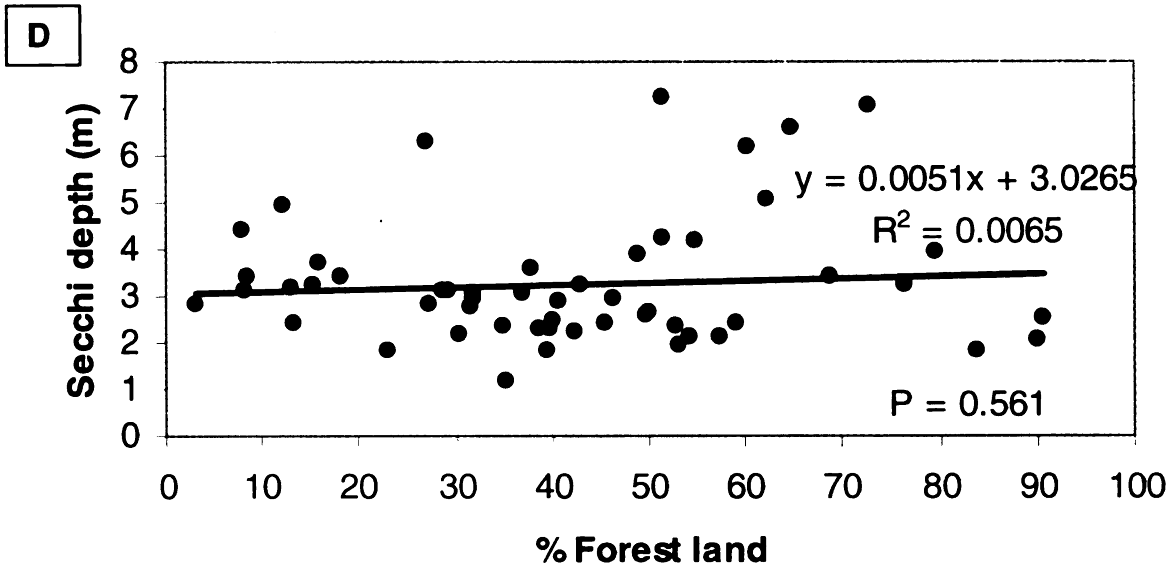


Figure 9 (cont'd.). Land use versus Secchi depth: 500 m buffers.



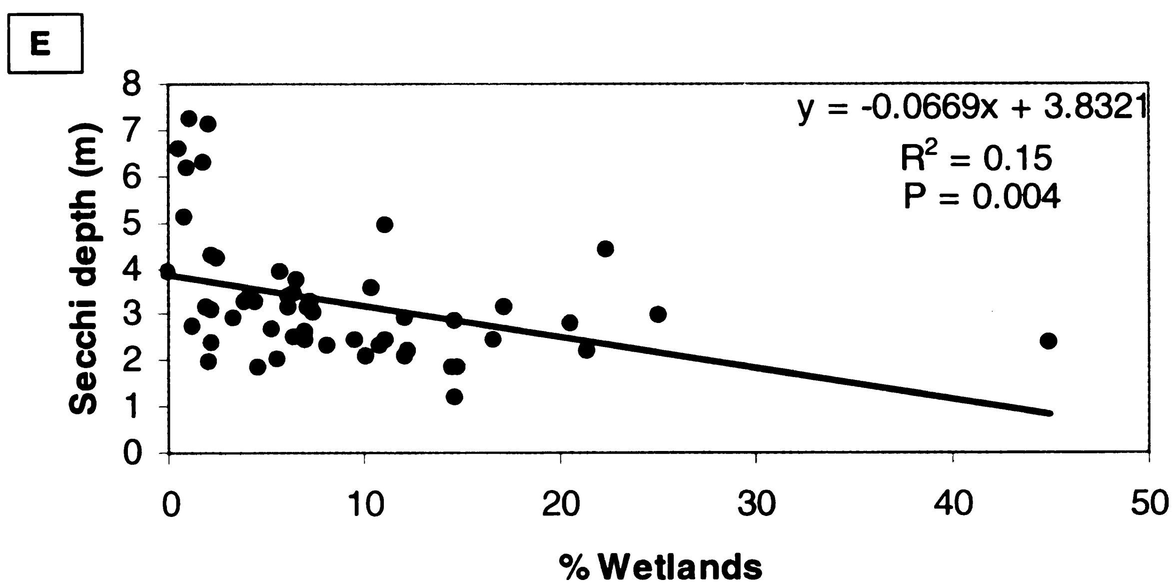
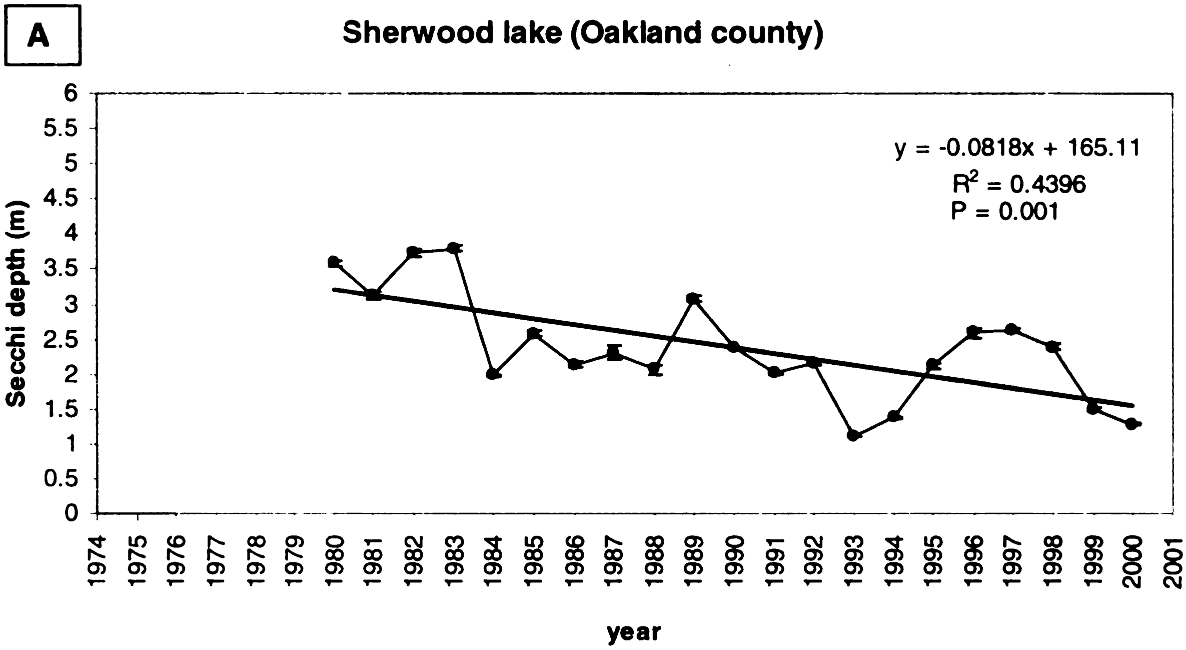


Figure 10. Examples of individual lake Secchi depth trends.



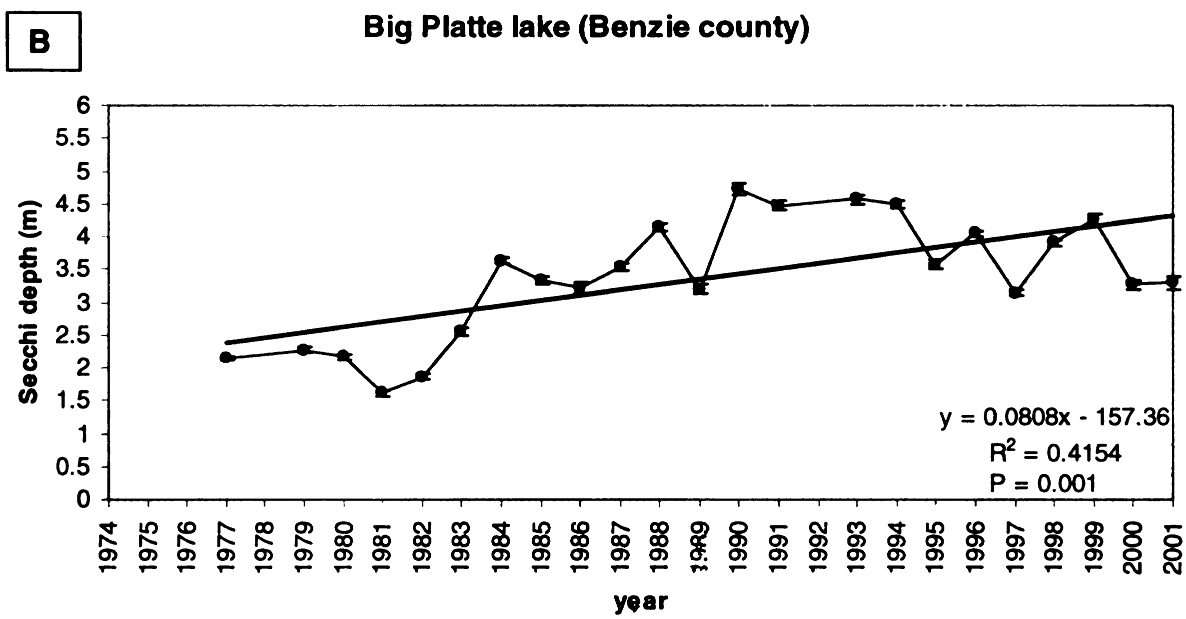
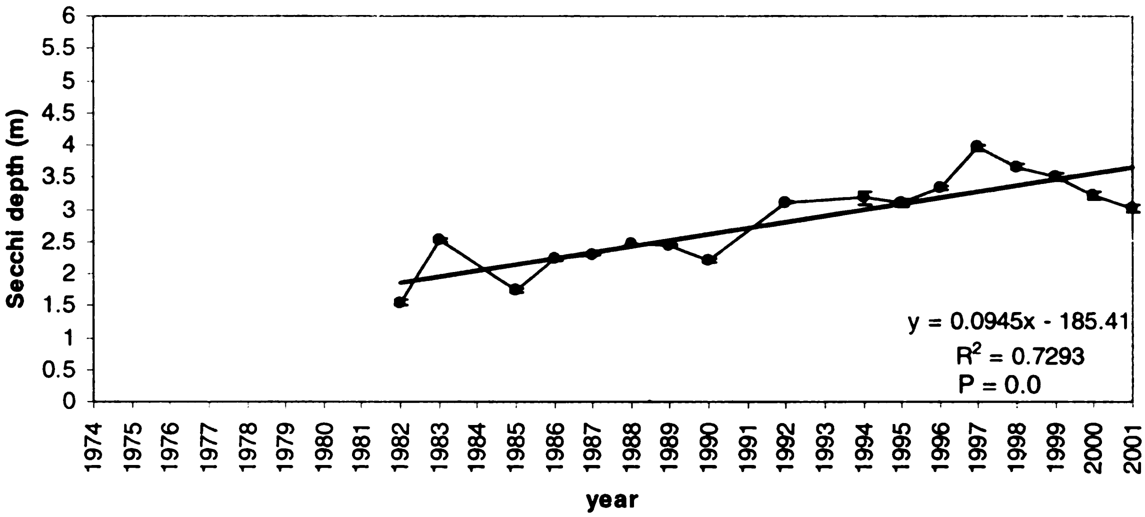


Figure 10 (cont'd.). Examples of individual lake Secchi depth trends.

C

Klinger lake (St. Joseph county)



D

Pleasant lake (St. Joseph county)

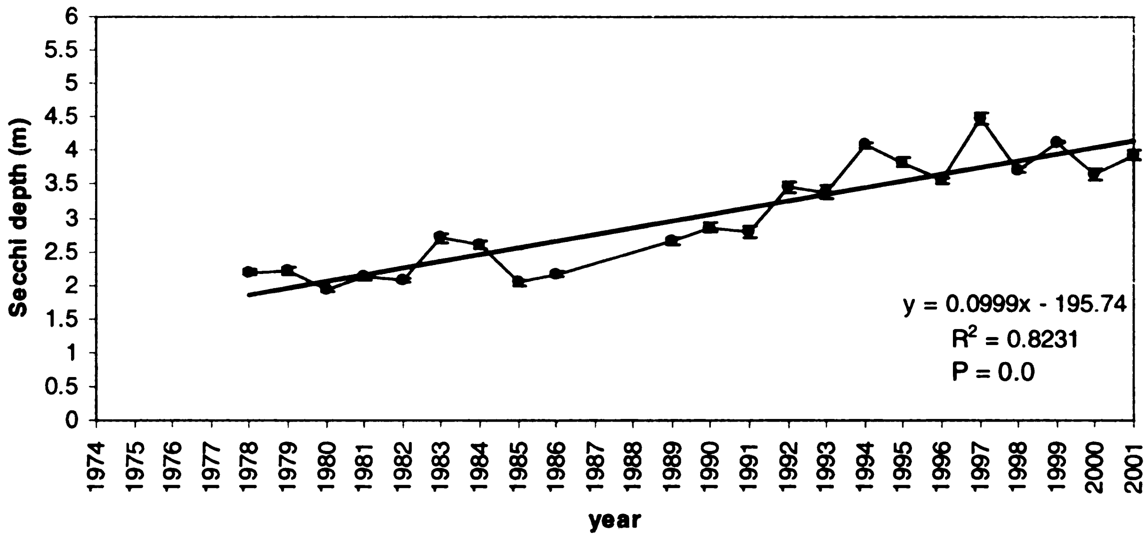


Figure 11. The influence of zebra mussels on average Secchi depth 1996-2001.

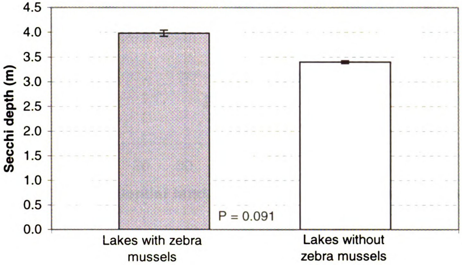


Figure 12. The influence of zebra mussels on average Secchi depth 1974-1990.

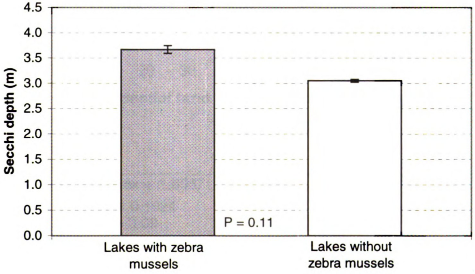


Figure 13a-c. Land use versus Secchi depth by ecoregions: residential and agricultural.

