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Relations Between Water Chemistry and Water Quality as Defined by Lake Users in Florida

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ABSTRACT

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A lake user survey was conducted on 116 Florida lakes concurrent with citizens' water sampling activities. Results showed there were significant relations between lake users perceptions of physical condition of water and associated lake trophic state water chemistry variables. There were also significant relations between lake users perceptions of recreational and aesthetic enjoyment of water and associated lake trophic state water chemistry variables. While the relations reported in this study were significant there was also a lot of variance in actual water chemistry for any perceived water quality. Some of this variance was attributed to regional differences in perceptions of water quality. Before this type of survey is used for lake management activities in Florida, it is recommended to expand the number of individuals surveyed per lake, especially from multiple lake users to better understand the variance in water chemistry around perceived water quality. It is also recommended to add questions pertaining to additional lake uses including activities like fishing, bird watching and other wildlife related uses.

Key Words: lake user survey, citizen monitoring, lake trophic state.

Citizen volunteers and professionals can successfully measure water chemistry in lakes systems (Canfield et al. 2002). Water chemistry analyses provide quantifiable measurements of the concentrations of elements and some biological organisms in a waterbody. Many citizens and professionals use the term water quality interchangeably with the term water chemistry. However, water quality can only be measured after first defining the desired use of a water body. Therefore, it is difficult to collect and evaluate information regarding water quality since it is use dependent.

There are many lake uses for which people would consider oligotrophic conditions as good water quality. For example, people who prefer swimming as a primary lake use generally consider lakes with water chemistry values of low nutrients, low chlorophyll and high water clarity as having good water quality. These same people generally consider lakes with water chemistry values of high nutrients, high chlorophyll and low water clarity as having bad water quality. They are concerned about swimming or recreating in water where they can see well and the undesirable water quality is an indicator of their concerns about underwater obstructions or fear of wildlife associated with green water such as alligators or snakes. There are also many lake uses for which people would consider eutrophic conditions as good water quality. For example, people who prefer fishing as a primary lake use would most likely look at the green water as good habitat for healthy fish populations. Reduced visibility to an angler is associated with greater productivity and abundance of fish, whereas clear water for these users might be less desirable. This conflict of lake uses is even evident among professionals with limnologists often working to remove phosphorous from lakes to clear the water (oligotrophication), which aggravates the fisheries biologist who is trying to maintain productive fisheries (Ney 1996).

Surveys given to lake users have been used to successfully examine the relations between water chemistry and lake user's perceptions of water quality (Heiskary and Walker 1988, Smeltzer and Heiskary 1990). The survey results were analyzed based on physiographic regions because water chemistry in lakes is primarily dependent on edaphic factors within the physiographic region that lakes reside (Jones and

Bachmann 1978, Canfield and Hoyer 1988). The survey results suggested regional differences in user survey responses were the result of water chemistry differences that define lake trophic status of lakes among regions.

Attempts to examine relations between lake users perceptions of water quality and actual water chemistry have been conducted on northern lakes (Minnesota and Vermont). We wished to examine these same relations for Florida lakes. Therefore, we asked citizen volunteers from the Florida LAKEWATCH program to answer the same survey question asked in northern surveys (Heiskary and Walker 1988, Smeltzer and Heiskary 1990). Our first objective was to determine if there were any relations between user perceptions regarding the physical condition of their water and the associated water chemistry and visibility data they collected on the same date. The second objective was to determine if user perceptions regarding recreational and aesthetic enjoyment were related to the associated water chemistry and visibility data they collected on the same date.

Methods

Survey

Florida LAKEWATCH is a highly successful citizen lake monitoring program with a goal of collecting monthly credible total phosphorus, total nitrogen, chlorophyll and Secchi disk data (Florida LAKEWATCH 2002). Citizen volunteers in the Florida LAKEWATCH program were asked to complete a survey form prior to their monthly sampling event any time between May and November 2002. We asked our volunteers to take a moment to give us their opinion of what their lake looks like on the date of sampling before beginning their normal sampling routine. They responded to two multiple-choice questions by circling the choice, that best described the physical condition and potential for aesthetic enjoyment of their lake (Table 1). For this study there was only one survey response per lake, from one lake sampler on one date.

