Minnesota Methods for Analyzing, Applying and Disseminating Volunteer Lake Monitoring Data

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Abstract: Secchi transparency monitoring is an effective means for estimating lake trophic status, detecting eutrophication trends, and providing a basis for setting water quality goals. Citizen volunteers have collected Secchi transparency and user perception data on nearly 700 of Minnesota's lakes since 1973 through the Citizen Lake-Monitoring Program (CLMP). All data are permanently stored in STORET, USEPA's national water quality database. The CLMP database provides a comprehensive data set spanning many years from which lake water quality trends and water quality goals can be identified. CLMP data is used in Minnesota's 305-b Report to Congress and in annual trend analysis. Nearly 300 lakes, with 4 or more readings per year and 8 or more years of data, are included in this analysis. Case studies are conducted on a subset of lakes using supporting data to assess if identified trends can be corroborated with other water quality data. Examples of trend assessment and goal setting using Secchi transparency data and user perception are provided. Various methods are used for information dissemination to increase public awareness and outreach. Key methods involve an annual report of current water quality conditions, fact sheets tailored for each county, and a program newsletter with a column designed for frequently asked questions. This program uses various forms of public advertisements for recruitment and awareness purposes. Recently, an innovative and interactive web site was developed allowing on-line data entry by volunteer monitors and a searchable section for water quality data.

One of the primary goals of lake monitoring programs is to develop databases that can be used to evaluate trends in water quality over time. Detecting trends in the trophic status of lakes over time requires comprehensive data sets spanning several years. Of the parameters commonly used to characterize lake trophic state – phosphorus, chlorophyll a, and Secchi transparency, the latter would seem to be the best measure to focus on for the following reasons: ease of measurement, low cost, amenable for volunteer monitoring, ability to collect a large number of measurements during the sampling season, and the ability to obtain measurements on a large number of lakes over a long period of time. In order for lake data to be inherently valuable, it needs to be dispersed so the information gets into the hands of the public, local officials and other decision-makers who can truly make a difference. Minnesota uses various methods for information dissemination and increasing public awareness. Key methods include an annual report, county fact sheets, newsletters, a newly designed interactive web site, press releases and advertisements.

Data and Methods

Minnesota's Citizen Lake-Monitoring Program (CLMP), initiated in 1973, provides a unique opportunity for characterizing trophic status and trends for Minnesota's lakes. In 1998, 816 participants collected data on nearly 700 lakes. Through this program, we stress the usefulness of citizen volunteer data for assessing trends; identifying data sets necessary to detect subtle trends in lake trophic state; characterizing the natural year to year variation in mean summer transparency; and conducting individual case studies using supporting data to evaluate whether statistically identified trends can be corroborated with other information. In our analysis, we are primarily interested in identifying "real trends" in Secchi transparency. Loftis et al. (1989) defines a real trend as "one that results from physical or chemical changes not from natural hydrologic variability." However, we also characterize the expected range of inter-annual variability in Secchi transparency based on an analysis of lakes in the database.