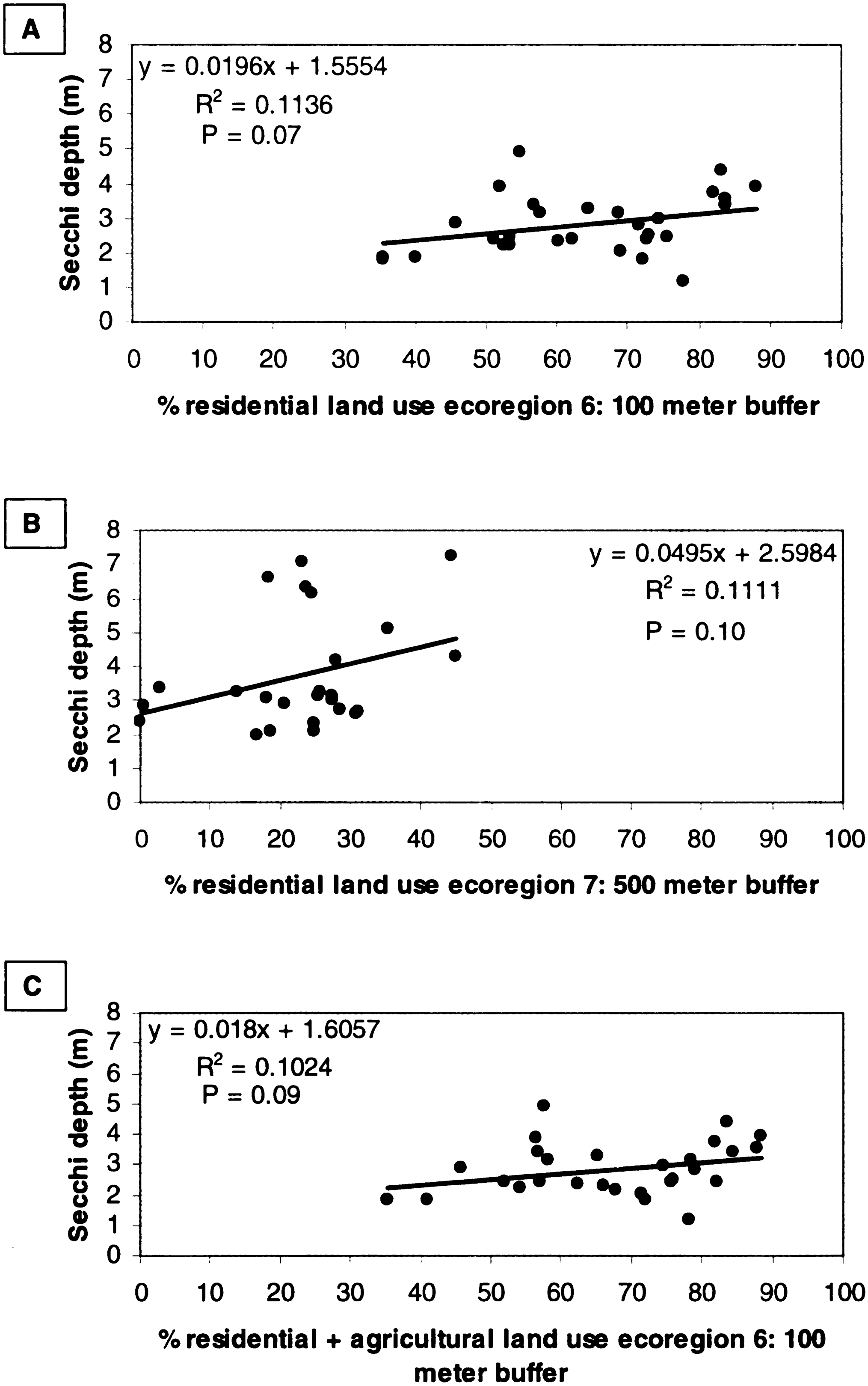
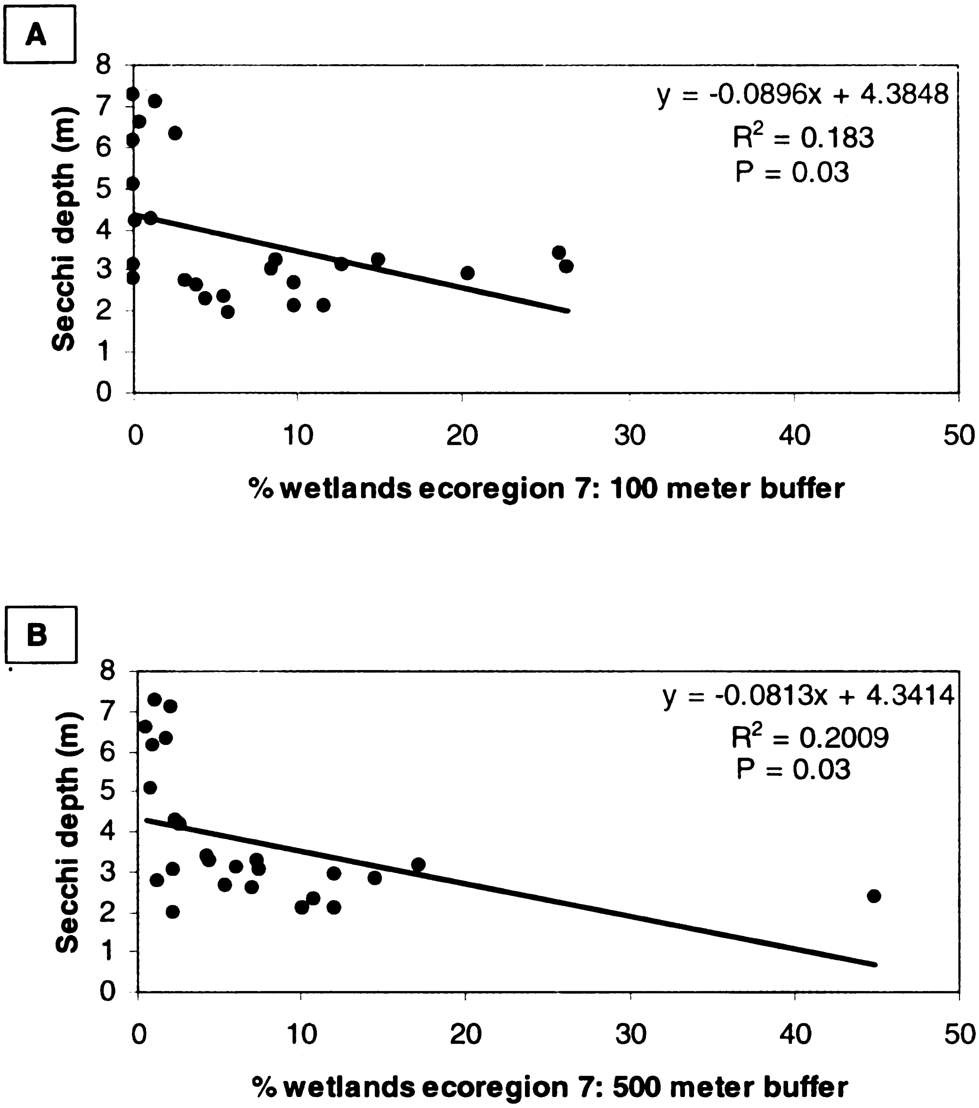


Figure 14a-b. Land use versus Secchi depth by ecoregions: wetlands



APPENDIX C: SAMPLING FREQUENCY RESULTS

Table 2. Sampling frequencies.

County	Lake Name	Data Span	Years with 1 missed month	Years sampling all frequencies	Years minimum 2 samples per month
Alcona	Vaughn	75-01	0	10	7
Allegan	Hutchins	75-01	1	26	15
Allegan & Van Buren	Eagle	76-01	1	16	13
Alpena	Beaver	77-01	1	25	20
Barry	Barlow	80-01	1	22	13
Barry	Payne	90-00	0	11	9
Benzie	Big Platte	77-01	0	23	23
Benzie	Crystal	76-01	3	11	4
Berrien	Little Paw Paw	92-01	1	10	9
Branch	Coldwater	77-01	0	25	21
Branch	Long	77-01	1	25	18
Cass	Christiana	78-01	1	10	9
Cass	Dewey	74-00	0	25	23
Cass	Donnell	78-01	1	21	18
Cass	Indiana	88-01	0	14	14
Cass	Juno	78-01	1	10	9
Cass	Painter	93-01	0	7	7
Cass	Twin Lakes- North	92-01	1	10	9
Clare	Crooked	80-01	0	15	12
Clare	Lake George	74-01	0	11	10
Clare	Shingle	74-01	0	10	8
Crawford	Lake Margrethe	75-01	1	12	7
Genesee	Byram	74-01	0	17	15
Genesee	Fenton	80-01	0	17	8
Grand Traverse	Arbutus	88-01	3	14	10
Grand Traverse	Duck	92-01	0	10	9
Grand Traverse	Long	79-01	1	15	12
Grand Traverse	Spider	80-01	0	11	8
Iosco	Long	74-01	3	28	21
Iosco	Van Etten	86-01	1	16	15
Jackson	Clear	81-01	2	17	14
Jackson	Vineyard	77-01	0	21	18
Kalkaska	Cub	93-01	0	9	9
Kent	Camp	90-00	1	9	3
Lake	Harper	89-01	2	11	9
Leelanau	Glen	79-01	4	17	11
Leelanau	Leelanau- North	77-01	0	25	25
Leelanau	Little Glen	79-01	2	18	13
Lenawee	Devils	80-01	1	11	5
Livingston	Coon	74-01	0	18	18
Livingston	Zukey	80-01	0	13	8
Manistee	Bear	77-01	1	24	19
Mason	Blue	88-01	1	14	8
Mason	Ford	83-00	3	18	13
Mason	Hackert	89-01	2	13	8
Mecosta	Blue	81-01	0	19	19

County	Lake Name	Data Span	Years with 1 missed month	Years sampling all frequencies	Years minimum 2 samples per month
Mecosta	Horsehead	81-01	2	21	18
Mecosta	Mecosta	81-01	0	18	17
Mecosta	Round	77-01	1	19	18
Mecosta	School Section	90-00	0	11	9
Missaukee	Sapphire	79-01	1	21	15
Montcalm	Baldwin	77-01	0	23	19
Montmorency	Avalon	80-01	1	15	9
Montmorency	West Twin	92-01	1	10	7
Newaygo	Bills	84-01	1	18	14
Newaygo	Emerald	80-01	2	20	17
Newaygo	Sylvan	80-01	1	20	18
Oakland	Lakeville	76-01	1	19	17
Oakland	Sherwood	80-00	1	21	19
Oakland	Taylor	74-01	1	16	14
Oakland	Walled	83-01	2	10	7
Oakland	White	76-01	2	13	10
Ottawa	Crockery	82-01	1	11	8
Roscommon	Higgins	74-01	1	26	11
Shiawassee	Leisure	81-01	2	14	11
St. Joseph	Clear	76-00	3	20	15
St. Joseph & Cass	Corey	74-01	0	28	28
St. Joseph	Klinger	82-01	1	17	14
St. Joseph	Pleasant	78-01	1	22	20
Van Buren	Lake of the Woods	81-01	0	21	19
Wexford	Stone Ledge	87-01	1	15	13

For the individual lake trend analysis using all sampling frequencies, I found 26 lakes with significant ($P \leq 0.1$) trends. For the dataset using years with a minimum of two samples or more per month, I found 28 lakes with significant ($P \leq .1$) trends. Of the 26 significant trend lakes using all sampling frequencies, six were not significant in the other dataset. These six only had a total of 3 years with a missed month of sampling. There was also a great decrease in years and range of data when using the minimum of 2 samples per month. The literature supports a minimum of 3 samples over the summer growing period. Therefore, for all my final analyses, I used the data set that had a minimum of 3 samples per summer.

APPENDIX D: METADATA

Data description: Secchi depth data for 71 selected lakes in the Cooperative Lakes Monitoring Program (CLMP). Data spans from 1974 to 2001.

Secchi depth data collection methods:
The Michigan Department of Environmental Quality (MDEQ). has developed standard procedures for Secchi depth measurements and volunteers are trained by MDEQ or Michigan Lakes & Streams Association staff yearly. Volunteers collect Secchi depth readings weekly or bi-weekly (every other week) from mid-May through mid-September, although not all volunteers sample this often. Although there is not complete control over the volunteers' sampling procedures, they are trained as follows. The Secchi depth is taken in the deepest basin of the lake and sometimes at additional stations. Readings are taken on the same day of each week and between 10:00am and 3:00pm to minimize sun angle differences between readings. Secchi data are recorded from an anchored boat and with some distance from the anchor to minimize turbidity created by dropping the anchor. The Secchi disk is lowered on the shaded side of the boat and volunteers are instructed not to wear sunglasses or tinted glasses in order to record more accurate and uniform readings. The Secchi disk is lowered until it disappears, raised until it appears again, and the reading is the average between these two depths.

Obtained from:
Michigan Department of Environmental Quality, Land and Water Management Division, Ralph Bednarz. bednarzr@michigan.gov

Complied by:
Laura Bruhn, Michigan State University. bruhnlau@msu.edu

Data format:

1974-1988:	Hard copy summary sheets showing "week of" sample dates.
1992:	Hard copy summary sheets showing "week of" sample dates.
1989-2001:	Hard copy individual lake sheets showing exact sample date (not summary sheets).
1995-2001:	Pre-entered Excel format electronic data. Data entry was done by a volunteer from CLMP.

Data entry of 'hard copy' sheets:

1. Occasionally, lakes had multiple samples per week, so to be consistent with the rest of the data, only one value was desired. To obtain one value per week for the summary sheets, the 1st date was used because no exact dates were available. For other data, I used date closest to the day of week that

other samples were taken. Almost always, the two Secchi values were very similar.

2. Heading dates are the 'week of' (meaning that date, and all future dates during the next week). Heading dates start on either Saturday or Sunday.

3. All data were reported in feet, and volunteers are instructed to round readings to the nearest half-foot. Occasionally on the hard copy data, the Secchi depths were recorded to the inch, and for transfer into electronic form, values were rounded to the nearest quarter-foot. In some cases with the electronic data, values were already entered to the exact nearest inch, and I left them as entered. Below is the rounding criteria that I used.

Inch	Rounded	Exact
1	.0	.08
2	.25	.16
3	.25	.25
4	.25	.33
5	.5	.41
6	.5	.5
7	.5	.58
8	.75	.67
9	.75	.75
10	.75	.83
11	.0	.91
12	.0	.0

Quality control/quality assurance:

1. On-screen double check at time of 1st entry (5/2002 & 6/2002).

2. Hard copy check on 6/20/02, 6/21/02, 6/28/02, 7/11/02. (Included check of 1995-2001 electronic data).

Warnings/ data limitations:

Secchi depth is only one component of water quality and Secchi readings cannot compressively indicate site-specific water quality conditions.

<u>Description of Excel files and sheets within the files</u>:

Secchi 74data.xls

1974 originalraw: Raw data from entry or electronic format, QA/QC. Data are in feet/ inches.

1974 summer: July through September data only. Multiple samples per week are excluded, and only primary sampling station is used. Data are in feet/inches.

These data files continue for every year (Secchi 75data.xls, Secchi 76data.xls, etc.).

Info lakes 8+ years data.xls

General info: The 71 selected lakes, including name, county, township, surface area, maximum depth, township, and notes.

Sampling freq: Lists the number of samples per three month summer period, (0 samples per month, 1, 2, and 3 or more samples per month) for each lake year. For example, "0-2-3" means 0 samples in July, 2 in August, and 3 or more in September. "1" means 1 sample in July, 1 in August, and 1 in September. A lake year of data was used in analyses if it only missed one month of sampling (one 0) and had a minimum of three samples over the entire summer period. A lake year of data was not used in analyses if it missed more than one month of sampling (two or more 0s).

Stats: Lists the regression results for each lake using all sampling frequencies versus using only 2 and 3 or more samples per month.

Zebra: Zebra mussel data from Sea Grant's (2001) database. This database records which lakes have been monitored for zebra mussels and what year they were first detected. The analyses compares the lakes containing zebra mussels to their clarity trends, and 1996-2001 mean Secchi depth for lakes with zebra mussels versus those without.

Significance: Lists the regression results for each lake, sorted by P-value, and the magnitude of the significant trends.

All_Lakes.xls

Dates: Summer weeks were put into a 1st week of the month, 2nd, 3rd, 4th, and 5th week of the month format. I did this for every summer month (July, August, September). This sheet shows how the dates matched up with each week of the month.

FT 0+1+2+3: Data from all lakes, all years, in feet/inches. Data uses all sampling frequencies (0 samples per month, 1, 2, and 3 or more samples per month).

