

# Analysis and Applications of Lake User Survey Data

---

**Eric Smeltzer**

Vermont Department of Environmental Conservation  
103 South Main Street, Building 10 North  
Waterbury, Vermont 05676

**Steven A. Heiskary**

Minnesota Pollution Control Agency  
520 Lafayette Road, St. Paul, Minnesota 55155

## ABSTRACT

Lake management often requires assessment of water quality impacts on lake users. Lake user surveys provide a means for linking sampling parameters such as total phosphorus, chlorophyll *a*, or transparency and user impacts such as nuisance algae levels and recreational impairment. A lake user survey was conducted on nearly 500 lakes in Minnesota and Vermont concurrently with citizens' water quality sampling programs. The results showed that quantifiable and statistically significant relationships existed between eutrophication-related water quality measurements and user perceptions of nuisance algal conditions. However, strong differences existed in these relationships between the two states and among lake regions within each state, indicating that specific regional relationships should be developed whenever possible. This report describes applications of lake user survey results, including statewide lake assessments, wastewater discharge impact evaluations, lake management goal setting, and water quality standards development.

## Introduction

Lake management often involves the understanding and control of adverse effects of eutrophication on lake uses such as recreation and aesthetic enjoyment. Water quality models and other quantitative methods have been used to determine the level of nutrient control required for a wide variety of lake management purposes. Empirically derived relationships linking nutrients such as phosphorus and nitrogen to their manifestations as chlorophyll *a* concentrations or transparency have been especially useful (e.g., Dillon and Rigler, 1974; Smith, 1982; Carlson, 1977). However, it has often been impossible to translate these water quality measurements into lake user impacts such as perceived algal nuisances and recreational impairment.

A lake user survey conducted as part of a statewide lake eutrophication monitoring program can provide a link between water quality variables and user responses (Heiskary and Walker, 1988). However, the initial analysis of Heiskary and Walker was limited to 40 lakes sampled by staff and therefore did not constitute a true "user" survey. The data set was also too small to permit analysis of regional differences in user responses.

User survey data have since been obtained on nearly 500 lakes in several distinct lake regions in Vermont and Minnesota, primarily from citizens' volunteer lake monitoring programs. The authors analyzed this much larger data set to better define the statistical relationships between eutrophication-related water quality variables and user perceptions of lake quality.

The wide variation in total phosphorus and other lake eutrophication criteria found in state water quality standards across the United States (Metro. Wash. Coun. Gov. 1982; U.S. Environ. Prot. Agency, 1988) suggested that regional differences in lake user perceptions and expectations would be an important consideration in analyzing these data. Further analysis of Minnesota user survey data also indicated that user perceptions associated with a particular water quality value varied considerably among lake ecoregions within the state (Heiskary, 1989a). Therefore, this study explored regional differences in user survey responses in detail for the combined Vermont–Minnesota data set.

The user survey data have proven useful in a variety of lake management applications in Vermont and Minnesota, including statewide lake assessments, lake eutrophication standards development, lake management goal setting, and wastewater discharge impact evaluation.

## Methodology and Data

Similar lake user surveys were conducted in Vermont and Minnesota during 1987 and 1988 as part of long-term citizens' lake monitoring programs. The field procedures and analytical methods used for the Vermont Lay Monitoring Program have been

described in detail (Vt. Dep. Water Res. Environ. Eng. 1987; Smeltzer et al. 1989). Vertically integrated euphotic zone samples for total phosphorus and chlorophyll *a* analysis, along with Secchi disk readings, were obtained weekly during June through August on 44 inland lakes and 24 stations in Lake Champlain during 1987 and 1988. The samples were analyzed at the Vermont Environmental Laboratory. The Minnesota Citizens' Lake Monitoring Program is generally limited to weekly summertime Secchi disk monitoring (Heiskary and Wilson, 1988). During 1987 and 1988, this program included 414 lakes distributed among four different ecoregions in Minnesota.

The distribution of monitored lakes within the various regions of Vermont and Minnesota is shown in Figure 1. Lake Champlain is an international body of water within the St. Lawrence River drainage system, shared by the states of Vermont and New York and the province of Quebec. Its 20,196 km<sup>2</sup> drainage basin includes forestland, farmland, and urban areas, with a basin population of over half a million people. Vermont's inland lakes are generally located in hilly, rural settings with predominantly forested watersheds and some farming.

Almost all of Minnesota's over 12,000 lakes are located in four of the state's seven ecoregions (Heiskary et al. 1987), including Northern Lakes and Forests, North Central Hardwood Forests, Northern