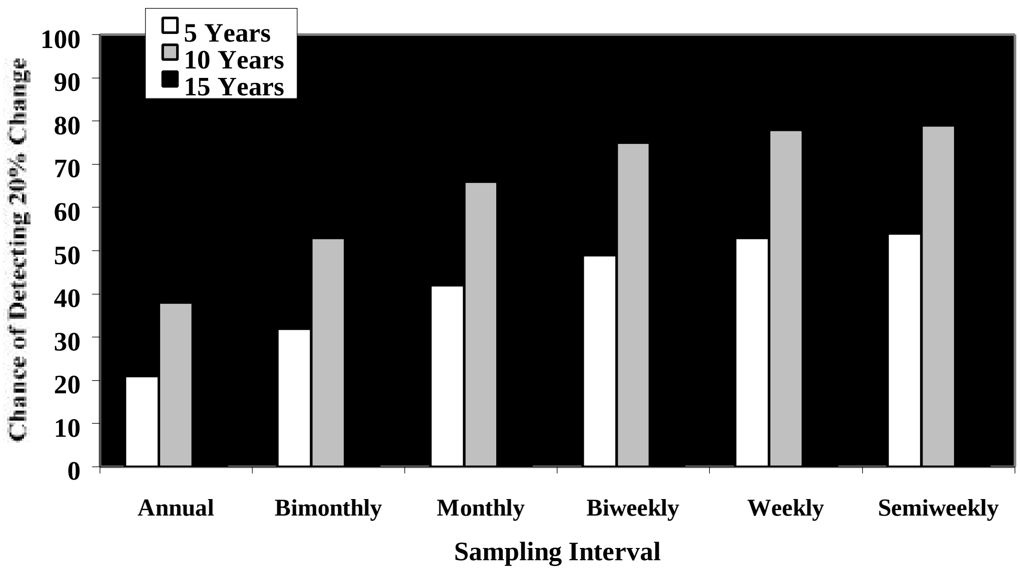
A variety of statistical tests can be used for trend analysis. Montgomery and Reckhow (1984) and Loftis et al. (1989) suggest the use of non-parametric tests if the data is not normally distributed or if the sample size is relatively small. Loftis et al. (1989) suggest using the Kendall-tau test for annual sample data and the seasonal Kendall test for seasonal data. Kendall's tau-b test has been used in previous MPCA 305(b) Reports to Congress (MPCA, 1990 and 1992) for assessing trends in Secchi transparency over time. Kendall's tau-b is a non-parametric procedure which computes correlation coefficients between variables (Gilbert, 1987) – in this case, summer-mean (June to September) Secchi transparency versus year. Kendall's tau-b has the range $-1 < \text{tau-b} < 1$. The null hypothesis is that there is no change (no trend) in mean summer Secchi transparency over time. For our analysis, positive tau-b values suggest an increasing trend in transparency, while negative tau-b suggest decreasing transparency over time. The strength (significance) of the relationship is a function of both the correlation coefficient and the number of years of measurement. For this study, a probability level $(p) < 0.1$ is used as a screening tool for identifying possible trends in transparency. At a probability level of $p < 0.1$, there is a 10 percent chance of rejecting the null hypothesis of "no trend" when it is true (i.e. 10 percent chance of identifying a trend when it does not exist). A probability level $(p) \leq 0.05$ is used for identifying significant trends. We limit our trend analysis to lakes with eight or more summers of Secchi measurements (with four or more measures per summer). Eight years has been identified as the minimum number necessary to detect subtle trends of 10 to 20 percent (Smeltzer et al. 1989).

Detecting a Significant Change in Transparency Over Time

The ability to detect a statistical trend in lake condition over time is related to the magnitude of the trend, statistical "power" of the test, number of observations in any single year, the number of years of observation, the variability among observations within each year, and the year-to-year variability. For example, detecting a 50 percent change in Secchi transparency (e.g., a halving of transparency) would require less data than if we are seeking to detect a more subtle shift (e.g., 10 or 20 percent). Based on the experience of Vermont lake managers, more subtle shifts of 10 to 20 percent, resulting from incremental nonpoint source nutrient loading, are more likely (Smeltzer et al., 1989) than very large shifts. Using statistics from Smeltzer et al. (1989) and a methodology developed by Walker (1988), we estimate the sampling frequency and number of years of data necessary to detect a 20 percent shift in transparency (residuals from our "trend lakes" average about 20 percent of the long term mean transparency).

In general, for Secchi transparency, weekly or bi-weekly (every other week) sampling for records of 5, 10, and 15 years yield a fairly comparable power of trend detection (Figure 1). For example, after 10 years of collection, bi-weekly and weekly samplings have a 75 and 78 percent chance of detecting a 20 percent change in Secchi transparency. In contrast, monthly and semi-weekly (twice a week) have a 66 and 79 percent chance of detecting a 20 percent change. Based on these results, a reasonable sampling interval for trend detection is weekly sampling (or bi-weekly at a minimum). Increasing to semi-weekly sampling yields little additional power, and reducing to monthly sampling requires at least 15 years for an 80 percent chance of detecting a 20 percent change in Secchi transparency.