Respondents to our lake survey were active volunteers and were not randomly chosen from the entire lake user population. The results represented the perceptions of an active portion of the lake user population in Florida. Our database consisted of user survey responses with associated water quality measurements from 116 lakes from 28 Florida Counties (Fig. 1).

Water Chemistry

In the field, citizen volunteers collected surface (0.5 m) water samples for total phosphorus and total nitrogen analyses by holding an inverted bottle below the water surface to elbow depth and filling it by turning it horizontally. Samples were collected (depending on lake size) from 1 to 6 evenly distributed locations using acid-washed, triple-rinsed, 250-ml Nalgene bottles

Table 1.-Lake User survey form.

Lake Name/County ______________________________ Month/Day/Year ______________________

Question 1. 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 nicer
2 Very minor aesthetic problems; excellent for swimming
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.

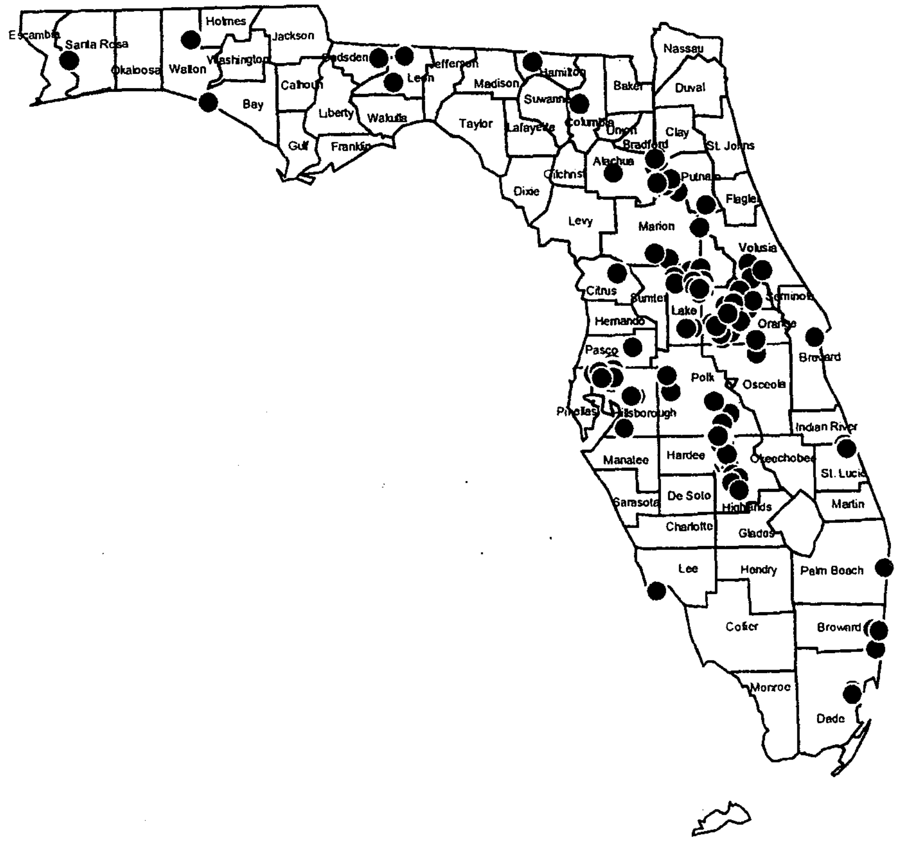

Figure 1.-Map of Florida with location of lakes.

for total phosphorus and total nitrogen. Volunteers collected additional surface water at each location in 4-L, tap-water rinsed plastic bottles. Volunteers also measured water clarity at each sampling location with a 20-cm diameter Secchi disk. Upon returning to shore, a measured volume of lake water from the 4-L bottles from each location was filtered through a Gelman Type A-E glass fiber filter to collect phytoplankton for laboratory chlorophyll analysis. All samples (filters and water) were frozen and sent to the Department of Fisheries and Aquatic Sciences' water quality laboratory where samples were analyzed for chlorophyll, total phosphorus, and total nitrogen concentrations.