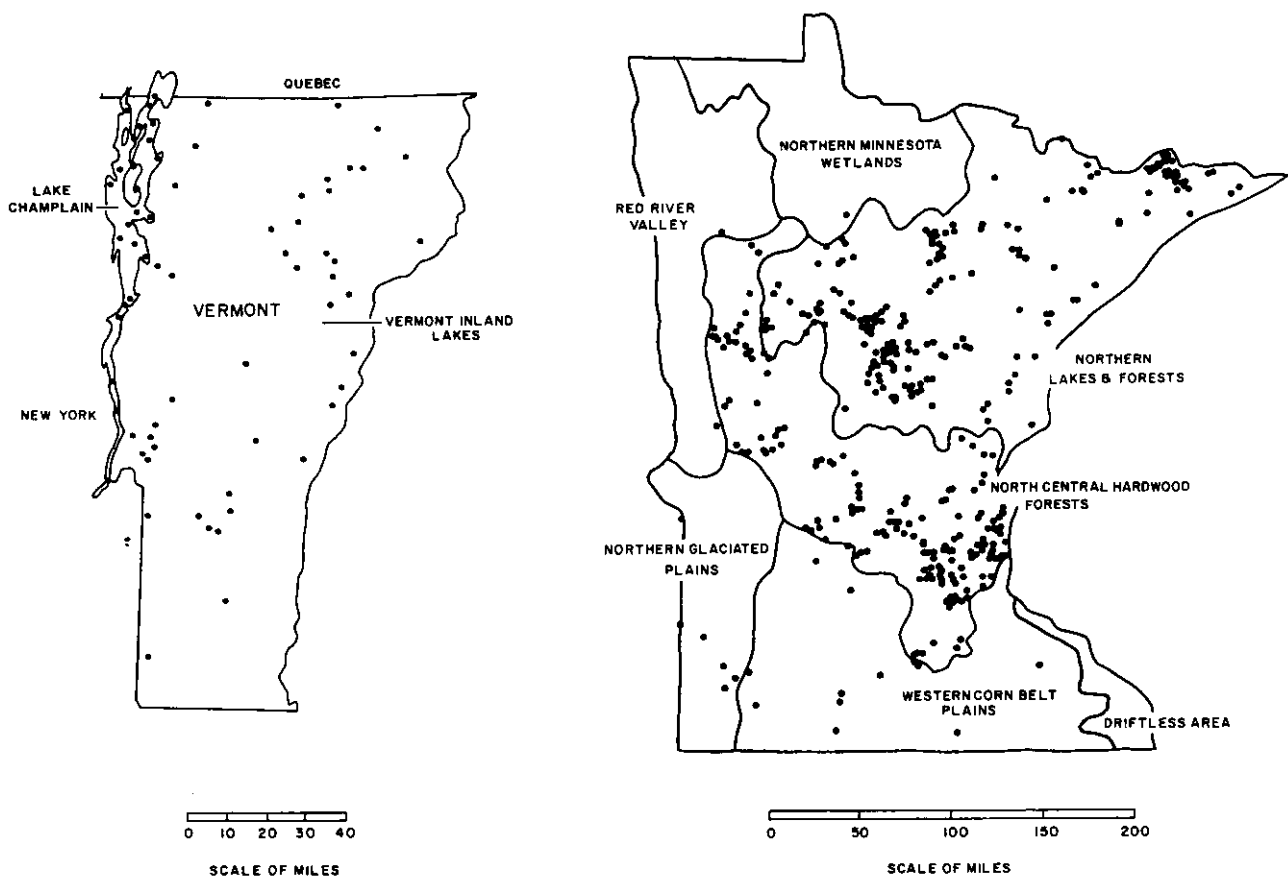


Figure 1.—Location of Vermont and Minnesota monitored lakes and ecoregions.

Glaciated Plains, and Western Corn Belt Plains. Typical land use varies regionally. The Northern Lakes and Forests ecoregion is dominated by forests with some water and marsh, while the Northern Glaciated Plains and Western Corn Belt Plains are primarily cultivated with some pasture and open land. The North Central Hardwood Forests ecoregion supports various land uses.

The citizen participants in the monitoring programs were asked to complete a user survey form each time a water quality sample or Secchi disk measurement was taken. The user survey form (Table 1) included two questions. Question A asked the user to choose from a list of five alternative responses describing the **physical condition** of the lake with respect to algal levels at the time the samples were taken. Question B sought a subjective opinion concerning the **recreational suitability** of the lake at the time of sampling. Instructions provided with the survey forms asked the observers to consider only the condition of the water itself and

not other problems such as nuisance aquatic plants or shoreline debris. The instructions also advised participants that there need be no correspondence between their ratings for the two questions.

The sample sizes for the combined Vermont-Minnesota data set are given in Table 2. Over 7,400 individual user survey responses paired with instantaneous water quality measurements were available for this analysis. The respondents to the user surveys were lake residents who were participating in citizens' monitoring programs, and therefore were not a randomly chosen sample of the entire lake user population. The results represent the perceptions of the more environmentally concerned and active segments of the lake user population in Vermont and Minnesota.

## Results

The relationships between the user survey responses and the water quality measurements were analyzed using an analysis variance procedure that also included the effect of lake region. The Secchi depth measurements were transformed to base 10 logarithms to improve normality. For the purpose of the variance analysis, Secchi depth was treated as the continuous, dependent variable, with survey response category and lake region as the experimental factors.

Separate analyses were conducted for the two user survey questions (A and B). The two southwestern Minnesota ecoregions (Northern Glaciated Plains and Western Corn Belt Plains) were combined into one region for the analysis because of the relatively small number of observations in each and the similarity of their lake resources. Statistical advice and assistance were provided by B. Clarkson, Vermont Department of Environmental Conservation.