Figure 1. Sensitivity To Sampling Intervals Over Time – Secchi Depth



Year-to-Year Variation in Summer-Mean Transparency

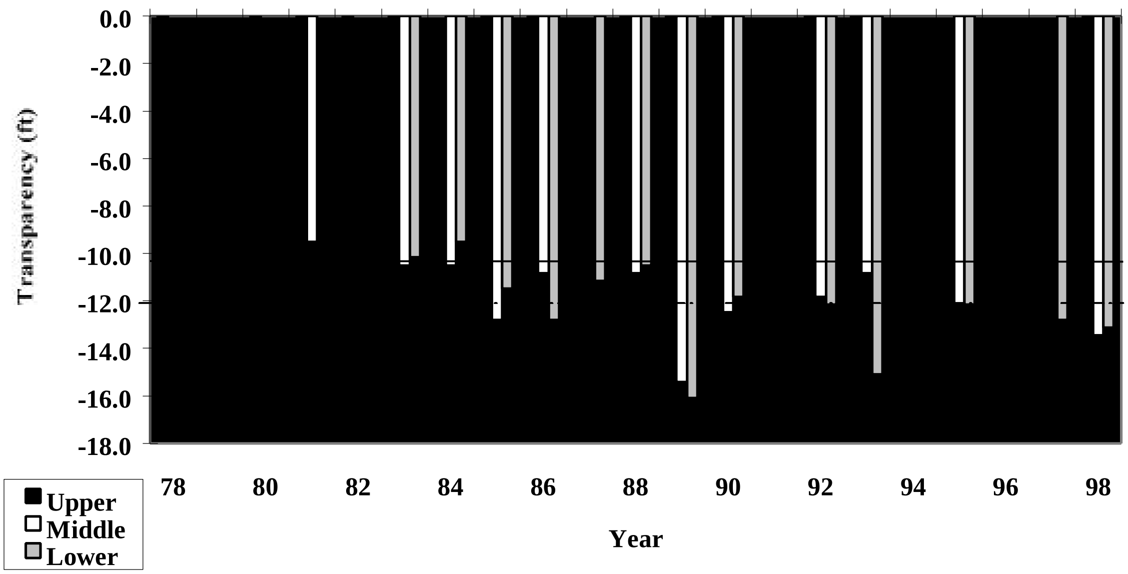
Summer-mean transparency in a lake varies from year to year due to climatic changes (precipitation, runoff, and temperature), nutrient and sediment loading, and biological factors. Understanding and quantifying the relative magnitude of this variability is essential to assessing trends. Based on a previous study (MPCA 1993), the year-to-year Secchi transparency variability was found to be on the order of 1 – 2 feet (0.3 – 0.6 m). In general, the annual transparencies in Minnesota lakes fluctuates within about 20 percent of the long-term mean. Lakes with larger fluctuations or non-random fluctuations relative to the long-term mean may be exhibiting a trend.

All lakes monitored through the CLMP are considered for annual trend assessments. Of the 698 lakes monitored in 1998, 54 percent had the required 8 or more years of data. According to Kendall's tau-b test at $p < 0.1$, 86 lakes (with 8 or more years of data) exhibited increased transparency, 13 exhibited decreased transparency, and the remainder showed no significant change. Several lakes were assessed in further detail (case studies) to determine whether other trophic status, user perception, morphometric, and/or watershed data support the existence of a change in trophic state, and where possible, we offer some explanation for the trend. Carlson's Trophic State Index (Carlson, 1977), the MINLEAP model (Wilson and Walker, 1988), and regression equations for predicting "background" phosphorus concentration (Vighi and Chiaudani, 1985) are among the analytical tools that can be used.

Case Study: Cullen Lake Chain – Brainerd, Minnesota

The Cullen Lakes Association (Association) is an example of an active lake association which has played a major role in assessing the quality of their lakes and working to protect the condition of the lakes. Members of the Association have been active over the years in the CLMP as well as other monitoring they have conducted on their own and with the MPCA. Figure 2 demonstrates trends in transparency as measured through the CLMP. These data reveal important information on water quality status and trends for the three lakes in the Chain. The majority of runoff (and nutrient loading) from the watershed enters the Upper Lake before entering Middle and Lower Cullen Lakes. As a result, long-term transparency averages about 10 feet in the Upper Lake as compared to about 12 feet for the Middle and Lower Lakes. Over time, the Upper Lake has declined in transparency, whereas; the Middle and Lower Lakes exhibit significant improvements. Recognition of these trends prompted the Association to request additional monitoring of the lake. As a result, MPCA staff cooperatively monitored the lake with the Association in 1999 in an attempt to document current water quality conditions and to see if additional trophic status data support the Secchi transparency trends. Results from 1999 revealed significantly higher phosphorus concentrations in Upper Cullen (23 µg/L) as compared to Lower and Middle Cullen Lakes (10 – 12 µg/L). Chlorophyll-a concentrations were higher in Upper Cullen as well, averaging 13 µg/L as compared to 5 µg/L in the other two lakes. This has prompted the Association to look for sources of excess nutrients to the Upper Lake.