Meters 0+1+2+3: Data from all lakes, all years, converted to meters. Data uses all sampling frequencies (0 samples per month, 1, 2, and 3 or more samples per month). Data also includes yearly Secchi depth average, number of samples per year, standard deviation and standard error.

Meters 2+3: Data from all lakes, all years, converted to meters. Data uses sampling frequencies of 2 and 3 or more samples per month. Data also includes yearly Secchi depth average, number of samples per year, standard deviation and standard error.

Lake trends: Time-based trends of individual lakes, using data from all sampling frequencies (0,1,2,3). The graphs show regression equation, and lakes with significant ($P \leq 0.1$)trends are noted.

Histograms: Distribution of yearly averages of individual lakes.

Trophic: State-wide and ecoregion trophic state divisions, based on Forsberg and Ryding's (1980) criteria and 1996-2001 average Secchi depths.

State-wide ave: State-wide clarity trend, divided by approximately 5-year intervals.

Ecoregion ave: Average Secchi depth, by ecoregion sections and subsections.

Ecoregion trends: Individual lake clarity trends, grouped by ecoregion section.

Land Use vs. Secchi: The land use information was obtained from Michigan Resource Information System (MIRIS) data from 1978. Therefore, I only included lakes with annual Secchi means within a ten-year span of these data (1974-1983). Secchi depths annual means were plotted against the percent land use within both a 100 and 500 meter buffer around each lake. The land use categories used were: residential, agriculture, residential combined with agriculture, forest and wetlands.

Ecoregion Land Use: Calculations of the average percent land use types for the two ecoregion sections (six and seven) for each of the land use classifications and buffer distances.

Ecoregion vs. Land Use: Ecoregion average Secchi depth versus ecoregion land uses. (These analyses not used in thesis).

APPENDIX E: LAKE SECCHI AVERAGE BY YEAR

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Alcona	Vaughn	1-29	1975	2.03	12	0.25	0.02
Alcona	Vaughn	1-29	1976	2.08	12	0.40	0.03
Alcona	Vaughn	1-29	1977	1.75	10	0.52	0 05
Alcona	Vaughn	1-29	1992	4.62	13	0.24	0.02
Alcona	Vaughn	1-29	1994	2.72	13	1.09	0.08
Alcona	Vaughn	1-29	1997	3.67	6	0.42	0.07
Alcona	Vaughn	1-29	1998	2.22	9	0.41	0.05
Alcona	Vaughn	1-29	1999	3.53	7	0.94	0.13
Alcona	Vaughn	1-29	2000	3.96	8	0.63	0.08
Alcona	Vaughn	1-29	2001	3.28	6	0.95	0.16
Allegan	Hutchins	3-178	1975	2.11	13	0.28	0.02
Allegan	Hutchins	3-178	1976	1.97	13	0.32	0.02
Allegan	Hutchins	3-178	1977	2.06	8	0.18	0.02
Allegan	Hutchins	3-178	1978	2.18	3	0.09	0.03
Allegan	Hutchins	3-178	1980	2.83	7	0.56	0.08
Allegan	Hutchins	3-178	1981	2.19	11	0.34	0.03
Allegan	Hutchins	3-178	1982	2.67	8	0.28	0.04
Allegan	Hutchins	3-178	1983	3.48	7	0.72	0.10
Allegan	Hutchins	3-178	1984	2.10	9	0.20	0.02
Allegan	Hutchins	3-178	1985	2.51	11	0.39	0.04
Allegan	Hutchins	3-178	1986	2.62	10	0.70	0.07
Allegan	Hutchins	3-178	1987	2.49	11	0.38	0.03
Allegan	Hutchins	3-178	1988	2.09	10	0.39	0.04
Allegan	Hutchins	3-178	1989	2.49	9	0.39	0.04
Allegan	Hutchins	3-178	1990	2.74	9	0.48	0.05
Allegan	Hutchins	3-178	1991	2.88	11	0.72	0.07
Allegan	Hutchins	3-178	1992	2.89	11	0.67	0.06
Allegan	Hutchins	3-178	1993	2.36	13	0.38	0.03
Allegan	Hutchins	3-178	1994	1.89	13	0.17	0.01
Allegan	Hutchins	3-178	1995	2.64	10	0.27	0.03
Allegan	Hutchins	3-178	1996	2.74	9	0.45	0.05
Allegan	Hutchins	3-178	1997	2.82	8	0.44	0.06
Allegan	Hutchins	3-178	1998	1.96	7	0.14	0.02
Allegan	Hutchins	3-178	1999	2.66	6	0.52	0.09
Allegan	Hutchins	3-178	2000	2.38	6	0.20	0.03
Allegan	Hutchins	3-178	2001	2.38	7	0.90	0.13
Allegan & Van Buren	Eagle	3-60	1976	3.12	11	0.47	0.04
Allegan & Van Buren	Eagle	3-60	1977	3.37	11	0.62	0.06
Allegan & Van Buren	Eagle	3-60	1978	3.78	12	0.70	0.06
Allegan & Van Buren	Eagle	3-60	1979	4.01	10	0.26	0.03
Allegan & Van Buren	Eagle	3-60	1980	3.24	12	0.42	0.03
Allegan & Van Buren	Eagle	3-60	1981	4.66	10	0.66	0.07
Allegan & Van Buren	Eagle	3-60	1982	4.45	12	0.57	0.05
Allegan & Van Buren	Eagle	3-60	1983	4.55	8	0.87	0.11
Allegan & Van Buren	Eagle	3-60	1984	4.27	12	1.01	0.08
Allegan & Van Buren	Eagle	3-60	1991	3.80	11	0.52	0.05
Allegan & Van Buren	Eagle	3-60	1992	2.66	5	0.18	0.04
Allegan & Van Buren	Eagle	3-60	1993	3.45	13	0.63	0.05
Allegan & Van Buren	Eagle	3-60	1997	3.79	13	0.89	0.07

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Allegan & Van Buren	Eagle	3-60	1999	3.97	13	0.80	0.06
Allegan & Van Buren	Eagle	3-60	2000	3.75	13	0.74	0.06
Allegan & Van Buren	Eagle	3-60	2001	4.50	11	0.28	0.03
Alpena	Beaver	4-1	1977	2.77	10	0.56	0.06
Alpena	Beaver	4-1	1978	3.28	12	0.37	0.03
Alpena	Beaver	4-1	1979	3.16	8	0.31	0.04
Alpena	Beaver	4-1	1980	3.55	11	0.45	0 04
Alpena	Beaver	4-1	1981	3.40	12	0.39	0.03
Alpena	Beaver	4-1	1982	3.20	12	0.28	0.02
Alpena	Beaver	4-1	1983	3.45	11	0.22	0.02
Alpena	Beaver	4-1	1984	2.41	10	0.42	0.04
Alpena	Beaver	4-1	1985	2.44	11	0.35	0.03
Alpena	Beaver	4-1	1986	2.33	11	0.28	0.03
Alpena	Beaver	4-1	1987	2.51	12	0.50	0.04
Alpena	Beaver	4-1	1988	2.37	9	0.52	0.06
Alpena	Beaver	4-1	1989	2.24	10	0.27	0.03
Alpena	Beaver	4-1	1990	2.62	10	0.20	0.02
Alpena	Beaver	4-1	1991	2.26	11	0.40	0.04
Alpena	Beaver	4-1	1992	3.47	13	0.52	0.04
Alpena	Beaver	4-1	1993	3.18	13	0.58	0.04
Alpena	Beaver	4-1	1994	3.73	9	0.23	0.03
Alpena	Beaver	4-1	1995	2.74	10	0.44	0.04
Alpena	Beaver	4-1	1996	3.63	11	0.54	0.05
Alpena	Beaver	4-1	1997	3.96	12	0.80	0.07
Alpena	Beaver	4-1	1998	3.80	13	0.42	0.03
Alpena	Beaver	4-1	1999	3.03	12	0.29	0.02
Alpena	Beaver	4-1	2000	3.32	13	0.59	0.05
Alpena	Beaver	4-1	2001	4.01	13	0.30	0.02
Barry	Barlow	8-586	1980	2.19	10	0.77	0.08
Barry	Barlow	8-586	1981	3.70	11	0.81	0.07
Barry	Barlow	8-586	1982	3.53	11	0.96	0.09
Barry	Barlow	8-586	1983	3.60	10	0.61	0.06
Barry	Barlow	8-586	1984	2.96	10	0.93	0.09
Barry	Barlow	8-586	1985	2.83	9	0.97	0.11
Barry	Barlow	8-586	1986	4.18	10	1.30	0.13
Barry	Barlow	8-586	1987	2.73	11	0.67	0.06
Barry	Barlow	8-586	1988	1.93	9	0.68	0.08
Barry	Barlow	8-586	1989	3.05	11	0.71	0.06
Barry	Barlow	8-586	1990	3.35	9	1.11	0.12
Barry	Barlow	8-586	1991	2.68	10	0.40	0.04
Barry	Barlow	8-586	1992	3.00	12	0.82	0.07
Barry	Barlow	8-586	1993	2.81	11	0.47	0.04
Barry	Barlow	8-586	1994	1.95	10	1.00	0.10
Barry	Barlow	8-586	1995	2.39	10	0.70	0.07
Barry	Barlow	8-586	1996	2.65	8	0.83	0.10
Barry	Barlow	8-586	1997	3.51	9	0.30	0.03
Barry	Barlow	8-586	1998	2.09	10	0.50	0.05
Barry	Barlow	8-586	1999	4.04	8	0.58	0.07
Barry	Barlow	8-586	2000	2.93	9	0.84	0.09
Barry	Barlow	8-586	2001	3.34	10	0.32	0.03
Barry	Payne	8-604	1990	2.30	9	0.27	0.03
Barry	Payne	8-604	1991	2.54	11	0.27	0.02
Barry	Payne	8-604	1992	2.59	11	0.47	0.04
Barry	Payne	8-604	1993	2.92	12	0.37	0.03
Barry	Payne	8-604	1994	2.42	10	0.36	0.04

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Barry	Payne	8-604	1995	2.25	8	0.45	0.06
Barry	Payne	8-604	1996	2.51	6	1.00	0.17
Barry	Payne	8-604	1997	3.05	6	0.73	0.12
Barry	Payne	8-604	1998	2.66	7	0.45	0.06
Barry	Payne	8-604	1999	3.05	6	0.87	0.14
Barry	Payne	8-604	2000	3.03	7	0.85	0.12
Benzie	Big Platte	10-39	1977	2.13	12	0.32	0.03
Benzie	Big Platte	10-39	1979	2.27	11	0.39	0.04
Benzie	Big Platte	10-39	1980	2.16	11	0.50	0.05
Benzie	Big Platte	10-39	1981	1.61	12	0.47	0.04
Benzie	Big Platte	10-39	1982	1.87	12	0.40	0.03
Benzie	Big Platte	10-39	1983	2.55	11	0.57	0.05
Benzie	Big Platte	10-39	1984	3.63	12	0.50	0.04
Benzie	Big Platte	10-39	1985	3.33	12	0.77	0.06
Benzie	Big Platte	10-39	1986	3.21	12	0.92	0.08
Benzie	Big Platte	10-39	1987	3.53	12	0.61	0.05
Benzie	Big Platte	10-39	1988	4.16	11	0.66	0.06
Benzie	Big Platte	10-39	1989	3.20	11	0.71	0.06
Benzie	Big Platte	10-39	1990	4.71	13	1.10	0.08
Benzie	Big Platte	10-39	1991	4.47	13	0.93	0.07
Benzie	Big Platte	10-39	1993	4.57	13	1.03	0.08
Benzie	Big Platte	10-39	1994	4.49	13	0.68	0.05
Benzie	Big Platte	10-39	1995	3.58	13	1.07	0.08
Benzie	Big Platte	10-39	1996	4.04	13	0.69	0.05
Benzie	Big Platte	10-39	1997	3.14	13	0.62	0.05
Benzie	Big Platte	10-39	1998	3.90	13	0.60	0.05
Benzie	Big Platte	10-39	1999	4.27	13	1.03	0.08
Benzie	Big Platte	10-39	2000	3.27	13	0.93	0.07
Benzie	Big Platte	10-39	2001	3.29	13	1.42	0.11
Benzie	Crystal	10-42	1976	5.82	12	0.83	0.07
Benzie	Crystal	10-42	1977	6.36	7	0.67	0.10
Benzie	Crystal	10-42	1978	5.89	3	1.50	0.50
Benzie	Crystal	10-42	1979	6.52	5	1.09	0.22
Benzie	Crystal	10-42	1987	5.46	10	0.99	0.10
Benzie	Crystal	10-42	1988	6.40	9	1.26	0.14
Benzie	Crystal	10-42	1989	6.81	10	1.47	0.15
Benzie	Crystal	10-42	1991	6.78	12	0.86	0.07
Benzie	Crystal	10-42	1998	5.85	4	0.62	0.15
Benzie	Crystal	10-42	2000	5.49	4	0.43	0.11
Benzie	Crystal	10-42	2001	6.81	3	1.41	0.47
Berrien	Little Paw Paw	11-2	1992	1.57	13	0.23	0.02
Berrien	Little Paw Paw	11-2	1993	1.35	13	0.12	0.01
Berrien	Little Paw Paw	11-2	1994	1.90	5	0.24	0.05
Berrien	Little Paw Paw	11-2	1995	1.90	12	0.40	0.03
Berrien	Little Paw Paw	11-2	1996	1.81	11	0.39	0.04
Berrien	Little Paw Paw	11-2	1997	1.61	11	0.32	0.03
Berrien	Little Paw Paw	11-2	1998	2.12	11	0.23	0.02
Berrien	Little Paw Paw	11-2	1999	1.88	11	0.24	0.02
Berrien	Little Paw Paw	11-2	2000	1.90	10	0.25	0.02
Berrien	Little Paw Paw	11-2	2001	2.13	11	0.41	0.04
Branch	Coldwater	12-90	1977	2.57	8	0.39	0.05
Branch	Coldwater	12-90	1978	2.36	12	0.66	0.06
Branch	Coldwater	12-90	1979	3.34	11	0.50	0.05
Branch	Coldwater	12-90	1980	2.86	12	0.71	0.06
Branch	Coldwater	12-90	1981	3.04	13	0.41	0.03