The statistical analysis was complicated by two problems. First, each observer contributed multiple responses to the overall data set, and the responses

**Table 1.—Lake user survey form.**

- A. Please circle the one number that best describes the *physical condition* of the lake water today.
1. Crystal clear water.
  2. Not quite crystal clear, a little algae visible.
  3. Definite algal greenness, yellowness, or brownness apparent.
  4. High algal levels with limited clarity and/or mild odor apparent.
  5. Severely high algae levels with one or more of the following: massive floating scums on lake or washed up on shore, strong foul odor, or fish kill.
- B. Please circle the one number that best describes your *opinion* on how suitable the lake water is for recreation and aesthetic enjoyment today.
1. Beautiful, could not be any nicer.
  2. Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
  3. Swimming and aesthetic enjoyment slightly impaired because of algae levels.
  4. Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels.
  5. Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels.

**Table 2.—Data set description.**

ECOREGION	NUMBER OF LAKES	TP	CHL a	SECCHI	NUMBER OF OBSERVATIONS											
					QUESTION A						QUESTION B					
					1	2	3	4	5	ALL	1	2	3	4	5	ALL
1	44	195	507	689	115	392	142	40	9	698	158	366	115	47	5	691
2	24	521	535	531	26	323	170	26	1	547	30	360	127	31	0	548
3	216	0	0	3672	953	1546	653	126	59	3337	1203	1404	502	162	66	3337
4	175	0	0	3168	460	1003	788	292	86	2629	598	981	657	319	104	2659
5	5	0	0	43	0	0	9	10	3	22	0	0	7	12	3	22
6	18	0	0	228	2	50	121	49	10	232	0	61	125	35	9	230
Total:	493	716	1042	8331	1556	3314	1883	544	168	7465	1989	3172	1533	606	187	7487

Regions:

1. VT-IL Vermont Inland Lakes
2. VT-LC Vermont Lake Champlain Stations
3. MN-NLF Minnesota Northern Lakes and Forests
4. MN-CHF Minnesota Central Hardwood Forests
5. MN-NGP Minnesota Northern Glaciated Plains
6. MN-WCP Minnesota Western Corn Belt Plains

for a particular observer might not be independent of another. Therefore, the experimental units for the analysis were defined as lakes (i.e., aggregate responses for each lake) within each survey response category rather than the individual observations (Steel and Torrie, 1960). A second problem was the unbalanced nature of the data set (see Table 2), with numbers of observations for the survey response categories and lake regions varying greatly.

To minimize the effects of these problems on the analysis, the Secchi depth means were computed for each survey response category for each lake. These means were used in a two-way analysis of variance appropriate for an unbalanced design (SAS Inst. 1985) to test for water quality differences across the five response categories and for differences between the lake regions.

The Secchi depth means for each lake response category are plotted in Figure 2. As would be expected, lower Secchi values generally correlated with higher algae levels and greater recreational impairment as perceived by the lake users. There were also striking regional differences in the Secchi values associated with a particular survey response category. Observers in Vermont tended to associate respective survey response categories with higher measured water transparencies than did lake users in Minnesota. Within Minnesota, the Secchi values for the Northern Lakes and Forests ecoregion were generally higher for a given response than in the other ecoregions. The regional differences were especially pronounced at the lower end of the survey scale.

The differences displayed in Figure 2 were statistically significant, as indicated by the analysis of variance results shown in Table 3. The relationship between Secchi depth and survey response was significant at  $p < .0001$  for both survey questions A and B. Both the effect of region and the interaction between region and survey response were also highly significant for both questions, indicating real differences in the way observers from different regions perceive lake water quality. The regional effect for

Table 3.—Analysis of variance results for Secchi depth and user survey response relationships.

SOURCE	d.f.	M.S.	F	p > F
<b>QUESTION A</b>				
Region	4	2.64	57.0	.0001
Survey Response	4	2.11	45.7	.0001
Region × Response	6	0.94	2.0	.009
Error	912	.046		
<b>QUESTION B</b>				
Region	4	2.67	61.7	.0001
Survey Response	4	3.81	87.9	.0001
Region × Response	4	.126	2.9	.0003
Error	880	.043		

Source: SAS Inst. Inc. 1985, GLM Procedure, Type III Sums of Squares.  
d.f. = degrees of freedom  
M.S. = mean square  
F = F-statistic