Figure 2. Cullen Chain of Lakes Summer Mean Transparency.
Long-term mean for Upper (solid line) and Middle and Lower (dashed line) indicated.



Case Study: Wilkins Lake – Palisade, Minnesota

Wilkins Lake has one of the best Secchi disk data bases of any lake in the state. Based on over 20 years of data (Figure 3), Wilkins exhibited a highly significant ($p = 0.0001$) increase (tau-b = 0.62) in transparency and has a long-term mean Secchi of about 13.7 feet (4.2 m). Summer-mean transparencies in the late 1970's were on the order of 10 – 11.5 feet (3.0 – 3.5 m). In contrast, transparencies in recent years have averaged 12 – 17 feet (3.6 – 5.2 m). Annual variation about the long-term mean ranged from 1 – 4 feet or between 2 – 30 percent. This amount of variation is greater than typical for Minnesota lakes. Supporting data for Wilkins Lake appear to corroborate the trend. For example, TP concentrations were higher in the late 1970's with summer-mean TP concentrations ranging from about 16 – 39 µg/L (1979 – 1981). In comparison, summer-means from 1989 – 1996 ranged from 14 – 18 µg/L (Figure 4).

Figure 3. Wilkins Lake Summer-Mean Secchi Transparency

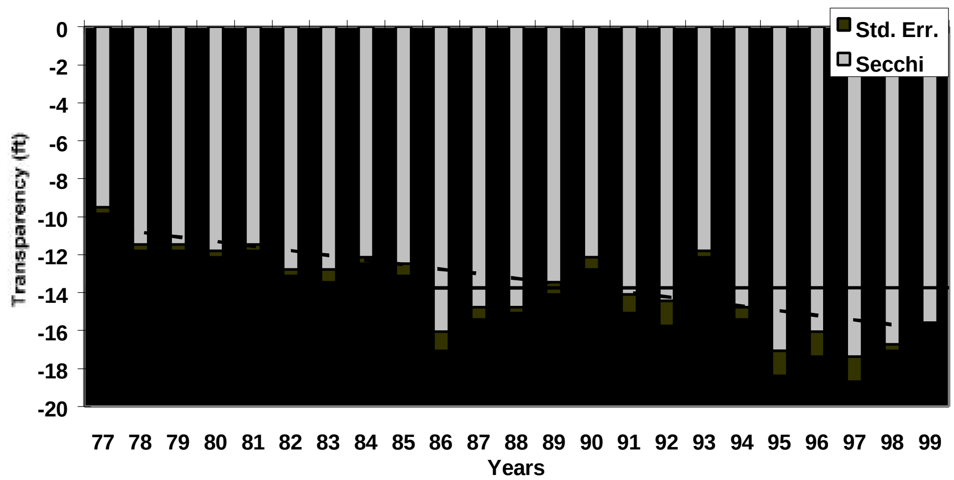
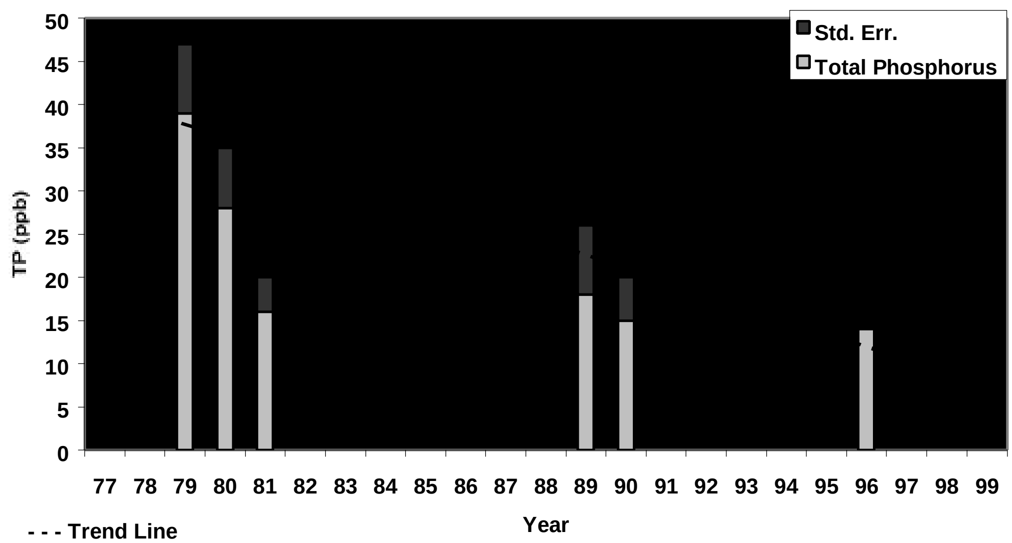