Chlorophyll concentrations ($\mu g \cdot L^{-1}$) were determined spectrophotometrically following pigment extraction with 90% ethanol (Sartory and Grobbelaar 1984). Total phosphorus concentrations ($\mu g \cdot L^{-1}$) were determined by the procedures of Murphy and Riley (1962) with a persulfate digestion (Menzel and Corwin 1965). Total nitrogen concentrations ($\mu g \cdot L^{-1}$) were determined by oxidizing water samples with persulfate and determining nitrate-nitrogen with second derivative spectroscopy (Crumpton et al. 1992; Bachmann and Canfield 1996).

Statistical Procedures

Statistical computations were performed using various procedures in the JMP statistical package (SAS Institute Inc. 2000). Analysis of variance was used to examine the relations between responses to a question (independent variable) and all three water chemistry variables along with Secchi depth readings (dependant variables). All chemistry measurements were transformed to their logarithms (base 10) before statistical analyses to accommodate heterogeneity of variances. For discussions regarding lake trophic status we used total phosphorus, total nitrogen, total chlorophyll and Secchi depth and the classification categories defined by Forsberg and Ryding (1980). For some analyses we used only chlorophyll because chlorophyll is the end product of phosphorus or nitrogen depending on which nutrient is limiting and chlorophyll also accounts for the majority of variance in Secchi depth readings. Statements of significance are at $p \leq 0.05$.

Results and Discussion

The lakes used in this study ranged in trophic status from oligotrophic to hypereutrophic using three water chemistry variables (total phosphorus, total nitrogen, and total chlorophyll concentrations) and the classification system of Forsberg and Ryding (1980). Water clarity measurements using a Secchi disk also showed that the lakes in this study ranged from oligotrophic to hypereutrophic. Total phosphorus and total nitrogen concentrations ranged from 4 µg/L to 1826 µg/L and 40 µg/L to 5020 µg/L, respectively (Table 2). Total chlorophyll concentrations ranged from 0.5 to 248 µg/L and Secchi depth ranged from 0.2 m to 5.5 m. These data show the wide range of lake trophic states that can occur in Florida and are similar to the data used by Canfield and Hoyer (1988) to describe the regional geology and trophic state characteristics of 165 Florida lakes.

Question 1 of the Lake User Survey form asked the lake 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 that water samples were taken (Table 1). The responses were designed to depict a gradient in lake trophic status with Response 1 listing crystal clear water and Response 5 listing severely high algal levels. The relations between survey responses and all four trophic state variables were significant (Table 3). In each case the mean for the trophic state variables increase with response number from Response 1 through Response 4 suggesting a direct relation between survey response and trophic state. Only two lake users answered Question 1 with Response 5 and these will be discussed below. These data also support the findings of Smeltzer and Heiskary (1990) who showed an inverse relation between Question 1 responses and Secchi depth readings, which shows a direct relation between trophic status and responses.

Lake users from Lake Burrell in Hillborough County and Lake Gatlin in Orange County answered Question 1 with Response 5. In these two cases the mean for the four trophic state variables did not follow the pattern of increasing response number with increasing trophic status. After discussing Question 1 responses with the two individual lake users, it was obvious that even though the water chemistry and water clarity values indicated moderate trophic state conditions, mats of exotic vegetation (primarily *Hydrilla verticillata*) with associated filamentous algae suggested severely high algal levels to these lake users. This illustrates the problem that exists trying to describe the physical condition or water quality of a lake using only water chemistry variables. This also points out the problem with trying to classify lake trophic status of a macrophyte dominated lake only with chemistry data from open water areas (Canfield et al. 1983).

The direct relations between responses to Question 1 and lake trophic state variables are again depicted in Fig. 2 where we plotted total chlorophyll values against responses to Question 1. Lines dividing chlorophyll levels into trophic state categories based on the classification system of Forsberg and Ryding (1980) are also plotted. This figure shows the wide range of chlorophyll values that actually exist for each individual response. Responses 1, 4, and 5 span three lake trophic states and Responses 2 and 3 span all four lake trophic states. These data indicate that lake user's perception of the physical condition of lake water can vary considerably depending on the individual.