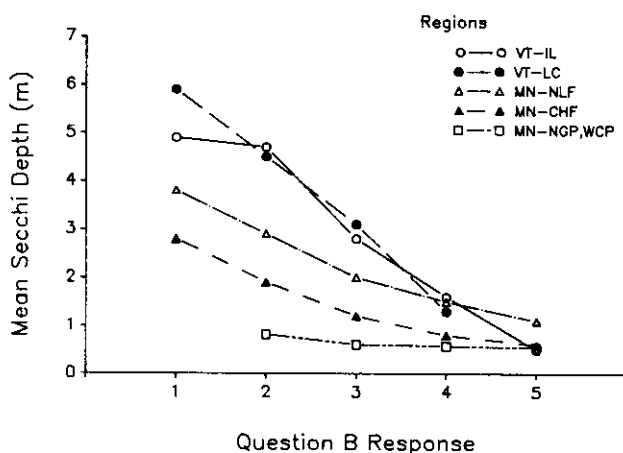
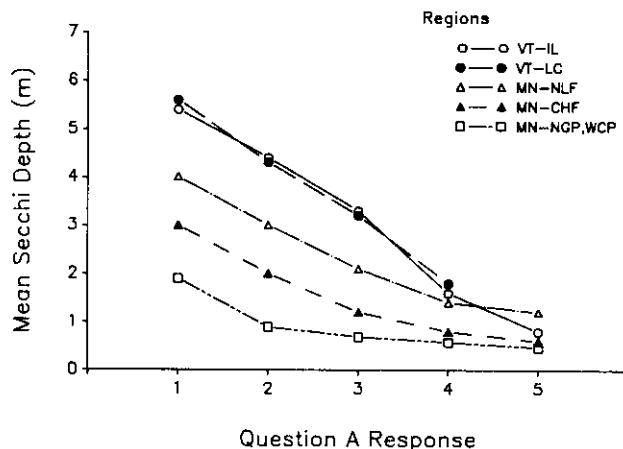


Figure 2.—Geometric mean Secchi depth plotted vs. user survey response category for lake regions in Vermont and Minnesota. See Table 2 for region definitions.

Question A may indicate that this item was not successful in eliciting an objective physical description of the water, independent of personal opinion and experience. The similarity in the ordering of the responses (1-5) between Question A and Question B may have influenced the observers by suggesting a correlation.

The authors suspected that the regional differences in user survey responses were the result of general differences in lake water quality between regions. Lake users in areas such as Vermont or northern Minnesota with predominantly oligotrophic and mesotrophic lakes might develop different water quality expectations and sensitivities than observers in southwestern Minnesota who were exposed to eutrophic or hypereutrophic lakes.

This effect was confirmed by plotting the median Secchi depth value for four different survey response categories from Table 1 against the median Secchi depth found within each of the lake regions. Figure 3