Figure 4. Wilkins Lake Summer Mean Total Phosphorus



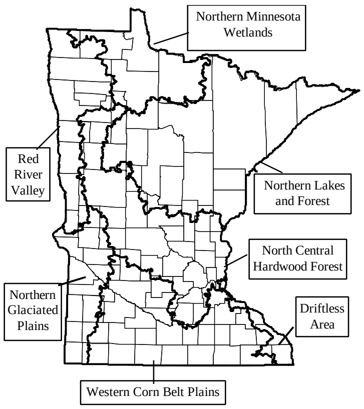
Information Dissemination

Secchi transparency data from the CLMP has been collected and stored in files since 1973. Knowing that a more informed public can make better decisions about environmental issues, the MPCA has created new ways to communicate the information collected through it's volunteer lake monitoring program. Information was included in 305(b) reports to Congress and reports back to program participants; but until recently, there had not been a real effort to get the word out to the rest of the general public about the overall health of Minnesota's lakes. The MPCA believes there is a real need to do more environmental reporting and stakeholder outreach. The CLMP uses various methods for increasing public awareness about the program itself and distributing information about the data that is collected through the program.

CLMP Data in 305(b) Reporting

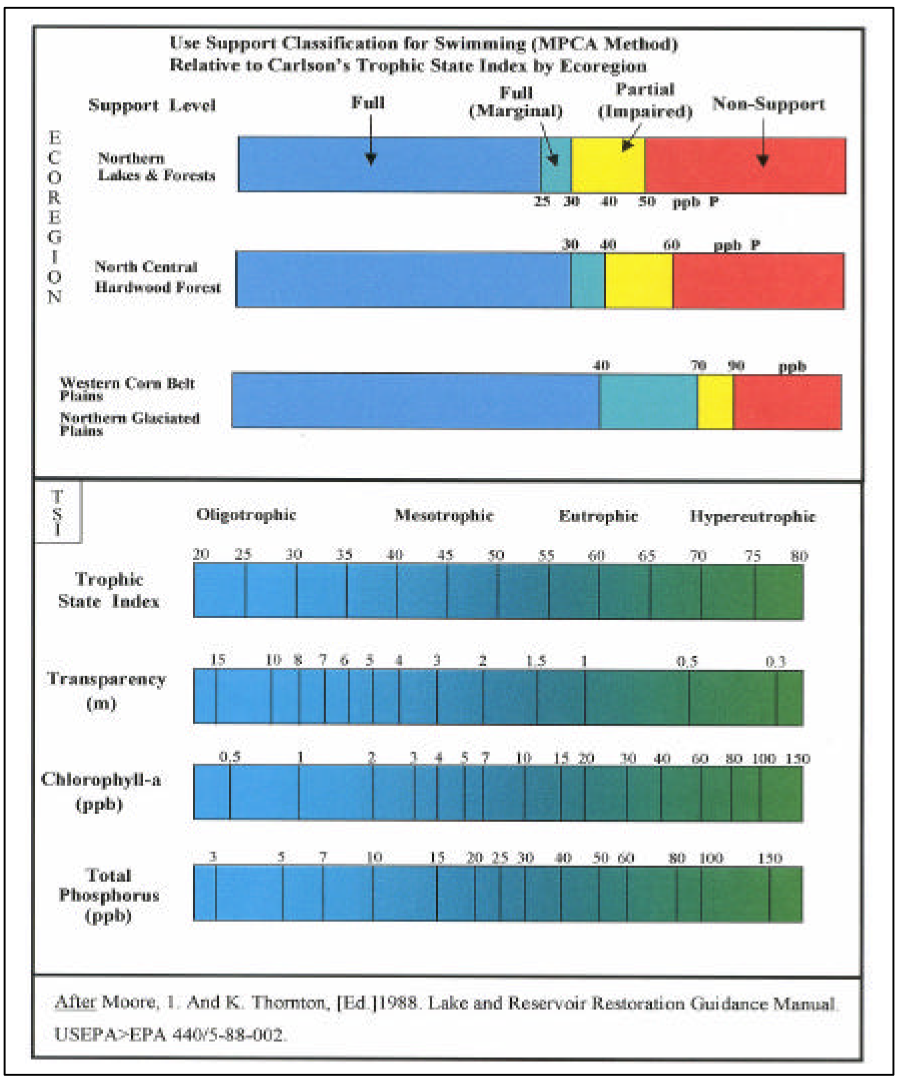
Swimmable use support assessments are often derived from lake trophic status information. For Minnesota, we make use of Carlson's Trophic State Index (TSI) (Carlson, 1977), combined with our ecoregion-based phosphorus criteria (Heiskary and Wilson, 1989). The phosphorus criteria (Figure 5) provides the rationale for the various degrees of use support: full, marginal, partial, and non-support; and Carlson's TSI provides the framework (index) for relating phosphorus, chlorophyll-a, and Secchi transparency (Figure 6). While phosphorus is the primary variable used to determine use support, chlorophyll-a or Secchi transparency may be used in the absence of phosphorus data to “estimate” use support. These assessments