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Branch	Coldwater	12-90	1982	3.00	12	0.52	0.04
Branch	Coldwater	12-90	1983	2.51	12	0.33	0.03
Branch	Coldwater	12-90	1984	2.90	13	0.53	0.04
Branch	Coldwater	12-90	1985	2.45	12	0.53	0 04
Branch	Coldwater	12-90	1986	2.43	12	0.43	0.04
Branch	Coldwater	12-90	1987	2.59	12	0.43	0.04
Branch	Coldwater	12-90	1988	1.83	11	0.27	0.02
Branch	Coldwater	12-90	1989	2.00	9	0.16	0.02
Branch	Coldwater	12-90	1990	2.24	12	0.47	0.04
Branch	Coldwater	12-90	1991	2.84	12	0.72	0.06
Branch	Coldwater	12-90	1992	2.92	12	0.63	0.05
Branch	Coldwater	12-90	1993	2.59	9	0.80	0.09
Branch	Coldwater	12-90	1994	3.69	11	0.71	0.06
Branch	Coldwater	12-90	1995	3.12	4	0.76	0.19
Branch	Coldwater	12-90	1996	2.73	9	0.43	0.05
Branch	Coldwater	12-90	1997	3.17	9	0.40	0.04
Branch	Coldwater	12-90	1998	2.74	6	0.39	0.06
Branch	Coldwater	12-90	1999	2.26	10	0.84	0.08
Branch	Coldwater	12-90	2000	2.25	8	0.35	0.04
Branch	Coldwater	12-90	2001	1.94	10	0.83	0.08
Branch	Long	12-86	1977	1.79	8	0.53	0.07
Branch	Long	12-86	1978	1.69	12	0.26	0.02
Branch	Long	12-86	1979	1.97	11	0.33	0.03
Branch	Long	12-86	1980	2.01	12	0.28	0.02
Branch	Long	12-86	1981	1.99	12	0.21	0.02
Branch	Long	12-86	1982	1.77	12	0.35	0.03
Branch	Long	12-86	1983	1.71	12	0.40	0.03
Branch	Long	12-86	1984	1.71	13	0.42	0.03
Branch	Long	12-86	1985	1.49	12	0.36	0.03
Branch	Long	12-86	1986	1.46	12	0.30	0.03
Branch	Long	12-86	1987	1.30	12	0.41	0.03
Branch	Long	12-86	1988	1.12	11	0.40	0.04
Branch	Long	12-86	1989	1.20	9	0.12	0.01
Branch	Long	12-86	1990	1.14	12	0.19	0.02
Branch	Long	12-86	1991	1.13	12	0.39	0.03
Branch	Long	12-86	1992	1.08	12	0.12	0.01
Branch	Long	12-86	1993	1.59	9	0.17	0.02
Branch	Long	12-86	1994	1.73	11	0.31	0.03
Branch	Long	12-86	1995	1.41	4	0.31	0.08
Branch	Long	12-86	1996	1.08	9	0.32	0.04
Branch	Long	12-86	1997	1.44	9	0.22	0.02
Branch	Long	12-86	1998	1.35	6	0.34	0.06
Branch	Long	12-86	1999	1.41	9	0.42	0.05
Branch	Long	12-86	2000	1.68	7	0.33	0.05
Branch	Long	12-86	2001	2.15	10	0.46	0.05
Cass	Christiana	14-400-GRP	1978	1.89	10	0.28	0.03
Cass	Christiana	14-400-GRP	1979	1.79	12	0.28	0.02
Cass	Christiana	14-400-GRP	1992	3.08	5	0.46	0.09
Cass	Christiana	14-400-GRP	1993	2.16	12	0.61	0.05
Cass	Christiana	14-400-GRP	1995	1.68	12	0.28	0.02
Cass	Christiana	14-400-GRP	1997	2.02	13	0.39	0.03
Cass	Christiana	14-400-GRP	1998	1.73	12	0.45	0.04
Cass	Christiana	14-400-GRP	1999	1.34	13	0.15	0.01
Cass	Christiana	14-400-GRP	2000	3.74	13	5.75	0.44
Cass	Christiana	14-400-GRP	2001	2.17	9	0.41	0.05

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Cass	Dewey	14-88	1974	0.84	13	0.45	0.03
Cass	Dewey	14-88	1975	0.81	6	0.41	0.07
Cass	Dewey	14-88	1976	1.60	12	0.32	0.03
Cass	Dewey	14-88	1977	1.27	12	0.12	0.01
Cass	Dewey	14-88	1980	1.74	9	0.19	0.02
Cass	Dewey	14-88	1981	0.76	12	0.64	0.05
Cass	Dewey	14-88	1982	0.76	12	0.37	0.03
Cass	Dewey	14-88	1983	1.52	11	0.47	0.04
Cass	Dewey	14-88	1984	0.86	12	0.14	0.01
Cass	Dewey	14-88	1985	1.30	12	0.17	0.01
Cass	Dewey	14-88	1986	1.08	12	0.04	0.00
Cass	Dewey	14-88	1987	1.23	12	0.26	0.02
Cass	Dewey	14-88	1988	2.41	11	0.25	0.02
Cass	Dewey	14-88	1989	2.34	11	0.23	0.02
Cass	Dewey	14-88	1990	2.21	10	0.35	0.04
Cass	Dewey	14-88	1991	1.04	11	0.26	0.02
Cass	Dewey	14-88	1992	1.29	13	0.24	0.02
Cass	Dewey	14-88	1993	1.32	12	0.12	0.01
Cass	Dewey	14-88	1994	1.37	12	0.09	0.01
Cass	Dewey	14-88	1995	1.55	10	0.25	0.02
Cass	Dewey	14-88	1996	1.31	12	0.22	0.02
Cass	Dewey	14-88	1997	2.11	11	0.22	0.02
Cass	Dewey	14-88	1998	2.12	13	0.35	0.03
Cass	Dewey	14-88	1999	1.85	12	0.16	0.01
Cass	Dewey	14-88	2000	1.44	11	0.49	0.04
Cass	Donnell	14-224	1978	2.30	12	0.93	0.08
Cass	Donnell	14-224	1979	2.92	12	1.19	0.10
Cass	Donnell	14-224	1980	2.24	12	0.50	0.04
Cass	Donnell	14-224	1981	2.11	12	0.79	0.07
Cass	Donnell	14-224	1982	3.41	11	1.59	0.14
Cass	Donnell	14-224	1983	2.08	11	0.50	0.05
Cass	Donnell	14-224	1984	2.07	13	0.96	0.07
Cass	Donnell	14-224	1985	1.74	12	0.41	0.03
Cass	Donnell	14-224	1986	2.12	12	0.72	0.06
Cass	Donnell	14-224	1987	1.75	12	0.38	0.03
Cass	Donnell	14-224	1988	1.87	11	0.51	0.05
Cass	Donnell	14-224	1989	1.91	11	0.85	0.08
Cass	Donnell	14-224	1990	1.78	9	0.54	0.06
Cass	Donnell	14-224	1991	1.84	12	0.55	0.05
Cass	Donnell	14-224	1995	3.35	8	0.56	0.07
Cass	Donnell	14-224	1996	3.03	11	1.26	0.11
Cass	Donnell	14-224	1997	3.24	12	0.77	0.06
Cass	Donnell	14-224	1998	2.85	12	0.36	0.03
Cass	Donnell	14-224	1999	2.50	8	0.68	0.09
Cass	Donnell	14-224	2000	2.98	11	0.61	0.06
Cass	Donnell	14-224	2001	2.31	6	0.74	0.12
Cass	Indiana	14-394	1988	4.09	12	1.34	0.11
Cass	Indiana	14-394	1989	2.73	13	0.45	0.03
Cass	Indiana	14-394	1990	4.06	13	0.91	0.07
Cass	Indiana	14-394	1991	4.21	13	1.07	0.08
Cass	Indiana	14-394	1992	3.66	12	0.86	0.07
Cass	Indiana	14-394	1993	4.91	13	1.35	0.10
Cass	Indiana	14-394	1994	5.88	12	1.38	0.11
Cass	Indiana	14-394	1995	4.89	13	1.21	0.09
Cass	Indiana	14-394	1996	4.71	11	1.09	0.10

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Cass	Indiana	14-394	1997	4.01	10	1.14	0.11
Cass	Indiana	14-394	1998	3.27	11	0.37	0.03
Cass	Indiana	14-394	1999	4.60	11	1.39	0.13
Cass	Indiana	14-394	2000	2.81	11	0.55	0.05
Cass	Indiana	14-394	2001	4.38	12	0.76	0.06
Cass	Juno	14-400-GRP	1978	1.76	11	0.34	0.03
Cass	Juno	14-400-GRP	1979	1.91	12	0.58	0.05
Cass	Juno	14-400-GRP	1992	3.05	4	0.41	0.10
Cass	Juno	14-400-GRP	1993	2.08	12	0.43	0.04
Cass	Juno	14-400-GRP	1995	1.70	12	0.24	0.02
Cass	Juno	14-400-GRP	1997	1.85	13	0.28	0.02
Cass	Juno	14-400-GRP	1998	1.61	12	0.39	0.03
Cass	Juno	14-400-GRP	1999	1.31	13	0.30	0.02
Cass	Juno	14-400-GRP	2000	1.98	13	0.19	0.01
Cass	Juno	14-400-GRP	2001	2.10	9	0.38	0.04
Cass	Painter	14-400-GRP	1993	1.85	12	0.35	0.03
Cass	Painter	14-400-GRP	1995	1.50	12	0.40	0.03
Cass	Painter	14-400-GRP	1997	1.79	13	0.36	0.03
Cass	Painter	14-400-GRP	1998	1.42	12	0.39	0.03
Cass	Painter	14-400-GRP	1999	1.63	13	0.49	0.04
Cass	Painter	14-400-GRP	2000	1.43	13	0.22	0.02
Cass	Painter	14-400-GRP	2001	1.76	9	0.27	0.03
Cass	Twin Lakes- North (Big)	14-75	1992	2.65	13	0.26	0.02
Cass	Twin Lakes- North (Big)	14-75	1993	2.86	13	0.54	0.04
Cass	Twin Lakes- North (Big)	14-75	1994	3.83	8	0.17	0.02
Cass	Twin Lakes- North (Big)	14-75	1995	3.38	12	1.08	0.09
Cass	Twin Lakes- North (Big)	14-75	1996	3.25	12	0.32	0.03
Cass	Twin Lakes- North (Big)	14-75	1997	4.24	12	0.31	0.03
Cass	Twin Lakes- North (Big)	14-75	1998	3.68	13	0.50	0.04
Cass	Twin Lakes- North (Big)	14-75	1999	4.31	13	0.39	0.03
Cass	Twin Lakes- North (Big)	14-75	2000	3.61	13	0.30	0.02
Cass	Twin Lakes- North (Big)	14-75	2001	3.90	13	1.09	0.08
Clare	Crooked	18-69	1980	2.60	11	0.34	0.03
Clare	Crooked	18-69	1981	2.67	12	0.26	0.02
Clare	Crooked	18-69	1982	3.52	11	0.21	0.02
Clare	Crooked	18-69	1983	4.18	10	0.39	0.04
Clare	Crooked	18-69	1984	3.46	11	0.12	0.01
Clare	Crooked	18-69	1992	3.31	12	0.16	0.01
Clare	Crooked	18-69	1993	3.14	13	0.16	0.01
Clare	Crooked	18-69	1994	2.43	13	0.17	0.01
Clare	Crooked	18-69	1995	2.50	10	0.29	0.03
Clare	Crooked	18-69	1996	2.53	12	0.14	0.01
Clare	Crooked	18-69	1997	2.96	13	0.44	0.03
Clare	Crooked	18-69	1998	3.14	10	0.23	0.02
Clare	Crooked	18-69	1999	3.33	7	0.13	0.02
Clare	Crooked	18-69	2000	3.78	7	0.39	0.06
Clare	Crooked	18-69	2001	3.51	9	0.27	0.03
Clare	Lake George	18-125	1974	2.37	13	0.21	0.02
Clare	Lake George	18-125	1992	3.26	13	0.47	0.04
Clare	Lake George	18-125	1993	2.22	13	0.31	0.02
Clare	Lake George	18-125	1994	2.69	11	0.19	0.02
Clare	Lake George	18-125	1995	2.24	13	0.41	0.03
Clare	Lake George	18-125	1996	3.11	13	0.76	0.06
Clare	Lake George	18-125	1997	3.73	13	0.49	0.04
Clare	Lake George	18-125	1998	2.91	13	0.35	0.03

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Clare	Lake George	18-125	1999	3.49	8	0.24	0.03
Clare	Lake George	18-125	2000	3.53	13	0.87	0.07
Clare	Lake George	18-125	2001	2.60	13	0.24	0.02
Clare	Shingle	18-124	1974	2.67	13	0.65	0.05
Clare	Shingle	18-124	1992	3.87	5	0.55	0.11
Clare	Shingle	18-124	1993	4.66	7	0.85	0.12
Clare	Shingle	18-124	1994	3.36	12	0.42	0.04
Clare	Shingle	18-124	1995	3.96	12	0.63	0.05
Clare	Shingle	18-124	1997	4.06	12	0.40	0.03
Clare	Shingle	18-124	1998	3.24	13	0.51	0.04
Clare	Shingle	18-124	1999	3.56	13	0.55	0.04
Clare	Shingle	18-124	2000	4.08	13	0.44	0.03
Clare	Shingle	18-124	2001	3.17	13	0.49	0.04
Crawford	Lake Margrethe	20-44	1975	4.67	9	0.46	0.05
Crawford	Lake Margrethe	20-44	1976	4.19	10	0.54	0.05
Crawford	Lake Margrethe	20-44	1977	4.14	11	0.30	0.03
Crawford	Lake Margrethe	20-44	1978	4.09	6	0.21	0.03
Crawford	Lake Margrethe	20-44	1979	4.19	10	0.28	0.03
Crawford	Lake Margrethe	20-44	1980	4.30	10	0.22	0.02
Crawford	Lake Margrethe	20-44	1981	4.25	8	0.37	0.05
Crawford	Lake Margrethe	20-44	1991	4.91	12	0.28	0.02
Crawford	Lake Margrethe	20-44	1997	4.61	4	0.31	0.08
Crawford	Lake Margrethe	20-44	1999	3.63	13	0.46	0.04
Crawford	Lake Margrethe	20-44	2000	3.77	11	0.46	0.04
Crawford	Lake Margrethe	20-44	2001	3.52	13	0.46	0.04
Genesee	Byram	25-54	1974	4.45	11	0.80	0.07
Genesee	Byram	25-54	1975	3.29	10	0.97	0.10
Genesee	Byram	25-54	1976	4.24	10	0.38	0.04
Genesee	Byram	25-54	1977	3.35	8	0.53	0.07
Genesee	Byram	25-54	1978	3.15	6	1.10	0.18
Genesee	Byram	25-54	1979	3.18	9	0.52	0.06
Genesee	Byram	25-54	1980	2.68	5	0.72	0.14
Genesee	Byram	25-54	1981	2.92	6	0.70	0.12
Genesee	Byram	25-54	1992	2.65	12	0.42	0.03
Genesee	Byram	25-54	1993	2.49	13	0.30	0.02
Genesee	Byram	25-54	1994	3.18	13	1.04	0.08
Genesee	Byram	25-54	1995	2.34	13	0.61	0.05
Genesee	Byram	25-54	1996	3.30	11	0.73	0.07
Genesee	Byram	25-54	1997	3.56	12	1.31	0.11
Genesee	Byram	25-54	1998	4.17	13	0.77	0.06
Genesee	Byram	25-54	1999	3.28	13	0.80	0.06
Genesee	Byram	25-54	2001	3.38	13	0.71	0.05
Genesee	Fenton	25-35	1980	4.08	10	0.75	0.07
Genesee	Fenton	25-35	1981	3.98	12	0.66	0.06
Genesee	Fenton	25-35	1982	4.93	9	0.38	0.04
Genesee	Fenton	25-35	1983	4.59	9	0.77	0.09
Genesee	Fenton	25-35	1984	4.44	9	0.59	0.07
Genesee	Fenton	25-35	1985	3.19	11	0.32	0.03
Genesee	Fenton	25-35	1986	3.99	11	0.37	0.03
Genesee	Fenton	25-35	1987	4.06	12	0.61	0.05
Genesee	Fenton	25-35	1988	3.60	10	0.66	0.07
Genesee	Fenton	25-35	1992	3.70	7	0.43	0.06
Genesee	Fenton	25-35	1994	3.30	3	0.58	0.19
Genesee	Fenton	25-35	1996	3.87	5	0.43	0.09
Genesee	Fenton	25-35	1997	4.52	3	0.77	0.26