Question 2 asked the lake user to choose from a list of five alternative responses describing the recreational suitability of the lake with respect to algal levels at the time that water samples were taken (Table 1). The responses were designed to depict a gradient in lake trophic status with Response 1 listing beautiful and Response 5 listing swimming and aesthetic enjoyment nearly impossible. Analyses of variance were used to examine the relations between responses to Question 2 (independent variable) and all three water chemistry variable along with Secchi depth readings (dependant variables). The relations between survey responses and all four trophic state variables were significant (Table 4). In each case the mean for the trophic state variables increase with response number from Response 1

Table 2.–Summary statistics for water chemistry data collected from 116 Florida lakes on the day citizen volunteers filled out a lake user survey (see Table 1).

Water Chemistry Variables	Number of Lakes	Mean	Standard Error	Minimum	Maximum
Total Phosphorus (µg/L)	116	55	16	4	1826
Total Nitrogen (µg/L)	116	845	67	40	5020
Chlorophyll (µg/L)	116	20	4	0	248
Secchi (m)	104	1.7	0.1	0.2	5.5

Table 3.–Summary statistics for water chemistry data collected from 116 Florida lakes on the day a citizen volunteer filled out a lake user survey. Water chemistry statistics are computed by variable and response to question one (see Table 1). Analysis of variance indicated a significant relation between response and each water chemistry variable ($p \leq 0.05$).

Total Phosphorus (μg/L)					
Response to Question 1	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	8	19	7	6	66
2	62	29	5	4	201
3	36	95	50	7	1826
4	8	116	47	13	392
5	2	22	3	19	25
Total Nitrogen (μg/L)					
Response to Question 1	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	8	565	133	40	1293
2	62	633	41	167	1885
3	36	958	94	250	3107
4	8	2234	613	307	5020
5	2	958	448	510	1407
Chlorophyll (μg/L)					
Response to Question 1	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	8	4	2	0	14
2	62	11	2	1	114
3	36	22	4	2	110
4	8	92	37	4	248
5	2	19	17	2	36
Secchi (m)					
Response to Question 1	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	7	2.9	0.6	1.1	5.5
2	54	2.0	0.1	0.3	4.3
3	35	1.1	0.1	0.3	2.4
4	7	0.5	0.1	0.2	1.2
5	1	0.6	–	0.6	0.6

through Response 5 suggesting a direct relation between survey response and trophic state. These data also support the findings of Smeltzer and Heiskary (1990) who showed an inverse relation between Question 2 responses and Secchi depth readings, which shows a direct relation between trophic status and response.

The direct relations between responses to Question 2 and lake trophic state variables are again depicted in Fig. 3 where we plotted total chlorophyll values against responses to Question 2. Lines dividing chlorophyll levels into trophic state categories based on the classification system of Forsberg and Ryding (1980) are also plotted. This figure shows the wide range of