are included as a part of our statewide database (and web site), in our basin information documents (BID’s) for major river basins in Minnesota, and in 305(b) reporting to EPA. This allows for geographic-based summaries of swimmable use support and an opportunity to prioritize lakes for more intensive monitoring (e.g. impaired lakes lacking phosphorus data) or restoration efforts.

Figure 5. Minnesota Ecoregions and Phosphorus Criteria



ECOREGION	SENSITIVE USE	P – C RITERIA
Northern Lakes & Forests	• Cold water fish • Drinking water • Swimmable	< 15 ppb < 15 ppb < 30 ppb
North Central Hardwood Forests	• Drinking water • Swimmable	< 30 ppb < 40 ppb
Western Corn Belt Plains	• Drinking water • Swim – Full • Swim – Partial	< 40 ppb < 40 ppb < 90 ppb
Northern Glaciated Plains	• Swim – Partial	< 90 ppb

Figure 6. Carlson’s Trophic State Index for Lakes and Use Support Classification



Annual Reports

An annual report entitled: Report on the Transparency of Minnesota Lakes, is published each year. This report is sent out to all CLMP participants and other interested parties, such as county local water planners and consulting firms, contained on a regularly updated mailing list. The annual reports previously included only the transparency of each lake monitored; however, the reports have evolved over recent years to contain additional information. Current annual reports now contain: a brief executive summary of the current year's Secchi transparency conditions – highlighting exceptionally low and high transparency lakes; an alphabetical (by county) listing of the transparency for each lake monitored; name of individual monitor; a section on lake trophic status and water quality trends with case studies.