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Genesee	Fenton	25-35	1998	3.94	3	0.12	0.04
Genesee	Fenton	25-35	1999	4.25	3	0.08	0.03
Genesee	Fenton	25-35	2000	4.83	3	0.23	0.08
Genesee	Fenton	25-35	2001	4.35	10	0.13	0.01
Grand Traverse	Arbutus	28-84	1988	5.26	8	0.53	0.07
Grand Traverse	Arbutus	28-84	1989	5.26	6	0.77	0.13
Grand Traverse	Arbutus	28-84	1990	4.45	5	0.46	0.09
Grand Traverse	Arbutus	28-84	1991	4.99	7	0.83	0.12
Grand Traverse	Arbutus	28-84	1992	5.98	8	0.43	0.05
Grand Traverse	Arbutus	28-84	1993	5.74	12	0.38	0.03
Grand Traverse	Arbutus	28-84	1994	5.26	11	0.24	0.02
Grand Traverse	Arbutus	28-84	1995	5.25	9	0.20	0.02
Grand Traverse	Arbutus	28-84	1996	4.53	8	0.57	0.07
Grand Traverse	Arbutus	28-84	1997	5.64	8	0.23	0.03
Grand Traverse	Arbutus	28-84	1998	5.38	9	0.13	0.01
Grand Traverse	Arbutus	28-84	1999	5.05	7	0.24	0.03
Grand Traverse	Arbutus	28-84	2000	4.41	13	0.39	0.03
Grand Traverse	Arbutus	28-84	2001	5.81	13	0.34	0.03
Grand Traverse	Duck	28-124	1992	3.41	10	0.24	0.02
Grand Traverse	Duck	28-124	1993	2.98	13	0.31	0.02
Grand Traverse	Duck	28-124	1994	3.05	12	0.23	0.02
Grand Traverse	Duck	28-124	1995	2.86	8	0.23	0.03
Grand Traverse	Duck	28-124	1996	3.05	11	0.43	0.04
Grand Traverse	Duck	28-124	1997	3.10	11	0.47	0.04
Grand Traverse	Duck	28-124	1998	3.17	13	0.38	0.03
Grand Traverse	Duck	28-124	1999	3.33	12	0.44	0.04
Grand Traverse	Duck	28-124	2000	3.18	12	0.30	0.03
Grand Traverse	Duck	28-124	2001	4.06	12	0.72	0.06
Grand Traverse	Long	28-214	1979	5.70	5	0.57	0.11
Grand Traverse	Long	28-214	1980	6.84	11	0.46	0.04
Grand Traverse	Long	28-214	1981	6.34	5	0.40	0.08
Grand Traverse	Long	28-214	1985	6.52	12	0.80	0.07
Grand Traverse	Long	28-214	1986	6.57	12	0.81	0.07
Grand Traverse	Long	28-214	1987	7.99	12	0.58	0.05
Grand Traverse	Long	28-214	1992	6.71	11	0.73	0.07
Grand Traverse	Long	28-214	1993	7.58	8	1.51	0.19
Grand Traverse	Long	28-214	1994	6.31	13	0.55	0.04
Grand Traverse	Long	28-214	1995	7.17	13	0.98	0.08
Grand Traverse	Long	28-214	1996	6.54	11	0.90	0.08
Grand Traverse	Long	28-214	1997	7.26	12	1.26	0.10
Grand Traverse	Long	28-214	1999	6.96	13	1.48	0.11
Grand Traverse	Long	28-214	2000	7.27	13	0.87	0.07
Grand Traverse	Long	28-214	2001	6.99	13	0.58	0.04
Grand Traverse	Spider	28-81	1980	5.07	7	0.78	0.11
Grand Traverse	Spider	28-81	1987	4.58	12	0.38	0.03
Grand Traverse	Spider	28-81	1988	4.93	11	0.33	0.03
Grand Traverse	Spider	28-81	1989	4.71	11	0.42	0.04
Grand Traverse	Spider	28-81	1990	4.16	11	0.66	0.06
Grand Traverse	Spider	28-81	1991	4.81	12	0.86	0.07
Grand Traverse	Spider	28-81	1997	4.79	10	0.93	0.09
Grand Traverse	Spider	28-81	1998	4.46	11	0.39	0.04
Grand Traverse	Spider	28-81	1999	4.10	11	0.47	0.04
Grand Traverse	Spider	28-81	2000	4.91	10	1.04	0.10
Grand Traverse	Spider	28-81	2001	4.79	11	0.68	0.06
Iosco	Long	35-96	1974	2.40	9	0.33	0.04

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Iosco	Long	35-96	1975	2.43	12	0.54	0.04
Iosco	Long	35-96	1976	2.75	13	0.20	0.02
Iosco	Long	35-96	1977	2.69	11	0.28	0.03
Iosco	Long	35-96	1978	2.55	12	0.17	0.01
Iosco	Long	35-96	1979	2.77	12	0.24	0.02
Iosco	Long	35-96	1980	2.53	12	0.21	0.02
Iosco	Long	35-96	1981	2.71	12	0.24	0.02
Iosco	Long	35-96	1982	2.68	12	0.22	0.02
Iosco	Long	35-96	1983	2.65	11	0.24	0.02
Iosco	Long	35-96	1984	2.60	12	0.21	0.02
Iosco	Long	35-96	1985	2.54	12	0.31	0.03
Iosco	Long	35-96	1986	2.58	12	0.21	0.02
Iosco	Long	35-96	1987	2.55	12	0.20	0.02
Iosco	Long	35-96	1988	2.59	11	0.18	0.02
Iosco	Long	35-96	1989	2.58	11	0.17	0.02
Iosco	Long	35-96	1990	2.62	3	0.02	0.01
Iosco	Long	35-96	1991	3.10	1	0.00	0.00
Iosco	Long	35-96	1992	4.10	8	0.10	0.01
Iosco	Long	35-96	1993	4.07	9	0.22	0.02
Iosco	Long	35-96	1994	2.74	13	0.23	0.02
Iosco	Long	35-96	1995	2.88	11	0.36	0.03
Iosco	Long	35-96	1996	3.08	11	0.24	0.02
Iosco	Long	35-96	1997	3.08	11	0.41	0.04
Iosco	Long	35-96	1998	2.87	10	0.26	0.03
Iosco	Long	35-96	1999	3.25	12	0.36	0.03
Iosco	Long	35-96	2000	2.92	5	0.39	0.08
Iosco	Long	35-96	2001	3.15	6	0.21	0.03
Iosco	Van Etten	35-219	1986	0.84	12	0.26	0.02
Iosco	Van Etten	35-219	1987	1.10	12	0.69	0.06
Iosco	Van Etten	35-219	1988	1.16	11	0.65	0.06
Iosco	Van Etten	35-219	1989	1.11	11	0.61	0.06
Iosco	Van Etten	35-219	1990	1.15	11	0.41	0.04
Iosco	Van Etten	35-219	1991	0.87	11	0.37	0.03
Iosco	Van Etten	35-219	1992	0.97	13	0.34	0.03
Iosco	Van Etten	35-219	1993	1.50	13	0.52	0.04
Iosco	Van Etten	35-219	1994	0.86	11	0.18	0.02
Iosco	Van Etten	35-219	1995	1.23	12	0.63	0.05
Iosco	Van Etten	35-219	1996	1.51	11	0.48	0.04
Iosco	Van Etten	35-219	1997	1.22	12	0.47	0.04
Iosco	Van Etten	35-219	1998	1.24	12	0.34	0.03
Iosco	Van Etten	35-219	1999	1.08	11	0.25	0.02
Iosco	Van Etten	35-219	2000	1.09	12	0.19	0.02
Iosco	Van Etten	35-219	2001	1.16	12	0.41	0.03
Jackson	Clear	38-32	1981	3.10	11	0.25	0.02
Jackson	Clear	38-32	1982	2.83	12	0.29	0.02
Jackson	Clear	38-32	1985	2.90	11	0.40	0.04
Jackson	Clear	38-32	1986	3.15	10	0.22	0.02
Jackson	Clear	38-32	1987	2.90	9	0.20	0.02
Jackson	Clear	38-32	1988	2.37	9	0.20	0.02
Jackson	Clear	38-32	1989	2.16	9	0.23	0.03
Jackson	Clear	38-32	1990	1.98	5	0.15	0.03
Jackson	Clear	38-32	1991	1.92	7	0.08	0.01
Jackson	Clear	38-32	1993	2.34	6	0.12	0.02
Jackson	Clear	38-32	1995	2.18	12	0.22	0.02
Jackson	Clear	38-32	1996	2.48	13	0.30	0.02

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Jackson	Clear	38-32	1997	3.14	13	0.42	0.03
Jackson	Clear	38-32	1998	3.07	13	0.87	0.07
Jackson	Clear	38-32	1999	3.26	13	0.42	0.03
Jackson	Clear	38-32	2000	2.81	11	0.22	0.02
Jackson	Clear	38-32	2001	2.88	13	0.29	0.02
Jackson	Vineyard	38-503	1977	2.98	11	0.29	0.03
Jackson	Vineyard	38-503	1978	2.34	9	0.39	0.04
Jackson	Vineyard	38-503	1979	2.87	7	0.39	0.06
Jackson	Vineyard	38-503	1980	1.83	11	0.39	0.04
Jackson	Vineyard	38-503	1981	2.13	12	0.23	0.02
Jackson	Vineyard	38-503	1982	2.37	11	0.39	0.04
Jackson	Vineyard	38-503	1983	2.07	10	0.26	0.03
Jackson	Vineyard	38-503	1984	2.22	12	0.40	0.03
Jackson	Vineyard	38-503	1985	2.46	12	0.44	0.04
Jackson	Vineyard	38-503	1986	2.97	12	0.81	0.07
Jackson	Vineyard	38-503	1987	2.90	12	0.68	0.06
Jackson	Vineyard	38-503	1988	2.74	11	0.66	0.06
Jackson	Vineyard	38-503	1989	2.92	11	0.36	0.03
Jackson	Vineyard	38-503	1990	3.31	11	0.24	0.02
Jackson	Vineyard	38-503	1991	3.42	9	0.36	0.04
Jackson	Vineyard	38-503	1992	2.84	11	0.58	0.05
Jackson	Vineyard	38-503	1997	3.51	6	0.95	0.16
Jackson	Vineyard	38-503	1998	2.88	13	0.78	0.06
Jackson	Vineyard	38-503	1999	2.56	13	1.05	0.08
Jackson	Vineyard	38-503	2000	2.91	13	1.07	0.08
Jackson	Vineyard	38-503	2001	2.65	12	0.91	0.08
Kalkaska	Cub	40-106	1993	5.06	13	0.27	0.02
Kalkaska	Cub	40-106	1994	4.88	12	0.60	0.05
Kalkaska	Cub	40-106	1995	5.26	11	0.51	0.05
Kalkaska	Cub	40-106	1996	5.51	11	0.66	0.06
Kalkaska	Cub	40-106	1997	5.84	12	0.25	0.02
Kalkaska	Cub	40-106	1998	5.21	13	0.34	0.03
Kalkaska	Cub	40-106	1999	6.15	12	0.50	0.04
Kalkaska	Cub	40-106	2000	6.82	13	0.55	0.04
Kalkaska	Cub	40-106	2001	5.81	13	0.52	0.04
Kent	Camp	41-516	1990	5.33	10	0.34	0.03
Kent	Camp	41-516	1991	2.91	11	0.48	0.04
Kent	Camp	41-516	1992	3.93	9	0.32	0.04
Kent	Camp	41-516	1993	5.58	13	0.86	0.07
Kent	Camp	41-516	1995	3.44	8	0.19	0.02
Kent	Camp	41-516	1996	5.19	6	0.59	0.10
Kent	Camp	41-516	1997	3.37	7	0.33	0.05
Kent	Camp	41-516	1998	4.19	8	0.63	0.08
Kent	Camp	41-516	2000	3.83	10	0.62	0.06
Lake	Harper	43-254	1989	3.98	11	1.63	0.15
Lake	Harper	43-254	1990	3.81	13	0.79	0.06
Lake	Harper	43-254	1991	4.97	13	1.53	0.12
Lake	Harper	43-254	1992	5.09	13	0.71	0.05
Lake	Harper	43-254	1993	4.58	12	0.86	0.07
Lake	Harper	43-254	1995	4.50	4	0.52	0.13
Lake	Harper	43-254	1996	4.88	5	0.68	0.14
Lake	Harper	43-254	1998	4.21	8	0.49	0.06
Lake	Harper	43-254	1999	3.47	12	0.46	0.04
Lake	Harper	43-254	2000	3.63	9	0.76	0.08
Lake	Harper	43-254	2001	4.64	13	0.58	0.04

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Leelanau	Glen (Big)	45-9	1979	7.51	8	5.26	0.66
Leelanau	Glen (Big)	45-9	1980	7.35	10	0.42	0.04
Leelanau	Glen (Big)	45-9	1982	4.94	5	0.50	0.10
Leelanau	Glen (Big)	45-9	1984	3.79	7	0.19	0.03
Leelanau	Glen (Big)	45-9	1985	4.95	10	0.42	0.04
Leelanau	Glen (Big)	45-9	1986	5.74	11	0.44	0.04
Leelanau	Glen (Big)	45-9	1987	5.06	11	0.18	0.02
Leelanau	Glen (Big)	45-9	1988	4.85	11	0.67	0.06
Leelanau	Glen (Big)	45-9	1989	4.62	7	0.21	0.03
Leelanau	Glen (Big)	45-9	1990	5.15	9	1.06	0.12
Leelanau	Glen (Big)	45-9	1991	4.96	8	0.49	0.06
Leelanau	Glen (Big)	45-9	1996	5.34	6	1.33	0.22
Leelanau	Glen (Big)	45-9	1997	5.00	9	0.91	0.10
Leelanau	Glen (Big)	45-9	1998	5.46	11	1.00	0.09
Leelanau	Glen (Big)	45-9	1999	5.32	9	0.90	0.10
Leelanau	Glen (Big)	45-9	2000	6.55	8	1.06	0.13
Leelanau	Glen (Big)	45-9	2001	5.72	11	1.30	0.12
Leelanau	Leelanau- North	45-3	1977	2.91	12	0.90	0.08
Leelanau	Leelanau- North	45-3	1978	2.54	11	0.32	0.03
Leelanau	Leelanau- North	45-3	1979	2.64	12	0.60	0.05
Leelanau	Leelanau- North	45-3	1980	2.88	12	0.47	0.04
Leelanau	Leelanau- North	45-3	1981	3.10	12	0.56	0.05
Leelanau	Leelanau- North	45-3	1982	2.18	12	0.51	0.04
Leelanau	Leelanau- North	45-3	1983	4.17	11	0.99	0.09
Leelanau	Leelanau- North	45-3	1984	3.37	12	0.69	0.06
Leelanau	Leelanau- North	45-3	1985	3.24	12	0.47	0.04
Leelanau	Leelanau- North	45-3	1986	3.62	12	0.62	0.05
Leelanau	Leelanau- North	45-3	1987	3.63	11	0.61	0.06
Leelanau	Leelanau- North	45-3	1988	3.30	11	0.58	0.05
Leelanau	Leelanau- North	45-3	1989	3.88	11	0.87	0.08
Leelanau	Leelanau- North	45-3	1990	3.83	11	0.64	0.06
Leelanau	Leelanau- North	45-3	1991	3.21	12	0.73	0.06
Leelanau	Leelanau- North	45-3	1992	3.79	13	0.92	0.07
Leelanau	Leelanau- North	45-3	1993	5.33	12	1.78	0.15
Leelanau	Leelanau- North	45-3	1994	3.89	11	0.56	0.05
Leelanau	Leelanau- North	45-3	1995	3.66	11	0.47	0.04
Leelanau	Leelanau- North	45-3	1996	3.44	11	0.34	0.03
Leelanau	Leelanau- North	45-3	1997	3.91	11	1.08	0.10
Leelanau	Leelanau- North	45-3	1998	3.63	11	0.62	0.06
Leelanau	Leelanau- North	45-3	1999	3.41	11	0.51	0.05
Leelanau	Leelanau- North	45-3	2000	3.99	10	0.70	0.07
Leelanau	Leelanau- North	45-3	2001	4.49	11	1.93	0.18
Leelanau	Little Glen	45-9	1979	2.37	12	0.21	0.02
Leelanau	Little Glen	45-9	1980	2.36	10	0.21	0.02
Leelanau	Little Glen	45-9	1981	3.19	10	0.34	0.03
Leelanau	Little Glen	45-9	1982	1.58	8	0.11	0.01
Leelanau	Little Glen	45-9	1983	2.00	6	0.43	0.07
Leelanau	Little Glen	45-9	1984	3.18	7	0.43	0.06
Leelanau	Little Glen	45-9	1985	2.41	6	0.30	0.05
Leelanau	Little Glen	45-9	1986	2.51	11	0.23	0.02
Leelanau	Little Glen	45-9	1987	2.60	12	0.40	0.03
Leelanau	Little Glen	45-9	1988	3.11	10	0.21	0.02
Leelanau	Little Glen	45-9	1989	2.80	10	0.44	0.04
Leelanau	Little Glen	45-9	1990	2.95	8	0.44	0.06
Leelanau	Little Glen	45-9	1991	2.06	8	0.14	0.02