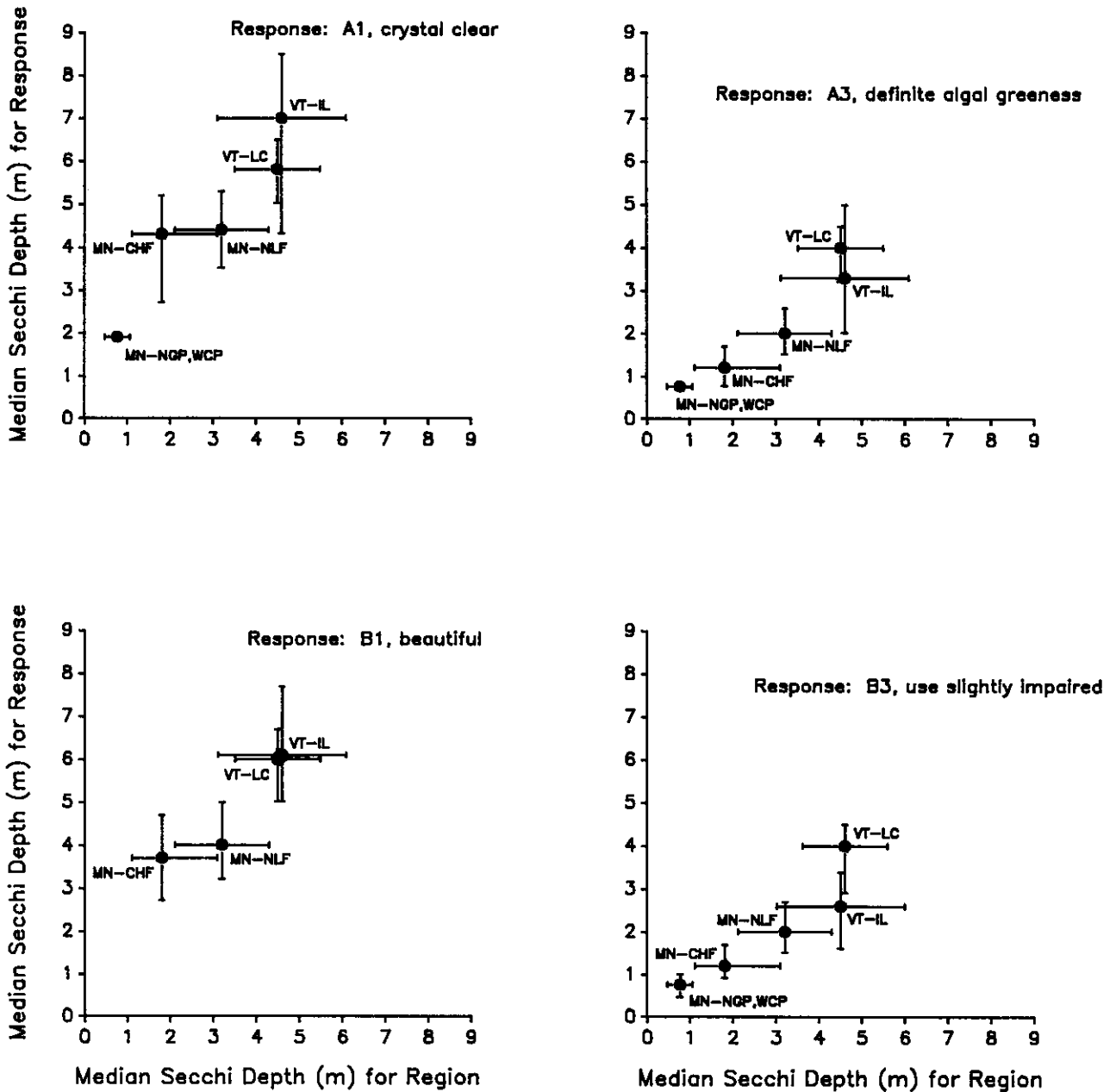


Figure 3.—Median Secchi depths for four user survey response categories plotted vs. the median Secchi depths for each lake ecoregion. Error bars represent Interquartile ranges. See Table 2 for region definitions.

shows that strong positive relationships exist in all cases. For example, among Vermont inland lakes where the median Secchi depth is 4.6 m, the median Secchi value associated with response category A1 ("crystal clear") is 7.0 m. The median Secchi depth associated with category B3 ("use slightly impaired") is 2.6 m. At the other extreme, the median Secchi depth in the southwestern Minnesota ecoregions is only 0.8 m. Here, lakes with a Secchi value of 1.9 m are typically described as crystal clear, and use impairment is not usually noted unless transparencies are below 0.8 m.

## Applications

### Statewide Lake Assessment

User survey data provide a means for defining and assessing the "swimmable" condition of the lakes on a statewide or regional basis as required in state water quality assessment (Section 305b) reports to Congress. Minnesota Pollution Control Agency staff perceptions of physical appearance and recreational suitabilities were used for this purpose (Minn. Pol-

lut. Control Agency, 1988). These responses were cross-tabulated with Carlson Trophic State Index (TSI) values (Carlson, 1977) for transparency, total phosphorus, and chlorophyll *a* according to the approach described in Heiskary and Walker (1988).

The degree to which lakes can support swimming depends on the frequency of nuisance conditions (e.g., algal blooms or reduced transparency) during the summer months (roughly mid-June through mid-September). Lakes exhibiting a high frequency of such conditions would be labeled "impaired swimming" or "no swimming." Definitions for support, partial support, and nonsupport used for the Minnesota Lake Water Quality Assessment Report (Minn. Pollut. Control Agency, 1988) are as follows:

- 1. Fully supporting:** Lakes fully supporting their uses should exhibit "impaired swimming" conditions (survey response B3) at less than a 10 percent frequency and should exhibit "high algal levels" (survey response A4) at less than a 10 percent frequency.
- 2. Fully supporting—threatened:** These lakes may exhibit "impaired swimming" conditions at a frequency of 11-25 percent and "high algal levels" at a frequency of 11-25 percent.
- 3. Partial support—impaired:** These lakes may exhibit "impaired swimming" at a 26-50 percent frequency and "no swimming" (survey response B4) at less than a 10 percent frequency. In terms of physical conditions, these lakes may exhibit "high algal levels" at a 26-50 percent frequency.
- 4. Non-support—impaired:** These lakes will exhibit "no swimming" conditions with greater than 25 percent frequency and "no recreation possible" (survey response B5) on occasion. In terms of physical condition, these lakes will exhibit "high algal levels" with greater than 50 percent frequency.

Based on these definitions and the cross-tabulation, Trophic State Index ranges were used as a basis for determining support levels. Lakes with an average TSI  $\leq 50$  were classified as fully supporting swimmable and aesthetic uses. From a trophic standpoint, this range would correspond to oligomesotrophic conditions. Lakes with an average TSI between 51-59 were classified as supporting but threatened. This TSI range corresponds to "mildly" eutrophic lakes. Lakes with an average TSI from 60-65 were classified as partially supporting but impaired. This range is on the border between eutrophic-hypereutrophic conditions. Lakes with an average TSI  $> 65$  were classified as non-supporting, and are frequently considered hypereutrophic.

## Lake Water Quality Standards Development

### VERMONT

Vermont's Water Quality Standards include a narrative standard for nutrients such as phosphorus that precludes increases that would have "an undue adverse effect on any beneficial values or uses." However, recent statutory and program changes require the development of specific numeric phosphorus criteria in this state.

The Vermont lake user survey results provide a basis for establishing numeric phosphorus criteria to protect recreational and aesthetic uses of lakes. For example, the relationship between user survey response and total phosphorus concentration in Lake Champlain is shown in Figure 4. The 521 total phosphorus measurements from Lake Champlain were divided into intervals of either 5 or 10  $\mu\text{g/L}$ , and the frequencies of the various survey responses were tabulated for each interval. Survey response categories A5 and B5 were extremely rare for Lake Champlain and so are not included in Figure 4.