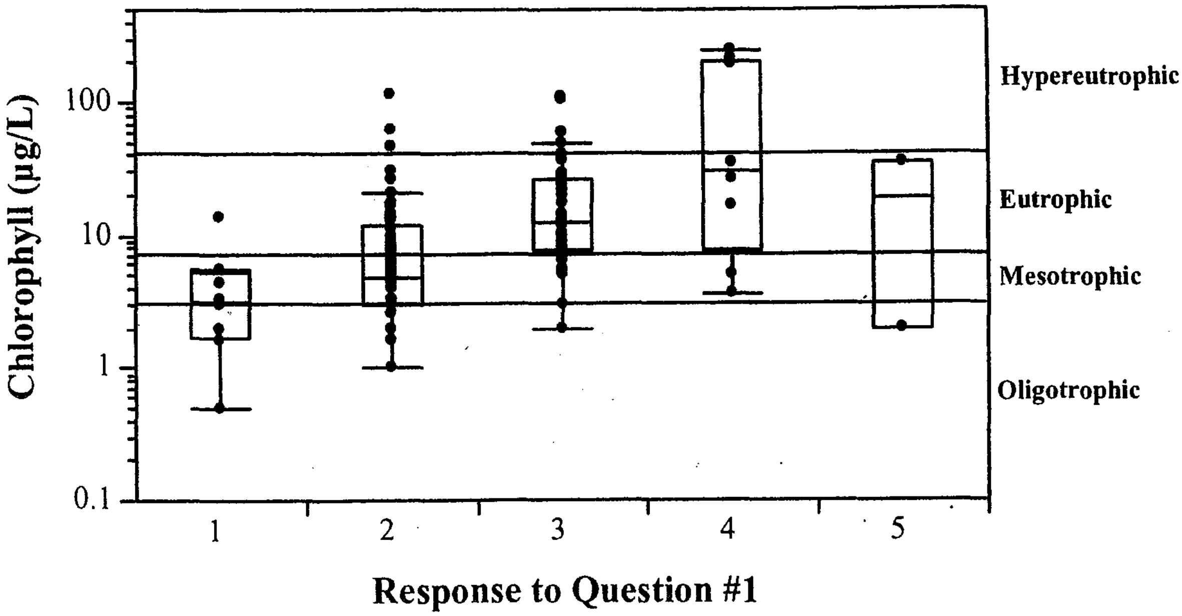

Figure 2.-Chlorophyll data collected from 116 Florida lakes on the day a citizen volunteer filled out a lake user survey plotted versus the response to Question 1 of the survey (See Table 1). The quantile box plots show the median as a line across the middle box, the 25th and 75th quantiles are the ends of the box and the 10th and 90th quantiles are the lines above and below the box. The trophic state levels drawn on the plot are from the classification system of Forsberg and Ryding (1980).

chlorophyll values that actually exist for each individual response. Responses 1 and 5 span three lake trophic states and responses 2, 3 and 4 span all four lake trophic states. These data indicate that lake user's perception of the recreational suitability of lake water can vary considerably depending on the individual.

Smeltzer and Heiskary (1990) analyzed their survey

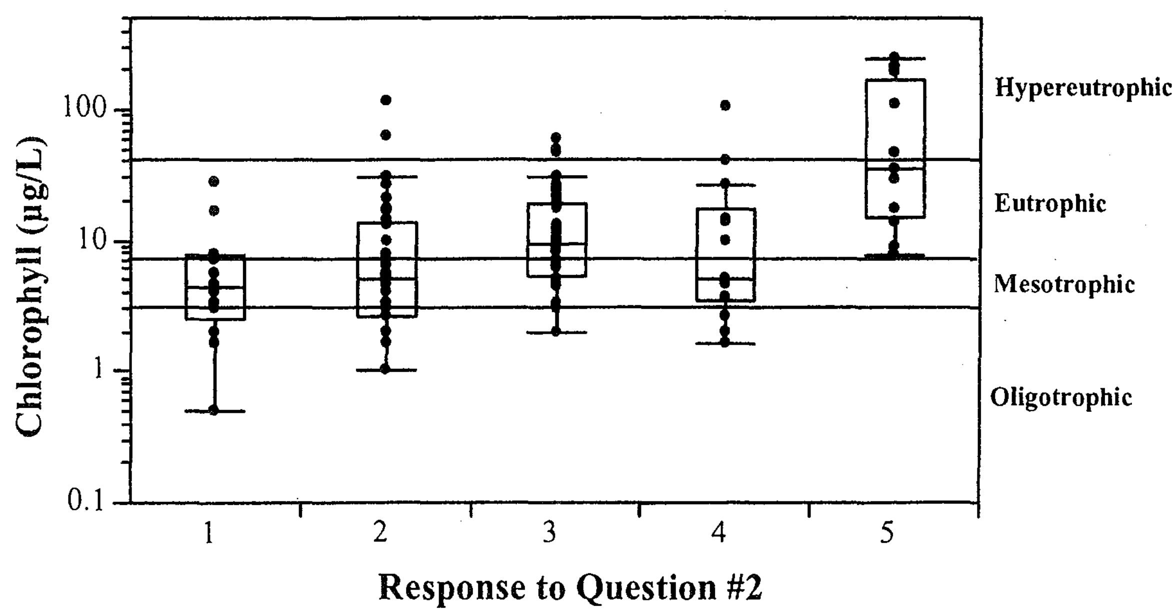

Figure 3.-Chlorophyll data collected from 116 Florida lakes on the day a citizen volunteer filled out a lake user survey plotted versus the response to Question 2 of the survey (See Table 1). The quantile box plots show the median as a line across the middle box, the 25th and 75th quantiles are the ends of the box and the 10th and 90th quantiles are the lines above and below the box. The trophic state levels drawn on the plot are from the classification system of Forsberg and Ryding (1980).