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Leelanau	Little Glen	45-9	1992	2.15	9	0.22	0.02
Leelanau	Little Glen	45-9	1996	2.24	11	0.35	0.03
Leelanau	Little Glen	45-9	1998	2.67	10	0.25	0.03
Leelanau	Little Glen	45-9	2000	1.83	10	0.20	0.02
Leelanau	Little Glen	45-9	2001	2.36	13	0.31	0.02
Lenawee	Devils	46-45	1980	2.11	6	0.51	0.09
Lenawee	Devils	46-45	1981	2.03	6	0.46	0.08
Lenawee	Devils	46-45	1982	2.57	8	0.56	0.07
Lenawee	Devils	46-45	1983	2.95	8	0.84	0.11
Lenawee	Devils	46-45	1984	2.44	7	0.66	0.09
Lenawee	Devils	46-45	1985	2.74	4	0.22	0.05
Lenawee	Devils	46-45	1987	2.55	7	0.40	0.06
Lenawee	Devils	46-45	1993	3.11	7	0.77	0.11
Lenawee	Devils	46-45	1995	5.42	12	0.94	0.08
Lenawee	Devils	46-45	2000	2.18	11	0.37	0.03
Lenawee	Devils	46-45	2001	3.20	4	0.45	0.11
Livingston	Coon	47-204	1974	2.54	12	0.36	0.03
Livingston	Coon	47-204	1975	2.49	6	0.30	0.05
Livingston	Coon	47-204	1976	2.46	12	0.30	0.03
Livingston	Coon	47-204	1977	2.68	12	0.27	0.02
Livingston	Coon	47-204	1978	2.17	12	0.19	0.02
Livingston	Coon	47-204	1979	2.68	12	0.22	0.02
Livingston	Coon	47-204	1980	2.27	11	0.45	0.04
Livingston	Coon	47-204	1981	2.21	12	0.31	0.03
Livingston	Coon	47-204	1982	2.21	12	0.33	0.03
Livingston	Coon	47-204	1983	2.49	11	0.71	0.06
Livingston	Coon	47-204	1986	2.59	12	0.19	0.02
Livingston	Coon	47-204	1987	2.15	12	0.75	0.06
Livingston	Coon	47-204	1988	2.48	10	0.48	0.05
Livingston	Coon	47-204	1989	1.75	10	0.15	0.01
Livingston	Coon	47-204	1990	2.66	13	0.20	0.02
Livingston	Coon	47-204	1991	2.17	13	0.39	0.03
Livingston	Coon	47-204	2000	2.28	13	0.53	0.04
Livingston	Coon	47-204	2001	2.09	13	0.38	0.03
Livingston	Zukey	47-97	1980	1.65	5	0.35	0.07
Livingston	Zukey	47-97	1981	1.57	10	0.28	0.03
Livingston	Zukey	47-97	1982	2.23	11	0.61	0.06
Livingston	Zukey	47-97	1992	1.89	10	0.61	0.06
Livingston	Zukey	47-97	1993	1.99	13	0.51	0.04
Livingston	Zukey	47-97	1994	1.95	13	0.32	0.02
Livingston	Zukey	47-97	1995	1.83	6	0.27	0.05
Livingston	Zukey	47-97	1996	1.88	6	0.36	0.06
Livingston	Zukey	47-97	1997	2.13	7	0.43	0.06
Livingston	Zukey	47-97	1998	2.29	6	0.66	0.11
Livingston	Zukey	47-97	1999	2.19	5	0.26	0.05
Livingston	Zukey	47-97	2000	2.87	13	0.45	0.03
Livingston	Zukey	47-97	2001	2.53	13	0.48	0.04
Manistee	Bear	51-132	1977	3.28	10	0.28	0.03
Manistee	Bear	51-132	1978	3.17	9	0.26	0.03
Manistee	Bear	51-132	1979	2.87	10	0.29	0.03
Manistee	Bear	51-132	1980	3.08	11	0.18	0.02
Manistee	Bear	51-132	1981	3.02	10	0.42	0.04
Manistee	Bear	51-132	1982	3.37	10	0.46	0.05
Manistee	Bear	51-132	1984	2.29	9	0.15	0.02
Manistee	Bear	51-132	1985	2.88	12	0.22	0.02

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Manistee	Bear	51-132	1986	2.67	12	0.10	0.01
Manistee	Bear	51-132	1987	3.40	12	0.14	0.01
Manistee	Bear	51-132	1988	3.57	11	0.18	0.02
Manistee	Bear	51-132	1989	3.06	11	0.16	0.01
Manistee	Bear	51-132	1990	3.84	6	0.24	0.04
Manistee	Bear	51-132	1991	3.05	12	0.16	0.01
Manistee	Bear	51-132	1992	2.69	11	0.14	0.01
Manistee	Bear	51-132	1993	3.02	12	0.20	0.02
Manistee	Bear	51-132	1994	3.23	12	0.28	0.02
Manistee	Bear	51-132	1995	2.73	10	0.18	0.02
Manistee	Bear	51-132	1996	2.59	9	0.35	0.04
Manistee	Bear	51-132	1997	2.79	7	0.40	0.06
Manistee	Bear	51-132	1998	2.81	7	0.25	0.04
Manistee	Bear	51-132	1999	2.90	7	0.62	0.09
Manistee	Bear	51-132	2000	2.32	10	0.17	0.02
Manistee	Bear	51-132	2001	2.22	13	0.19	0.01
Mason	Blue	53-131	1988	4.82	10	0.81	0.08
Mason	Blue	53-131	1989	4.17	9	0.60	0.07
Mason	Blue	53-131	1990	2.74	8	0.37	0.05
Mason	Blue	53-131	1991	3.94	6	0.88	0.15
Mason	Blue	53-131	1992	6.93	11	0.94	0.09
Mason	Blue	53-131	1993	2.82	6	0.77	0.13
Mason	Blue	53-131	1994	3.81	7	0.68	0.10
Mason	Blue	53-131	1995	8.02	8	1.20	0.15
Mason	Blue	53-131	1996	8.32	10	1.51	0.15
Mason	Blue	53-131	1997	8.08	10	1.47	0.15
Mason	Blue	53-131	1998	7.74	9	1.46	0.16
Mason	Blue	53-131	1999	9.92	9	0.66	0.07
Mason	Blue	53-131	2000	7.96	8	0.55	0.07
Mason	Blue	53-131	2001	6.13	9	1.26	0.14
Mason	Ford	53-135	1983	4.19	12	0.62	0.05
Mason	Ford	53-135	1984	4.32	12	0.76	0.06
Mason	Ford	53-135	1985	4.22	12	0.71	0.06
Mason	Ford	53-135	1986	4.09	12	0.78	0.07
Mason	Ford	53-135	1987	5.21	12	0.87	0.07
Mason	Ford	53-135	1988	5.09	10	1.47	0.15
Mason	Ford	53-135	1989	3.69	9	0.54	0.06
Mason	Ford	53-135	1990	4.49	11	0.82	0.07
Mason	Ford	53-135	1991	5.45	9	0.72	0.08
Mason	Ford	53-135	1992	4.30	10	0.71	0.07
Mason	Ford	53-135	1993	4.91	9	0.18	0.02
Mason	Ford	53-135	1994	5.03	6	0.57	0.10
Mason	Ford	53-135	1995	3.84	12	0.73	0.06
Mason	Ford	53-135	1996	4.57	12	0.50	0.04
Mason	Ford	53-135	1997	4.17	13	0.69	0.05
Mason	Ford	53-135	1998	3.67	12	0.59	0.05
Mason	Ford	53-135	1999	3.51	13	0.71	0.05
Mason	Ford	53-135	2000	5.46	13	0.31	0.02
Mason	Hackert	53-101	1989	3.73	10	0.82	0.08
Mason	Hackert	53-101	1990	3.40	12	0.72	0.06
Mason	Hackert	53-101	1991	2.74	12	0.61	0.05
Mason	Hackert	53-101	1992	3.76	9	0.57	0.06
Mason	Hackert	53-101	1993	3.79	7	0.39	0.06
Mason	Hackert	53-101	1994	2.97	8	0.39	0.05
Mason	Hackert	53-101	1995	4.33	9	0.62	0.07

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Mason	Hackert	53-101	1996	4.72	12	0.59	0.05
Mason	Hackert	53-101	1997	4.78	13	0.72	0.06
Mason	Hackert	53-101	1998	3.92	13	0.43	0.03
Mason	Hackert	53-101	1999	3.96	10	0.70	0.07
Mason	Hackert	53-101	2000	2.78	9	0.47	0.05
Mason	Hackert	53-101	2001	2.70	7	0.27	0.04
Mecosta	Blue	54-53	1981	3.35	12	0.26	0.02
Mecosta	Blue	54-53	1982	3.73	12	0.33	0.03
Mecosta	Blue	54-53	1983	3.08	11	0.16	0.01
Mecosta	Blue	54-53	1984	2.72	13	0.46	0.04
Mecosta	Blue	54-53	1985	2.84	12	0.46	0.04
Mecosta	Blue	54-53	1986	2.59	8	0.27	0.03
Mecosta	Blue	54-53	1987	3.69	11	0.21	0.02
Mecosta	Blue	54-53	1988	3.41	11	0.38	0.03
Mecosta	Blue	54-53	1989	3.37	11	0.29	0.03
Mecosta	Blue	54-53	1991	3.25	12	0.20	0.02
Mecosta	Blue	54-53	1993	3.66	13	0.35	0.03
Mecosta	Blue	54-53	1994	4.01	13	0.48	0.04
Mecosta	Blue	54-53	1995	3.86	12	0.47	0.04
Mecosta	Blue	54-53	1996	4.34	11	0.48	0.04
Mecosta	Blue	54-53	1997	4.52	12	0.55	0.05
Mecosta	Blue	54-53	1998	4.49	13	0.58	0.04
Mecosta	Blue	54-53	1999	4.21	13	0.81	0.06
Mecosta	Blue	54-53	2000	4.01	13	0.80	0.06
Mecosta	Blue	54-53	2001	3.73	12	0.98	0.08
Mecosta	Horsehead	54-136	1981	2.47	10	0.35	0.04
Mecosta	Horsehead	54-136	1982	2.81	11	0.39	0.04
Mecosta	Horsehead	54-136	1983	2.97	10	0.41	0.04
Mecosta	Horsehead	54-136	1984	2.22	12	0.31	0.03
Mecosta	Horsehead	54-136	1985	2.17	12	0.26	0.02
Mecosta	Horsehead	54-136	1986	2.22	12	0.56	0.05
Mecosta	Horsehead	54-136	1987	2.15	11	0.24	0.02
Mecosta	Horsehead	54-136	1988	2.32	10	0.39	0.04
Mecosta	Horsehead	54-136	1989	2.41	11	0.32	0.03
Mecosta	Horsehead	54-136	1990	3.09	10	0.39	0.04
Mecosta	Horsehead	54-136	1991	2.51	8	0.14	0.02
Mecosta	Horsehead	54-136	1992	3.03	9	0.27	0.03
Mecosta	Horsehead	54-136	1993	3.25	10	0.18	0.02
Mecosta	Horsehead	54-136	1994	3.33	11	0.23	0.02
Mecosta	Horsehead	54-136	1995	3.43	8	0.26	0.03
Mecosta	Horsehead	54-136	1996	3.79	9	0.38	0.04
Mecosta	Horsehead	54-136	1997	3.83	10	0.58	0.06
Mecosta	Horsehead	54-136	1998	2.96	11	0.75	0.07
Mecosta	Horsehead	54-136	1999	3.12	12	0.21	0.02
Mecosta	Horsehead	54-136	2000	3.19	6	0.63	0.10
Mecosta	Horsehead	54-136	2001	2.89	13	0.32	0.02
Mecosta	Mecosta	54-54	1981	2.51	12	0.19	0.02
Mecosta	Mecosta	54-54	1982	3.19	11	0.25	0.02
Mecosta	Mecosta	54-54	1983	3.40	12	0.21	0.02
Mecosta	Mecosta	54-54	1984	3.28	12	0.40	0.03
Mecosta	Mecosta	54-54	1985	3.60	10	0.53	0.05
Mecosta	Mecosta	54-54	1986	3.45	11	0.43	0.04
Mecosta	Mecosta	54-54	1989	3.06	9	0.30	0.03
Mecosta	Mecosta	54-54	1990	2.93	13	0.42	0.03
Mecosta	Mecosta	54-54	1991	2.82	12	0.14	0.01

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Mecosta	Mecosta	54-54	1993	3.84	11	0.43	0.04
Mecosta	Mecosta	54-54	1994	4.08	13	0.23	0.02
Mecosta	Mecosta	54-54	1995	4.27	10	0.43	0.04
Mecosta	Mecosta	54-54	1996	3.64	6	0.26	0.04
Mecosta	Mecosta	54-54	1997	3.70	13	0.10	0.01
Mecosta	Mecosta	54-54	1998	4.33	10	0.46	0.05
Mecosta	Mecosta	54-54	1999	3.47	12	0.61	0.05
Mecosta	Mecosta	54-54	2000	3.08	9	0.29	0.03
Mecosta	Mecosta	54-54	2001	3.75	9	0.66	0.07
Mecosta	Round	54-51	1977	3.16	4	0.27	0.07
Mecosta	Round	54-51	1981	2.70	11	0.26	0.02
Mecosta	Round	54-51	1982	2.56	11	0.21	0.02
Mecosta	Round	54-51	1983	3.85	11	0.60	0.05
Mecosta	Round	54-51	1984	3.28	13	0.47	0.04
Mecosta	Round	54-51	1985	3.19	11	0.37	0.03
Mecosta	Round	54-51	1986	3.00	12	0.29	0.02
Mecosta	Round	54-51	1987	3.05	11	0.24	0.02
Mecosta	Round	54-51	1988	2.94	11	0.25	0.02
Mecosta	Round	54-51	1991	2.44	12	0.18	0.02
Mecosta	Round	54-51	1993	3.56	13	1.14	0.09
Mecosta	Round	54-51	1994	2.86	13	0.29	0.02
Mecosta	Round	54-51	1995	3.31	13	0.45	0.03
Mecosta	Round	54-51	1996	3.32	10	0.17	0.02
Mecosta	Round	54-51	1997	3.70	13	0.41	0.03
Mecosta	Round	54-51	1998	3.58	13	0.37	0.03
Mecosta	Round	54-51	1999	3.54	13	0.34	0.03
Mecosta	Round	54-51	2000	3.61	12	0.46	0.04
Mecosta	Round	54-51	2001	2.83	13	0.47	0.04
Mecosta	School Section	54-57	1990	2.46	12	0.17	0.01
Mecosta	School Section	54-57	1991	2.86	12	0.32	0.03
Mecosta	School Section	54-57	1992	2.87	13	0.28	0.02
Mecosta	School Section	54-57	1993	3.26	12	0.45	0.04
Mecosta	School Section	54-57	1994	2.48	10	0.26	0.03
Mecosta	School Section	54-57	1995	3.74	12	0.29	0.02
Mecosta	School Section	54-57	1996	4.13	12	0.20	0.02
Mecosta	School Section	54-57	1997	4.17	11	0.18	0.02
Mecosta	School Section	54-57	1998	4.08	12	0.30	0.03
Mecosta	School Section	54-57	1999	3.93	13	0.19	0.01
Mecosta	School Section	54-57	2000	4.08	12	0.21	0.02
Missaukee	Sapphire	57-70	1979	2.23	10	0.16	0.02
Missaukee	Sapphire	57-70	1980	2.06	10	0.16	0.02
Missaukee	Sapphire	57-70	1981	1.94	12	0.15	0.01
Missaukee	Sapphire	57-70	1982	2.01	11	0.15	0.01
Missaukee	Sapphire	57-70	1983	2.27	11	0.14	0.01
Missaukee	Sapphire	57-70	1984	2.41	10	0.12	0.01
Missaukee	Sapphire	57-70	1986	2.49	11	0.14	0.01
Missaukee	Sapphire	57-70	1987	2.23	11	0.10	0.01
Missaukee	Sapphire	57-70	1988	1.56	8	0.32	0.04
Missaukee	Sapphire	57-70	1990	2.36	6	0.23	0.04
Missaukee	Sapphire	57-70	1991	2.29	6	0.17	0.03
Missaukee	Sapphire	57-70	1992	2.57	7	0.24	0.03
Missaukee	Sapphire	57-70	1993	2.44	10	0.16	0.02
Missaukee	Sapphire	57-70	1994	1.81	9	0.18	0.02
Missaukee	Sapphire	57-70	1995	2.09	7	0.30	0.04
Missaukee	Sapphire	57-70	1996	1.92	8	0.41	0.05