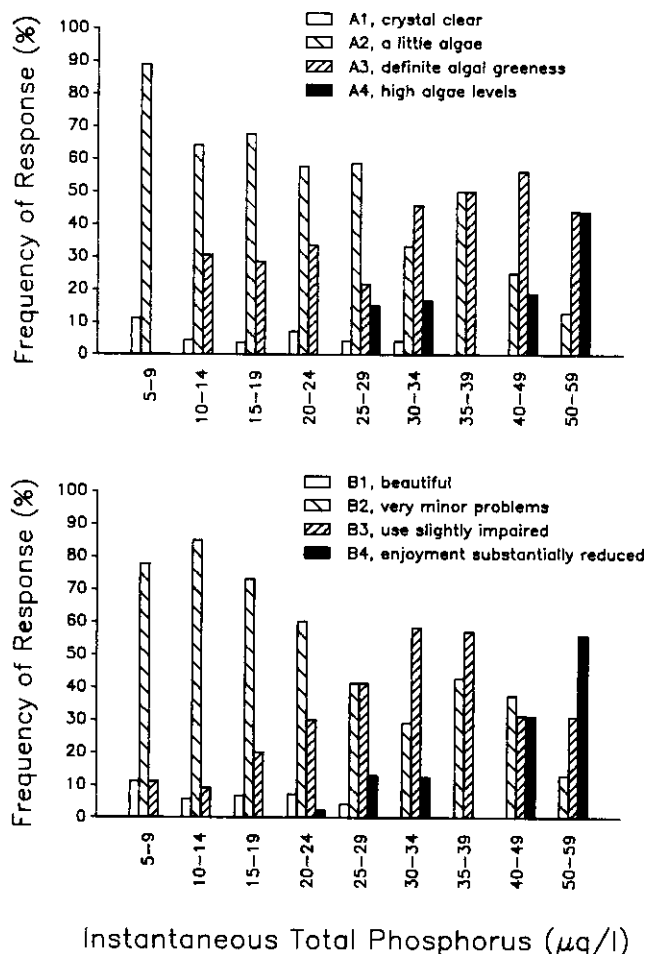


Figure 4.—Relationship between user survey response and total phosphorus concentration in Lake Champlain.

**Table 4.—Minnesota most sensitive lake uses by ecoregion and corresponding total phosphorus criteria.**

ECOREGION	MOST SENSITIVE USES	PHOSPHORUS CRITERIA ( $\mu\text{g/L}$ )
Northern Lakes and Forests	Drinking water supply	< 15
	Cold-water fishery	< 15
	Primary contact recreation and aesthetics	< 30
North Central Hardwood Forests	Drinking water supply	< 30
	Primary contact recreation and aesthetics	< 40
Western Corn Belt Plains	Drinking water supply	< 40
	Primary contact recreation and aesthetics (full support)	< 40
	(partial support)	< 90
Northern Glaciated Plains	Recreation and aesthetics (partial support)	< 90

User perceptions are typically recorded on a weekly basis in conjunction with Secchi transparency measurements taken by the citizen participants. This provides a basis for correlating Secchi transparency values and/or chlorophyll *a* concentrations with acceptable or unacceptable conditions for primary contact recreation and aesthetics. In turn, the Secchi transparency and chlorophyll *a* values corresponding to "acceptable" conditions can be related to phosphorus concentrations (Heiskary and Walker, 1988). These values (Secchi, chlorophyll *a*, and total phosphorus) and user perception information may be compared to values from the appropriate ecoregion, and specific goals for protecting or restoring water quality may be established. In some instances further sampling and modeling may be required to determine if that goal is realistically attainable for a specific lake.

## Wastewater Discharge Impact Evaluation

The Vermont Department of Fish and Wildlife has proposed a state salmonid fish hatchery for the shore of Lake Champlain, with a treated wastewater phosphorus discharge to the lake at a maximum summer rate of 5.8 kg/day. Lake modeling analyses (Walker, 1988; Aquatec, 1988) indicated that the hatchery's phosphorus discharge would raise average phosphorus concentrations in the surrounding area of the lake by less than 2  $\mu\text{g/L}$ , except for a small area in the immediate vicinity of the outfall. Existing total phosphorus concentrations in the area average about 16  $\mu\text{g/L}$ .

User survey results were used to translate a 2  $\mu\text{g/L}$  phosphorus increase into direct lake user impacts (Smeltzer, 1989). An increase in the summer average phosphorus concentration from 16 to 18  $\mu\text{g/L}$  would correspond to an increase in the 1 percent frequency extreme value from 28 to 32  $\mu\text{g/L}$ . Figure 4 shows that this change would shift the perceptions of about 24 percent of the lake users from "a

little algae" to "definite algal greenness" on the rare occasions when the nuisance phosphorus value occurred. About 17 percent of the observers would experience a shift from "very minor problems" to "use slightly impaired" when phosphorus was at its upper 1 percent level.

These results were used by the Vermont Department of Environmental Conservation to support a decision to issue a discharge permit for the fish hatchery. The relatively small shifts in user perceptions, combined with the limited spatial extent of the 2  $\mu\text{g/L}$  phosphorus increase in the lake and the highly conservative nature of the modeling analyses, were all considerations that led to a finding of "no undue adverse effect" for the hatchery's predicted impact on phytoplankton growth. While not eliminating all subjective judgment from the permit decision, the user survey results provided a well-documented and publicly accessible basis for interpreting Vermont's narrative nutrient standard.

## Limitations

The lake user survey approach has certain limitations that should be recognized. First, as noted earlier, the survey respondent group did not provide a randomly chosen sample of public opinion. The citizen participants were probably more environmentally informed and concerned than the general population, as indicated by their willingness to volunteer their time for taking water samples. The user survey results may therefore be biased toward a greater than average sensitivity to eutrophication-related water quality problems.