Newsletters

A six-page newsletter entitled: The Secchi Reader, is published twice a year for the program. The newsletter is designed to maintain contact with program participants and others interested in the CLMP throughout the year. There are four main sections to the newsletter: Main Topic, News and Notes, Ask the Professor, and Fun Stuff. The main topic section usually highlights an individual volunteer or group of volunteers – such as past award winners. The "News and Notes" section alerts volunteers and others about any major program concerns, and any upcoming events or monitoring activities in their area. The "Ask the Professor" section is the newest addition to the newsletter. It is a special column to answer frequently asked lake-related questions. Also, anyone can send in their own water quality question and the "Professor" will answer it. Feedback about this newest column has been very positive. The "Fun Stuff" section was added because learning should be fun. This section usually has some type of puzzle or trivia question for individuals to solve. Puzzles are lake-related word searches or crossword puzzles designed from articles contained in the current issue. Prizes such as CLMP program T-shirts, hats, and mugs are awarded to individuals who solve the puzzles and send in the solutions in the least amount of time.

Fact Sheets

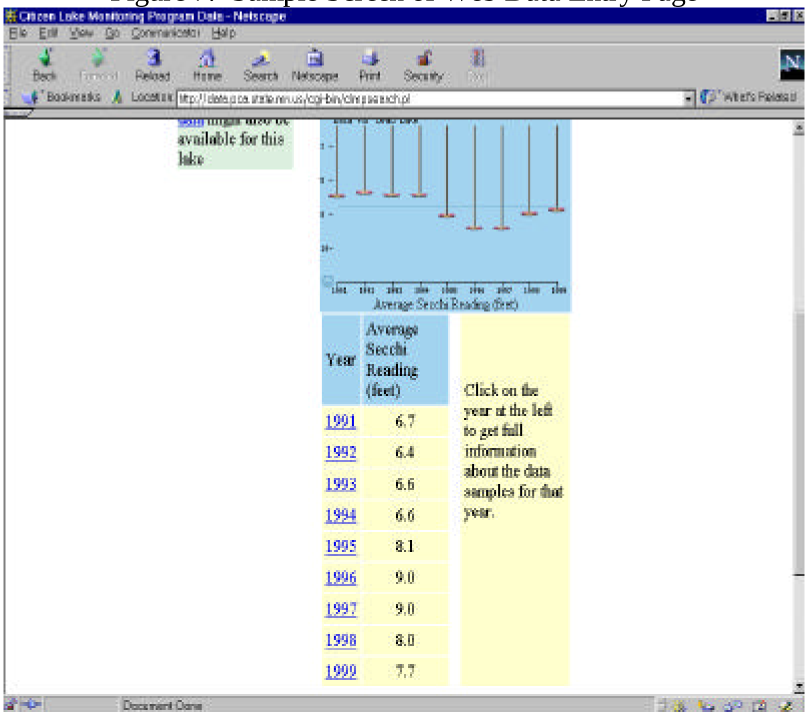
The MPCA now has summaries of lake transparency data available on a county-by-county basis for select counties. These county fact sheets show Secchi transparency data for lakes in the county which have been monitored by volunteers over a sufficient time period to reveal trends of improving or degrading Secchi transparency. The county summaries are produced so the public can get a better idea of the water quality trends at their lake and in their area. The fact sheets show long-term Secchi monitoring locations within each county, along with summary data showing trends and average transparencies over time for the lakes. The fact sheets also include tips on various Best Management Practices (BMP's) for lakeshore property owners and the general public on how individuals can make a difference in reducing the impact of human activities on Minnesota's lakes. Fact sheet are produced for those counties with typically 7 – 8 (or more) lakes currently enrolled in the CLMP. Last year, twenty-six of Minnesota's eighty-seven counties had fact sheets produced. Each participant in the CLMP receives a fact sheet for their county (if one was produced). Last year, a press release was also sent to all the local newspapers announcing the availability of the county fact sheets to the general public.

Entering Data Electronically

We recently conducted a survey to see if participants would be interested in entering their own data electronically through the MPCA's CLMP web page. We sent out about 900 surveys and had a return rate of 82 percent. Of the returned surveys, 53 percent said that they had access to the internet and that they would be willing to enter their own data. Since over half of the volunteers would be willing to enter their data, we decided to go ahead and develop the site to do this. Benefits to having volunteers enter their own data via the web site are: a) the data becomes immediately reviewable by the volunteer and anyone else looking for lake data; b) provides the volunteer with a sense of "ownership" of the data they enter; c) speeds up the data entry process into STORET with much of the data already electronic. Only registered participants in the CLMP have access to the data entry page of the web site; however, anyone can review the data that has been entered. One of the primary features of this web page is that the entered data is charted along with any historic Secchi data also available for each lake

(Figure 7). In addition, there is also a link on this page to review any additional chemistry data for the lake as well.