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Missaukee	Sapphire	57-70	1997	1.85	7	0.21	0.03
Missaukee	Sapphire	57-70	1998	1.59	11	0.39	0.04
Missaukee	Sapphire	57-70	1999	2.58	13	0.17	0.01
Missaukee	Sapphire	57-70	2000	2.41	13	0.08	0.01
Missaukee	Sapphire	57-70	2001	2.32	13	0 07	0.01
Montcalm	Baldwin	59-99	1977	2.24	12	0.30	0.03
Montcalm	Baldwin	59-99	1978	2.64	10	0.34	0.03
Montcalm	Baldwin	59-99	1979	2.16	10	0.27	0.03
Montcalm	Baldwin	59-99	1981	2.98	9	0.43	0.05
Montcalm	Baldwin	59-99	1982	2.50	7	0.34	0.05
Montcalm	Baldwin	59-99	1983	2.20	12	0.89	0.07
Montcalm	Baldwin	59-99	1984	2.20	12	0.41	0.03
Montcalm	Baldwin	59-99	1985	2.49	9	0.51	0.06
Montcalm	Baldwin	59-99	1986	2.88	12	0.22	0.02
Montcalm	Baldwin	59-99	1987	2.55	10	0.20	0.02
Montcalm	Baldwin	59-99	1988	2.87	10	0.28	0.03
Montcalm	Baldwin	59-99	1989	2.79	10	0.20	0.02
Montcalm	Baldwin	59-99	1991	2.61	9	0.27	0.03
Montcalm	Baldwin	59-99	1992	2.89	9	0.29	0.03
Montcalm	Baldwin	59-99	1993	3.13	13	0.44	0.03
Montcalm	Baldwin	59-99	1994	2.70	12	0.30	0.03
Montcalm	Baldwin	59-99	1995	3.81	10	0.30	0.03
Montcalm	Baldwin	59-99	1996	3.30	12	0.72	0.06
Montcalm	Baldwin	59-99	1997	3.92	11	0.41	0.04
Montcalm	Baldwin	59-99	1998	3.61	12	0.47	0.04
Montcalm	Baldwin	59-99	1999	3.27	11	0.34	0.03
Montcalm	Baldwin	59-99	2000	3.27	11	0.34	0.03
Montcalm	Baldwin	59-99	2001	3.24	13	0.36	0.03
Montmorency	Avalon	60-162	1980	7.04	10	2.35	0.24
Montmorency	Avalon	60-162	1981	7.13	9	1.02	0.11
Montmorency	Avalon	60-162	1985	5.65	11	0.92	0.08
Montmorency	Avalon	60-162	1989	7.92	10	2.58	0.26
Montmorency	Avalon	60-162	1990	7.26	9	1.21	0.13
Montmorency	Avalon	60-162	1991	8.20	10	0.75	0.08
Montmorency	Avalon	60-162	1992	6.59	13	0.15	0.01
Montmorency	Avalon	60-162	1994	7.18	11	0.87	0.08
Montmorency	Avalon	60-162	1995	7.16	13	2.22	0.17
Montmorency	Avalon	60-162	1996	6.93	11	0.91	0.08
Montmorency	Avalon	60-162	1997	5.52	8	1.12	0.14
Montmorency	Avalon	60-162	1998	6.73	11	1.37	0.12
Montmorency	Avalon	60-162	1999	9.22	4	1.71	0.43
Montmorency	Avalon	60-162	2000	7.01	7	2.10	0.30
Montmorency	Avalon	60-162	2001	6.82	8	1.60	0.20
Montmorency	West Twin	60-19	1992	3.43	8	0.64	0.08
Montmorency	West Twin	60-19	1993	4.15	7	0.76	0.11
Montmorency	West Twin	60-19	1994	3.31	12	0.25	0.02
Montmorency	West Twin	60-19	1995	3.39	12	0.50	0.04
Montmorency	West Twin	60-19	1996	3.24	11	0.33	0.03
Montmorency	West Twin	60-19	1997	3.34	10	0.42	0.04
Montmorency	West Twin	60-19	1998	3.08	10	0.27	0.03
Montmorency	West Twin	60-19	1999	3.40	8	0.23	0.03
Montmorency	West Twin	60-19	2000	3.85	11	0.37	0.03
Montmorency	West Twin	60-19	2001	3.58	6	0.34	0.06
Newaygo	Bills	62-75	1984	3.34	11	0.80	0.07
Newaygo	Bills	62-75	1985	2.69	8	0.30	0.04

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Newaygo	Bills	62-75	1986	3.10	12	0.24	0.02
Newaygo	Bills	62-75	1987	3.39	12	0.48	0.04
Newaygo	Bills	62-75	1988	3.99	10	0.39	0.04
Newaygo	Bills	62-75	1989	3.29	9	0 37	0.04
Newaygo	Bills	62-75	1990	3.54	13	0.22	0.02
Newaygo	Bills	62-75	1991	2.35	10	0.56	0.06
Newaygo	Bills	62-75	1992	3.14	13	0.19	0.01
Newaygo	Bills	62-75	1993	3.34	9	0.33	0.04
Newaygo	Bills	62-75	1994	3.24	11	0.60	0.05
Newaygo	Bills	62-75	1995	3.12	9	0.25	0.03
Newaygo	Bills	62-75	1996	3.39	8	0.50	0.06
Newaygo	Bills	62-75	1997	3.73	8	0.36	0.04
Newaygo	Bills	62-75	1998	3.26	10	0.70	0.07
Newaygo	Bills	62-75	1999	2.83	10	0.48	0.05
Newaygo	Bills	62-75	2000	2.91	9	0.34	0.04
Newaygo	Bills	62-75	2001	2.58	11	0.42	0.04
Newaygo	Emerald	62-82	1980	3.02	12	0.84	0.07
Newaygo	Emerald	62-82	1981	2.98	12	0.44	0.04
Newaygo	Emerald	62-82	1982	2.55	8	0.36	0.05
Newaygo	Emerald	62-82	1983	2.72	12	0.53	0.04
Newaygo	Emerald	62-82	1984	2.60	12	0.41	0.03
Newaygo	Emerald	62-82	1985	2.62	12	0.42	0.04
Newaygo	Emerald	62-82	1986	3.31	12	0.44	0.04
Newaygo	Emerald	62-82	1987	2.38	11	0.20	0.02
Newaygo	Emerald	62-82	1988	3.18	9	0.51	0.06
Newaygo	Emerald	62-82	1989	2.68	10	0.35	0.03
Newaygo	Emerald	62-82	1990	3.11	10	0.31	0.03
Newaygo	Emerald	62-82	1991	2.41	6	0.57	0.09
Newaygo	Emerald	62-82	1993	2.34	11	0.51	0.05
Newaygo	Emerald	62-82	1994	1.79	13	0.33	0.03
Newaygo	Emerald	62-82	1996	2.34	13	0.34	0.03
Newaygo	Emerald	62-82	1997	2.67	12	0.45	0.04
Newaygo	Emerald	62-82	1998	2.29	12	0.82	0.07
Newaygo	Emerald	62-82	1999	3.35	12	1.07	0.09
Newaygo	Emerald	62-82	2000	2.96	10	0.43	0.04
Newaygo	Emerald	62-82	2001	3.89	11	0.61	0.06
Newaygo	Sylvan	62-81	1980	3.05	12	0.91	0.08
Newaygo	Sylvan	62-81	1981	3.16	12	0.60	0.05
Newaygo	Sylvan	62-81	1982	3.14	10	0.25	0.03
Newaygo	Sylvan	62-81	1983	3.12	12	0.74	0.06
Newaygo	Sylvan	62-81	1984	2.67	12	0.47	0.04
Newaygo	Sylvan	62-81	1985	2.50	12	0.56	0.05
Newaygo	Sylvan	62-81	1986	3.15	12	0.30	0.03
Newaygo	Sylvan	62-81	1987	2.34	11	0.20	0.02
Newaygo	Sylvan	62-81	1988	3.23	9	0.46	0.05
Newaygo	Sylvan	62-81	1989	2.90	10	0.52	0.05
Newaygo	Sylvan	62-81	1990	3.72	10	0.55	0.06
Newaygo	Sylvan	62-81	1991	3.25	6	0.37	0.06
Newaygo	Sylvan	62-81	1993	3.09	11	0.33	0.03
Newaygo	Sylvan	62-81	1994	2.29	13	0.69	0.05
Newaygo	Sylvan	62-81	1996	2.09	13	0.17	0.01
Newaygo	Sylvan	62-81	1997	2.48	12	0.50	0.04
Newaygo	Sylvan	62-81	1998	1.85	12	0.49	0.04
Newaygo	Sylvan	62-81	1999	2.44	12	0.64	0.05
Newaygo	Sylvan	62-81	2000	2.87	10	0.50	0.05

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Newaygo	Sylvan	62-81	2001	3.49	11	0.97	0.09
Oakland	Lakeville	63-1650	1976	2.92	13	0.65	0.05
Oakland	Lakeville	63-1650	1977	2.69	12	0.52	0.04
Oakland	Lakeville	63-1650	1978	2.63	12	0.43	0.04
Oakland	Lakeville	63-1650	1979	2.46	12	0.51	0.04
Oakland	Lakeville	63-1650	1980	2.99	11	0.76	0.07
Oakland	Lakeville	63-1650	1981	3.04	12	1.00	0.08
Oakland	Lakeville	63-1650	1982	3.89	12	1.39	0.12
Oakland	Lakeville	63-1650	1983	2.49	12	0.22	0.02
Oakland	Lakeville	63-1650	1984	2.53	5	0.30	0.06
Oakland	Lakeville	63-1650	1985	2.38	11	0.62	0.06
Oakland	Lakeville	63-1650	1986	2.80	11	0.42	0.04
Oakland	Lakeville	63-1650	1992	3.42	10	0.43	0.04
Oakland	Lakeville	63-1650	1993	2.61	10	0.21	0.02
Oakland	Lakeville	63-1650	1994	2.40	11	0.27	0.02
Oakland	Lakeville	63-1650	1996	3.23	7	0.33	0.05
Oakland	Lakeville	63-1650	1997	3.89	10	0.48	0.05
Oakland	Lakeville	63-1650	1998	3.24	8	2.32	0.29
Oakland	Lakeville	63-1650	2000	2.78	13	0.66	0.05
Oakland	Lakeville	63-1650	2001	3.85	13	0.85	0.07
Oakland	Sherwood	63-252	1980	3.58	4	0.15	0.04
Oakland	Sherwood	63-252	1981	3.13	9	0.48	0.05
Oakland	Sherwood	63-252	1982	3.74	11	0.55	0.05
Oakland	Sherwood	63-252	1983	3.79	10	0.47	0.05
Oakland	Sherwood	63-252	1984	1.98	12	0.22	0.02
Oakland	Sherwood	63-252	1985	2.58	11	0.42	0.04
Oakland	Sherwood	63-252	1986	2.13	10	0.46	0.05
Oakland	Sherwood	63-252	1987	2.30	10	0.93	0.09
Oakland	Sherwood	63-252	1988	2.07	9	0.61	0.07
Oakland	Sherwood	63-252	1989	3.08	10	0.39	0.04
Oakland	Sherwood	63-252	1990	2.37	13	0.26	0.02
Oakland	Sherwood	63-252	1991	2.01	12	0.16	0.01
Oakland	Sherwood	63-252	1992	2.16	13	0.19	0.01
Oakland	Sherwood	63-252	1993	1.11	13	0.07	0.01
Oakland	Sherwood	63-252	1994	1.37	13	0.28	0.02
Oakland	Sherwood	63-252	1995	2.12	12	0.43	0.04
Oakland	Sherwood	63-252	1996	2.59	12	0.86	0.07
Oakland	Sherwood	63-252	1997	2.63	12	0.27	0.02
Oakland	Sherwood	63-252	1998	2.39	12	0.53	0.04
Oakland	Sherwood	63-252	1999	1.49	12	0.36	0.03
Oakland	Sherwood	63-252	2000	1.28	13	0.12	0.01
Oakland	Taylor	63-1025	1974	5.04	12	0.36	0.03
Oakland	Taylor	63-1025	1980	4.01	6	0.41	0.07
Oakland	Taylor	63-1025	1983	5.75	10	0.39	0.04
Oakland	Taylor	63-1025	1984	5.32	10	0.13	0.01
Oakland	Taylor	63-1025	1985	5.08	12	0.23	0.02
Oakland	Taylor	63-1025	1986	4.67	12	0.10	0.01
Oakland	Taylor	63-1025	1987	3.96	12	0.47	0.04
Oakland	Taylor	63-1025	1988	5.32	11	1.09	0.10
Oakland	Taylor	63-1025	1990	4.07	13	0.19	0.01
Oakland	Taylor	63-1025	1991	4.08	13	0.51	0.04
Oakland	Taylor	63-1025	1992	3.50	9	0.49	0.05
Oakland	Taylor	63-1025	1993	3.89	9	0.48	0.05
Oakland	Taylor	63-1025	1998	4.71	13	0.59	0.05
Oakland	Taylor	63-1025	1999	4.90	13	0.52	0.04