This possible bias may be entirely appropriate, however, for some applications of the user survey data. Lake water quality standards should not necessarily be based on a random public opinion survey. Survey responses derived from a group of concerned citizens trained to carefully observe water quality conditions and cognizant of eutrophication concepts may, in fact, provide an ideal data base for

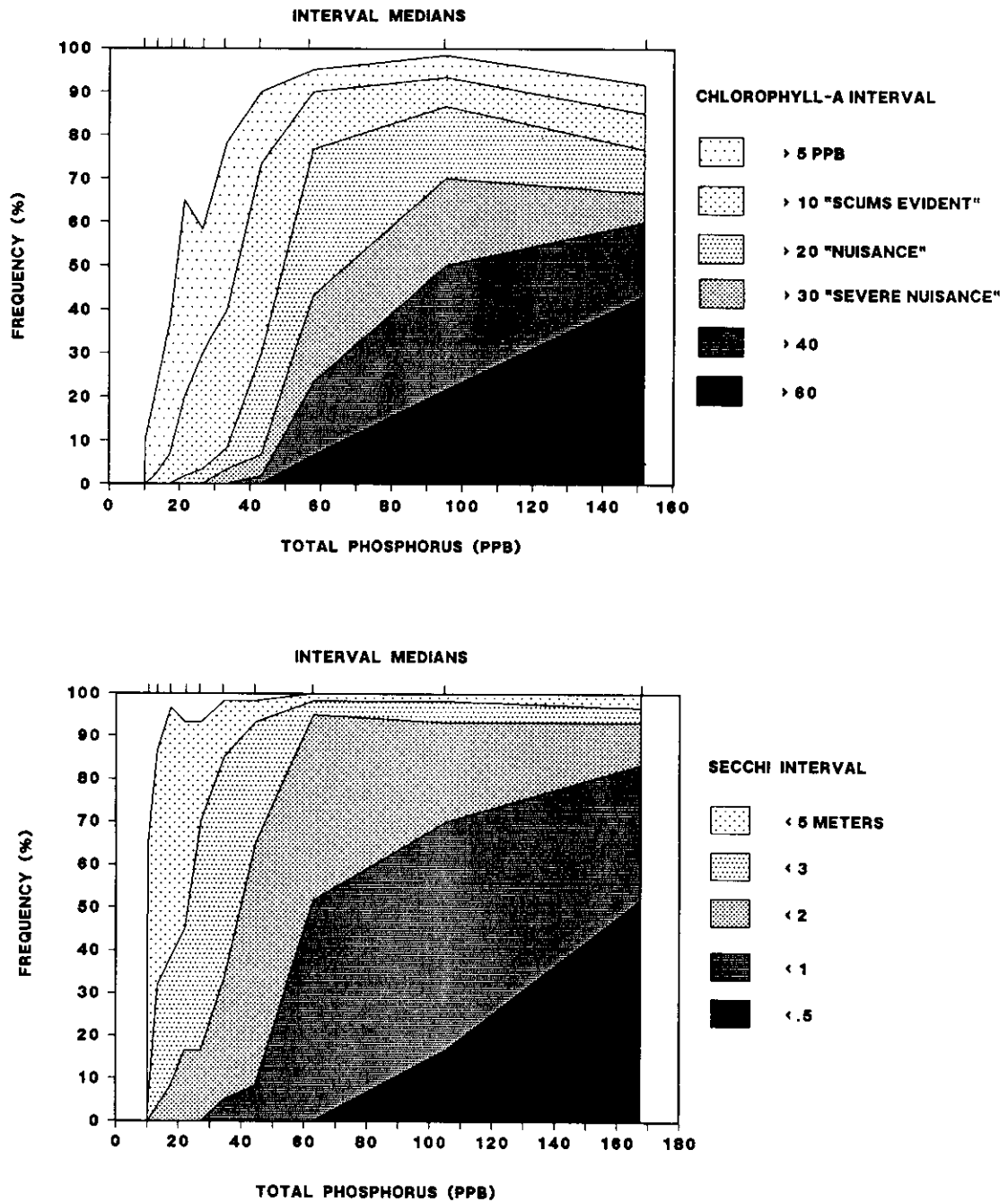


Figure 6.—Chlorophyll a and transparency interval frequencies vs. total phosphorus, based on data from Minnesota's reference lakes (taken from Helskary and Walker, 1988).

developing phosphorus and other criteria for state lake standards.

When used for goal setting on individual lakes, the user survey results may be biased as a result of the small number of observers on the lake, some of whom may have unreasonably high expectations for the resource. Ideally, this information should be obtained by more than one person for each lake. A solution might be to monitor different bays or locations in the lake using different observers. Comparisons with regional values can provide a guide, both in

terms of user response and water quality, as to the reasonableness of lake user expectations.

A further limitation of the present user survey is that it addresses only aesthetic and recreational impacts from algae growth in open water areas of lakes. Other potential eutrophication impacts such as shoreline periphyton and aquatic plant growth, hypolimnetic dissolved oxygen depletion, fisheries impacts, and water supply impairment were not considered. However, the scope of the survey could be expanded to include consumers of potable lake water

supplies who would provide responses on the level of eutrophication related drinking water problems such as taste and odor. Criteria to protect water supply uses could then be developed.