Table 4.–Summary statistics for water chemistry data collected from 116 Florida lakes on the day a citizen volunteer filled out a lake user survey. Water chemistry statistics are computed by variable and response to question two (see Table 1). Analysis of variance indicated a significant relation between response and each water chemistry variable (p≤0.05).

Total Phosphorus (µg/L)

Response to Question 2	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	13	15	2	6	30
2	39	27	6	4	132
3	36	37	7	7	235
4	14	65	28	7	392
5	12	220	148	20	1826

Total Nitrogen (µg/L)

Response to Question 2	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	13	578	81	40	1197
2	39	637	52	167	1827
3	36	744	61	247	1963
4	14	785	123	307	1897
5	12	2091	426	350	5020

Chlorophyll (µg/L)

Response to Question 2	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	13	7	2	0	27
2	39	12	3	1	114
3	36	14	2	2	58
4	14	17	7	2	104
5	12	80	25	8	248

Secchi (m)

Response to Question 2	Number of Responses	Mean	Standard Error	Minimum	Maximum
1	11	2.3	0.3	0.9	4.3
2	35	2.0	0.2	0.4	3.8
3	33	1.6	0.2	0.4	4.3
4	11	1.7	0.5	0.2	5.5
5	12	0.8	0.1	0.3	1.8

results by ecoregion and concluded that regional differences in user survey responses were the result of general differences in lake water chemistry among regions. For example, 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 mostly eutrophic or hypereutrophic lakes. Florida's geology is very diverse and recently Griffith et al. (1997) defined and characterized 47 lake regions using drainage maps, lake water chemistry data and scientific expertise on the limnology of Florida lakes. This diversity made it difficult to do any analyses based on region because our sample size was not large enough in most lake regions. However, we had limited multiple survey responses from two Lake Regions that differed greatly in average lake trophic state variables.

We had nine survey responses from lakes in the Trail Ridge lake region located in north central Florida. Lakes in the Trail Ridge have a median chlorophyll of 3.4 µg/L and range from 0.5 µg/L to 17.7 µg/L (Griffith et al. 1997; Horsburgh 1999). We also had ten survey responses from lakes in the Central Valley lake region located in north central Florida. Lakes in the Central Valley have a median chlorophyll of 24.2 µg/L and range from 0.7 µg/L to 95.3 µg/L. The chlorophyll values associated with Response 1, 2 and 3 to Question 2 were all higher for lakes in the Central Valley than chlorophyll values associated with the same responses from lakes in the Trail Ridge lake region (Fig. 4). These data support the findings of Smeltzer and Heiskary (1990) and suggest that lake users located in areas dominated by eutrophic lakes are more likely to tolerate green water and consider it good water quality. However, the chlorophyll values associated with Response 4 to Question 2 were similar in the Central Valley and the Trail Ridge lake region (Fig. 4) and there was no Response 5 in the Trail Ridge lake region. Thus, more lake survey data will be needed in the future to confirm these findings.

Conclusion and Management Implications

In Florida, there are significant relations between lake users perceptions of the physical condition of water and the associated lake trophic state water chemistry variables. There are also significant relations between lake users perceptions of recreational and aesthetic enjoyment of water and the associated lake trophic state water chemistry variables. This study confirms findings from earlier lake user surveys conducted in Minnesota and Vermont (Smeltzer and Heiskary 1990). While the relations reported in this study are significant there is also a lot of variance in actual water chemistry for any perceived water quality. Some of this variance can be attributed to regional differences in perceptions of water quality.