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Oakland	Taylor	63-1025	2000	4.70	13	0.28	0.02
Oakland	Taylor	63-1025	2001	5.63	13	0.60	0.05
Oakland	Walled	63-16	1983	3.72	10	0.95	0.10
Oakland	Walled	63-16	1984	2.80	11	0.58	0.05
Oakland	Walled	63-16	1985	2.04	12	0.46	0.04
Oakland	Walled	63-16	1986	3.51	10	0.78	0.08
Oakland	Walled	63-16	1987	2.78	11	0.39	0.04
Oakland	Walled	63-16	1988	2.61	9	0.23	0.03
Oakland	Walled	63-16	1989	2.37	7	0.25	0.04
Oakland	Walled	63-16	1990	1.89	8	0.23	0.03
Oakland	Walled	63-16	2000	3.69	7	0.84	0.12
Oakland	Walled	63-16	2001	4.38	8	0.47	0.06
Oakland	White	63-575	1976	3.66	13	0.70	0.05
Oakland	White	63-575	1977	3.57	11	0.21	0.02
Oakland	White	63-575	1978	3.83	9	0.65	0.07
Oakland	White	63-575	1979	4.22	12	0.49	0.04
Oakland	White	63-575	1980	4.40	7	0.54	0.08
Oakland	White	63-575	1981	3.87	11	0.74	0.07
Oakland	White	63-575	1992	2.71	12	0.34	0.03
Oakland	White	63-575	1993	3.03	4	0.11	0.03
Oakland	White	63-575	1994	2.90	4	0.45	0.11
Oakland	White	63-575	1998	6.38	12	0.42	0.03
Oakland	White	63-575	1999	3.71	13	0.10	0.01
Oakland	White	63-575	2000	5.15	13	0.57	0.04
Oakland	White	63-575	2001	4.60	6	0.20	0.03
Ottawa	Crockery	70-164	1982	2.19	10	0.26	0.03
Ottawa	Crockery	70-164	1989	1.32	9	0.15	0.02
Ottawa	Crockery	70-164	1993	0.92	6	0.54	0.09
Ottawa	Crockery	70-164	1994	1.10	10	0.68	0.07
Ottawa	Crockery	70-164	1995	2.65	11	0.84	0.08
Ottawa	Crockery	70-164	1996	2.27	12	0.80	0.07
Ottawa	Crockery	70-164	1997	1.93	11	0.43	0.04
Ottawa	Crockery	70-164	1998	2.21	12	0.81	0.07
Ottawa	Crockery	70-164	1999	1.54	12	0.46	0.04
Ottawa	Crockery	70-164	2000	1.47	11	0.37	0.03
Ottawa	Crockery	70-164	2001	1.62	12	0.58	0.05
Roscommon	Higgins	72-117	1974	5.86	9	1.65	0.18
Roscommon	Higgins	72-117	1975	7.01	8	1.89	0.24
Roscommon	Higgins	72-117	1976	6.35	11	1.02	0.09
Roscommon	Higgins	72-117	1977	10.28	11	2.16	0.20
Roscommon	Higgins	72-117	1978	7.73	11	1.56	0.14
Roscommon	Higgins	72-117	1979	6.19	10	0.91	0.09
Roscommon	Higgins	72-117	1980	7.01	5	0.57	0.11
Roscommon	Higgins	72-117	1983	7.62	10	0.55	0.05
Roscommon	Higgins	72-117	1984	8.26	9	0.65	0.07
Roscommon	Higgins	72-117	1985	8.13	11	2.91	0.26
Roscommon	Higgins	72-117	1986	8.19	11	2.31	0.21
Roscommon	Higgins	72-117	1987	6.34	10	1.08	0.11
Roscommon	Higgins	72-117	1988	8.06	10	1.12	0.11
Roscommon	Higgins	72-117	1989	8.57	9	0.97	0.11
Roscommon	Higgins	72-117	1990	8.32	8	3.02	0.38
Roscommon	Higgins	72-117	1991	7.57	10	0.88	0.09
Roscommon	Higgins	72-117	1992	9.02	10	0.84	0.08
Roscommon	Higgins	72-117	1993	8.02	10	1.17	0.12
Roscommon	Higgins	72-117	1994	6.76	9	0.64	0.07

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Roscommon	Higgins	72-117	1995	5.26	9	0.93	0.10
Roscommon	Higgins	72-117	1996	7.70	6	0.38	0.06
Roscommon	Higgins	72-117	1997	7.82	3	0.63	0.21
Roscommon	Higgins	72-117	1998	7.32	3	2.13	0.71
Roscommon	Higgins	72-117	1999	6.71	6	1.47	0.24
Roscommon	Higgins	72-117	2000	8.11	5	0.79	0.16
Roscommon	Higgins	72-117	2001	7.87	6	2.70	0.45
Shiawassee	Leisure	n/a	1981	3.73	12	0.66	0.06
Shiawassee	Leisure	n/a	1982	3.73	12	0.86	0.07
Shiawassee	Leisure	n/a	1983	1.95	9	0.36	0.04
Shiawassee	Leisure	n/a	1984	2.95	8	0.37	0.05
Shiawassee	Leisure	n/a	1989	3.82	11	0.26	0.02
Shiawassee	Leisure	n/a	1990	3.89	13	0.88	0.07
Shiawassee	Leisure	n/a	1991	3.17	9	0.79	0.09
Shiawassee	Leisure	n/a	1994	3.15	13	0.76	0.06
Shiawassee	Leisure	n/a	1996	5.51	12	1.41	0.12
Shiawassee	Leisure	n/a	1997	5.65	11	0.73	0.07
Shiawassee	Leisure	n/a	1998	4.47	13	0.85	0.07
Shiawassee	Leisure	n/a	1999	3.61	13	0.84	0.06
Shiawassee	Leisure	n/a	2000	2.84	10	0.22	0.02
Shiawassee	Leisure	n/a	2001	3.34	11	0.76	0.07
St. Joseph	Clear	78-93	1976	3.70	10	0.29	0.03
St. Joseph	Clear	78-93	1977	3.52	12	0.38	0.03
St. Joseph	Clear	78-93	1978	3.43	12	0.56	0.05
St. Joseph	Clear	78-93	1979	3.58	12	0.33	0.03
St. Joseph	Clear	78-93	1981	3.14	11	0.31	0.03
St. Joseph	Clear	78-93	1982	2.94	10	0.55	0.06
St. Joseph	Clear	78-93	1983	3.51	10	0.66	0.07
St. Joseph	Clear	78-93	1984	2.93	12	0.25	0.02
St. Joseph	Clear	78-93	1985	2.87	12	0.51	0.04
St. Joseph	Clear	78-93	1986	2.64	12	0.42	0.03
St. Joseph	Clear	78-93	1987	2.68	12	0.46	0.04
St. Joseph	Clear	78-93	1992	3.21	10	0.46	0.05
St. Joseph	Clear	78-93	1993	2.76	7	0.23	0.03
St. Joseph	Clear	78-93	1994	3.12	4	0.26	0.06
St. Joseph	Clear	78-93	1995	3.24	8	0.52	0.06
St. Joseph	Clear	78-93	1996	2.88	10	0.39	0.04
St. Joseph	Clear	78-93	1997	2.88	12	0.96	0.08
St. Joseph	Clear	78-93	1998	3.12	2	0.11	0.05
St. Joseph	Clear	78-93	1999	4.31	4	0.26	0.07
St. Joseph	Clear	78-93	2000	4.27	5	0.15	0.03
St. Joseph & Cass	Corey	14-159	1974	2.98	13	0.58	0.04
St. Joseph & Cass	Corey	14-159	1975	3.34	10	0.27	0.03
St. Joseph & Cass	Corey	14-159	1976	3.19	12	0.71	0.06
St. Joseph & Cass	Corey	14-159	1977	2.87	10	0.36	0.04
St. Joseph & Cass	Corey	14-159	1978	4.11	10	0.80	0.08
St. Joseph & Cass	Corey	14-159	1979	4.35	11	0.62	0.06
St. Joseph & Cass	Corey	14-159	1980	2.80	10	0.27	0.03
St. Joseph & Cass	Corey	14-159	1981	3.15	10	0.64	0.06
St. Joseph & Cass	Corey	14-159	1982	2.36	11	0.28	0.03
St. Joseph & Cass	Corey	14-159	1983	2.52	11	0.58	0.05
St. Joseph & Cass	Corey	14-159	1984	2.81	12	0.57	0.05
St. Joseph & Cass	Corey	14-159	1985	2.33	11	0.12	0.01
St. Joseph & Cass	Corey	14-159	1986	2.95	12	0.41	0.03
St. Joseph & Cass	Corey	14-159	1987	3.66	11	1.09	0.10

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
St. Joseph & Cass	Corey	14-159	1988	3.08	11	0.32	0.03
St. Joseph & Cass	Corey	14-159	1989	2.53	10	0.66	0.07
St. Joseph & Cass	Corey	14-159	1990	2.59	10	0.26	0.03
St. Joseph & Cass	Corey	14-159	1991	3.44	10	0.61	0.06
St. Joseph & Cass	Corey	14-159	1992	3.00	13	0.80	0.06
St. Joseph & Cass	Corey	14-159	1993	2.51	10	0.49	0.05
St. Joseph & Cass	Corey	14-159	1994	2.67	12	0.36	0.03
St. Joseph & Cass	Corey	14-159	1995	2.85	11	0.45	0.04
St. Joseph & Cass	Corey	14-159	1996	2.67	11	0.88	0.08
St. Joseph & Cass	Corey	14-159	1997	3.20	13	0.70	0.05
St. Joseph & Cass	Corey	14-159	1998	2.98	11	0.51	0.05
St. Joseph & Cass	Corey	14-159	1999	3.65	13	0.64	0.05
St. Joseph & Cass	Corey	14-159	2000	2.67	13	0.71	0.05
St. Joseph & Cass	Corey	14-159	2001	3.31	12	0.75	0.06
St. Joseph	Klinger	78-171	1982	1.55	6	0.22	0.04
St. Joseph	Klinger	78-171	1983	2.54	11	0.32	0.03
St. Joseph	Klinger	78-171	1985	1.74	5	0.20	0.04
St. Joseph	Klinger	78-171	1986	2.22	12	0.12	0.01
St. Joseph	Klinger	78-171	1987	2.29	12	0.11	0.01
St. Joseph	Klinger	78-171	1988	2.45	10	0.17	0.02
St. Joseph	Klinger	78-171	1989	2.45	11	0.13	0.01
St. Joseph	Klinger	78-171	1990	2.20	13	0.24	0.02
St. Joseph	Klinger	78-171	1992	3.11	12	0.20	0.02
St. Joseph	Klinger	78-171	1994	3.18	6	0.54	0.09
St. Joseph	Klinger	78-171	1995	3.11	10	0.53	0.05
St. Joseph	Klinger	78-171	1996	3.34	11	0.35	0.03
St. Joseph	Klinger	78-171	1997	3.96	11	0.56	0.05
St. Joseph	Klinger	78-171	1998	3.66	11	0.43	0.04
St. Joseph	Klinger	78-171	1999	3.51	12	0.62	0.05
St. Joseph	Klinger	78-171	2000	3.21	12	0.72	0.06
St. Joseph	Klinger	78-171	2001	3.02	13	0.76	0.06
St. Joseph	Pleasant	78-94	1978	2.19	11	0.47	0.04
St. Joseph	Pleasant	78-94	1979	2.22	11	0.54	0.05
St. Joseph	Pleasant	78-94	1980	1.94	11	0.27	0.02
St. Joseph	Pleasant	78-94	1981	2.12	12	0.46	0.04
St. Joseph	Pleasant	78-94	1982	2.07	10	0.39	0.04
St. Joseph	Pleasant	78-94	1983	2.70	10	0.80	0.08
St. Joseph	Pleasant	78-94	1984	2.60	12	0.71	0.06
St. Joseph	Pleasant	78-94	1985	2.04	11	0.52	0.05
St. Joseph	Pleasant	78-94	1986	2.16	12	0.55	0.05
St. Joseph	Pleasant	78-94	1989	2.66	11	0.59	0.05
St. Joseph	Pleasant	78-94	1990	2.85	11	0.80	0.07
St. Joseph	Pleasant	78-94	1991	2.79	9	0.67	0.07
St. Joseph	Pleasant	78-94	1992	3.46	11	0.95	0.09
St. Joseph	Pleasant	78-94	1993	3.38	12	1.14	0.10
St. Joseph	Pleasant	78-94	1994	4.09	12	0.49	0.04
St. Joseph	Pleasant	78-94	1995	3.82	11	0.68	0.06
St. Joseph	Pleasant	78-94	1996	3.56	12	0.49	0.04
St. Joseph	Pleasant	78-94	1997	4.48	11	0.95	0.09
St. Joseph	Pleasant	78-94	1998	3.71	12	0.48	0.04
St. Joseph	Pleasant	78-94	1999	4.13	13	0.20	0.02
St. Joseph	Pleasant	78-94	2000	3.64	11	0.85	0.08
St. Joseph	Pleasant	78-94	2001	3.93	11	0.81	0.07
Van Buren	Lake of the Woods	80-288	1981	2.23	10	0.32	0.03
Van Buren	Lake of the Woods	80-288	1982	1.81	11	0.45	0.04

County	Lake name	NKC	Year	Ave.	n	St.Dev	St.Err
Van Buren	Lake of the Woods	80-288	1983	2.91	11	0.46	0.04
Van Buren	Lake of the Woods	80-288	1984	3.08	13	0.60	0.05
Van Buren	Lake of the Woods	80-288	1985	2.62	11	0.37	0.03
Van Buren	Lake of the Woods	80-288	1986	2.50	12	0.17	0.01
Van Buren	Lake of the Woods	80-288	1987	3.03	11	0.32	0.03
Van Buren	Lake of the Woods	80-288	1988	3.02	10	0.24	0.02
Van Buren	Lake of the Woods	80-288	1989	3.54	10	0.39	0.04
Van Buren	Lake of the Woods	80-288	1990	3.78	9	0.46	0.05
Van Buren	Lake of the Woods	80-288	1991	2.02	11	0.15	0.01
Van Buren	Lake of the Woods	80-288	1992	2.36	12	0.57	0.05
Van Buren	Lake of the Woods	80-288	1993	2.30	13	0.57	0.04
Van Buren	Lake of the Woods	80-288	1994	2.37	13	0.21	0.02
Van Buren	Lake of the Woods	80-288	1995	3.78	9	0.08	0.01
Van Buren	Lake of the Woods	80-288	1996	3.15	11	0.32	0.03
Van Buren	Lake of the Woods	80-288	1997	2.50	12	0.30	0.03
Van Buren	Lake of the Woods	80-288	1998	3.02	13	0.34	0.03
Van Buren	Lake of the Woods	80-288	1999	2.98	13	0.52	0.04
Van Buren	Lake of the Woods	80-288	2000	3.99	10	1.03	0.10
Van Buren	Lake of the Woods	80-288	2001	3.10	13	0.23	0.02
Wexford	Stone Ledge	83-17	1987	2.04	12	0.12	0.01
Wexford	Stone Ledge	83-17	1988	3.14	11	0.20	0.02
Wexford	Stone Ledge	83-17	1989	2.73	10	0.62	0.06
Wexford	Stone Ledge	83-17	1990	2.58	13	0.56	0.04
Wexford	Stone Ledge	83-17	1991	2.54	13	0.28	0.02
Wexford	Stone Ledge	83-17	1992	2.93	9	0.31	0.03
Wexford	Stone Ledge	83-17	1993	3.23	12	0.40	0.03
Wexford	Stone Ledge	83-17	1994	2.75	13	0.35	0.03
Wexford	Stone Ledge	83-17	1995	3.59	13	0.19	0.01
Wexford	Stone Ledge	83-17	1996	2.77	13	0.22	0.02
Wexford	Stone Ledge	83-17	1997	3.22	13	0.27	0.02
Wexford	Stone Ledge	83-17	1998	2.34	13	0.42	0.03
Wexford	Stone Ledge	83-17	1999	3.14	13	0.15	0.01
Wexford	Stone Ledge	83-17	2000	2.74	13	0.25	0.02
Wexford	Stone Ledge	83-17	2001	3.17	13	0.29	0.02

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