User responses may be influenced to some extent by the type of algae dominating a bloom and the location of the bloom in the water column. For example, a bloom of blue-green algae at the surface of a lake may elicit a response of "no swimming" even though transparencies may be relatively high. In contrast, a lake with a bloom of green algae mixed throughout the water column and yielding a very low transparency may be perceived as only "swimming impaired." Thus, whenever possible, qualitative assessment of the algal population should be made in conjunction with the user surveys.

## Conclusions

It is clear from the analysis of the Vermont and Minnesota regional data that most applications of lake user surveys will require the development of region-specific or even lake-specific relationships. Whenever possible, total phosphorus and chlorophyll *a* measurements should be collected in addition to transparency and user perception information. Lake user expectations and sensitivities to eutrophication conditions differ greatly between regions. A recent national lake standards survey found that many respondents desired locally based standards and criteria and wished to avoid uniform federally imposed requirements (N. Am. Lake Manage. Soc. 1988). The user survey results presented here confirm the wisdom of using a locally based approach.

The lake user survey results have proven their utility in a wide variety of lake management applications in Vermont and Minnesota. A user survey such as the one discussed in this paper can be easily implemented wherever a citizens' water quality monitoring program exists. It is suggested that other states consider ways to incorporate user surveys into their lake management programs.

## References

- Aquatec Inc. 1987. Preliminary study, Grand Isle Hatchery site feasibility study. Prep. for Vt. Dep. State Buildings, Montpelier.
- Carlson, R.E. 1977. A trophic state index for lakes. *Limnol. Oceanogr.* 23:361-369.
- Dillon, P.J. and F.H. Rigler. 1974. The phosphorus-chlorophyll relationship in lakes. *Limnol. Oceanogr.* 19:767-73.
- Duda, A.M., M.L. Iwanski, R.J. Johnson, and J.A. Jaksch. 1987. Numerical standards for managing lake and reservoir water quality. *Lake Reserv. Manage.* 3:1-16.
- Heiskary, S.A. 1989a. Integrating ecoregion concepts into state lake management programs. Pages 89-100 in *Enhancing State Lake Management Programs*. Proc. Natl. Conf., May 12-13, 1988. Chicago, IL.
- . 1989b. Lake assessment program: A cooperative lake study program. *Lake Reserv. Manage.* 5:85-94.
- Heiskary, S.A. and W.W. Walker. 1988. Developing phosphorus criteria for Minnesota lakes. *Lake Reserv. Manage.* 4:1-10.
- Heiskary, S.A. and C.B. Wilson. 1988. Minnesota lake water quality assessment report. Minn. Pollut. Control Agency. St. Paul.
- . 1989. The regional nature of lake water quality across Minnesota: An analysis for improving resource management. *J. Minn. Acad. Sci.* 55:71-7.
- Heiskary, S.A., C.B. Wilson, and D.P. Larsen. 1987. Analysis of regional patterns in lake water quality: Using ecoregions for lake management in Minnesota. *Lake Reserv. Manage.* 3:337-44.
- Metropolitan Washington Council of Governments. 1982. A review of state water quality standards which pertain to nutrient enrichment. Washington, DC.
- Minnesota Pollution Control Agency. 1988. Minnesota Water Quality - Water Years 1984-1985. The 1988 Report to the Congress of the United States. St. Paul, MN.
- North American Lake Management Society. 1988. Water Quality Standards for Lakes. A survey. Preliminary report. Merrifield, VA.
- SAS Institute Inc. 1985. SAS User's Guide: Statistics. Cary, NC.
- Smeltzer, E. 1989. Water quality review of the discharge permit application for the Vermont State Fish Hatchery at Grand Isle. Vt. Dep. Environ. Conserv. Waterbury.
- Smeltzer, E., W.W. Walker, and V. Garrison. 1989. Eleven years of lake eutrophication monitoring in Vermont: A critical evaluation. Pages 53-62 in *Enhancing State Lake Management Programs*. Proc. Natl. Conf., May 12-13, 1988. Chicago, IL.
- Smith, V.H. 1982. The nitrogen and phosphorus dependence of algal biomass in lakes: An empirical and theoretical analysis. *Limnol. Oceanogr.* 27:1101-12.
- Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.
- U.S. Environmental Protection Agency. 1988. Water quality criteria summaries: A Compilation of State/Federal Criteria: Phosphorus. EPA 440/5-88/012. Off. Water Reg. Stand., Washington, DC.
- Vermont Department of Water Resources and Environmental Engineering. 1987. Vermont Lay Monitoring Manual. Water Qual. Serv. Ser. Rep. No. 14. Waterbury, VT.
- Walker, W.W. 1985. Statistical bases for mean chlorophyll *a* criteria. Pages 57-62 in *Lake and Reservoir Management: Practical Applications*. N. Am. Lake Manage. Soc.
- . 1988. Transport modeling for the Vermont State Fish Hatchery at Grand Isle. Prep. for Vt. Dep. State Buildings, Montpelier.