Figure 7. Sample Screen of Web Data Entry Page



Recruitment and Retention

Recruitment and retention of volunteers is a very important aspect of any volunteer lake-monitoring program. The MPCA uses various methods to recruit and retain volunteer monitors. To recruit new monitors, the principal method is through word of mouth from current volunteers. We have also bought advertising space in the Minnesota's Fishing Rules and Regulations to recruit volunteers. This method was fairly successful since the publication is circulated to over three million Minnesota residents who are also interested in our state's surface waters. We have also sent out press releases to all the local papers calling for additional volunteers. In spring of 2000, we are trying a new approach through the use of public service announcements on radio stations.

The MPCA began an awards recognition program in 1994 as a way of thanking those long-term volunteers who donate so much of their time to protecting Minnesota's lakes through their participation in CLMP. Length of service awards are distributed on a local (county) level at events such as lake association meetings and county board meetings. This "local level" method not only increases local recognition for the participants, but it also increases public awareness of the program and the importance of long-term monitoring. After five years of participation, volunteers receive a certificate of appreciation and program mug. After ten years of participation, volunteers receive a specially designed program lapel pin. After fifteen years of active participation, volunteers receive a program patch and a framed certificate of commendation from the Governor of Minnesota recognizing fifteen years of volunteer service. After twenty years of participation, volunteers receive a 20-year patch and a framed certificate of commendation from the Governor of Minnesota recognizing 20 years of volunteer service. At twenty-five years of participation, volunteers receive a specially designed program coin clock with wooden base.

Volunteers who have dropped out of the program have typically done so after the first one to three years of participation. We have since developed an incentive program to retain volunteers through this period. After a volunteer completes one year of monitoring, they receive a program T-shirt. After their second year of participation, they receive a program baseball hat. At three years, volunteers receive a covered clipboard. We have found that these awards not only recognize volunteers that have participated in the CLMP for multiple years, they also serve as milestones of accomplishment, thus improving volunteer retention.

Conclusions and Recommendations

Long term Secchi monitoring at a consistent site(s) in a lake is an efficient means for detecting trends in eutrophication over time. Secchi measurements should be taken weekly (or at a minimum every other week) to allow for at least a 70 percent chance of detecting a 20 percent change in transparency after 10 years. Year-to-year fluctuation in transparency is to be expected in all lakes. While Secchi transparency may be the best means for trend detection, it is also helpful to have supporting information for the lake to corroborate the trend. Summer-mean total phosphorus and chlorophyll a (for multiple years), morphometric and watershed data user perceptions, and lake/watershed histories which might document changes in land use etc. are all valuable additions to a lakes database.

For Minnesota's CLMP (and volunteer programs in other states) efforts should be made to maintain volunteers in the program at consistent sites if trend analysis is desired. Program coordinators and citizen volunteers (e.g., lake associations) should evaluate Secchi data routinely (e.g., annually). Volunteers should be encouraged to collect supporting information (lake morphometry, watershed size and land use, history) as time permits. Whenever possible, lakes exhibiting trends in Secchi transparency (and lacking other supporting trophic status information) should be included in monitoring efforts conducted by the state or local unit of government (e.g., watershed district) to begin to more fully ascertain the condition of the lake and determine if there may be a need for more extensive study or other management activities.

Collecting data for analysis is an important part of any volunteer monitoring program. Another aspect, that should not be overlooked, is the development of methods for reporting back to not only program participants, but to the general public as well. Communicating the information back to the public creates a more well informed public that can make better decisions about environmental issues. Using various methods for increasing public awareness about programs and the data collected increases the overall awareness by stakeholders and increases the populace of those aware of the monitoring programs and information. Methods that have worked well in Minnesota include an annual report, county fact sheets, newsletters, web site, press releases and advertisements. Volunteer recruitment and retention methods should also be an important aspect of any volunteer lake monitoring program. For Minnesota, an awards program recognizing volunteers for long-term service has worked well for volunteer retention while press releases and various forms of advertising have been useful for recruitment of new volunteers.

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