However, there will always be considerable variance in these relations because a lake can not be all things to all people. Even professionals classify the trophic status of lakes differently using classification systems that are most comfortable to the perceptions of the individual professional (Klapper et al. 1989)

Lake user surveys have been used to successfully

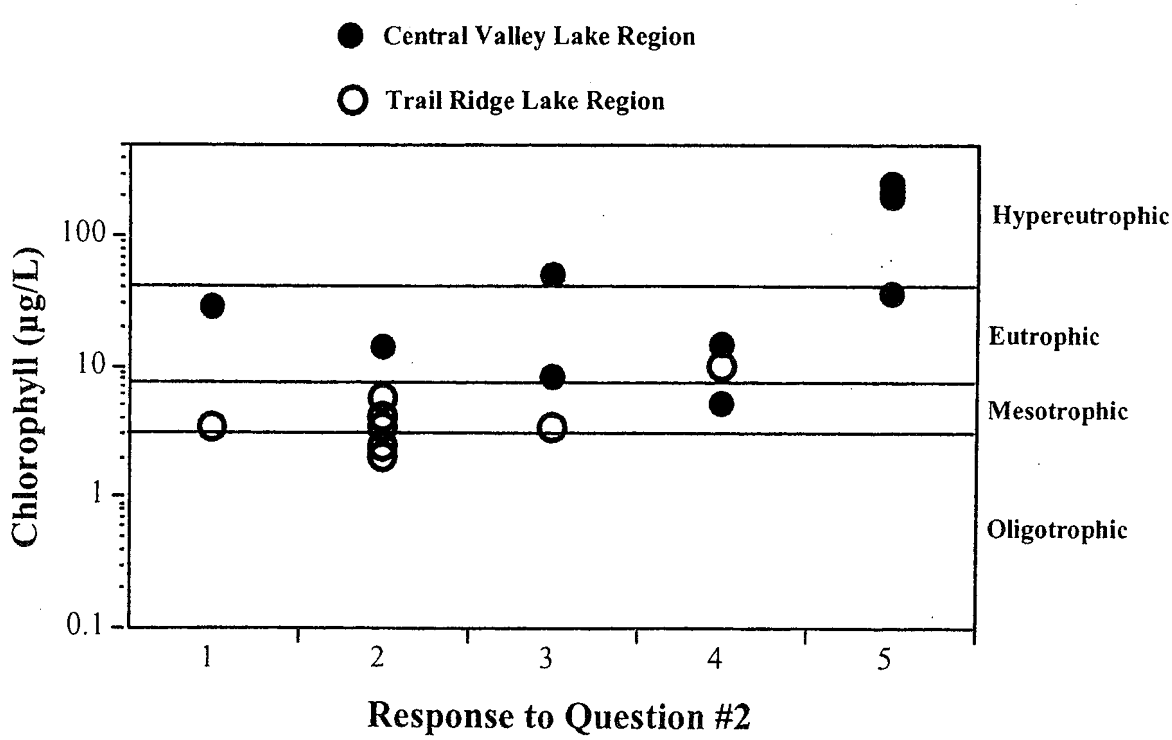

Figure 4.–Chlorophyll data from 10 lakes in the Central Valley lake region (closed circles) and 9 lakes in the Trail Ridge lake region (open circles) collected on the day a citizen volunteer filled out a lake user survey plotted versus the response to Question 2 of the survey (See Table 1). The trophic state levels drawn on the plot are from the classification system of Forsberg and Ryding (1980).

develop phosphorus criteria for Minnesota lakes (Heiskary and Walker 1988), set water quality standards for Vermont lakes, and evaluate wastewater discharge impact to Lake Champlain (Smeltzer and Heiskary 1990). The lake user survey reported on here was at a much smaller scale than earlier northern surveys and before it is used to help manage Florida lakes it needs to be expanded. The Florida survey had only one response from one lake resident on one date and it would be beneficial to have several residents from the same lake fill out responses throughout a year. This would yield a much better grasp of how lake users perceive water quality and how it might be related to water chemistry.

The questions used in all surveys were centered around aesthetic and recreational impacts from algae in open water areas and ignore other forms of lake use. Additional survey questions need to be asked to incorporate the majority of lake use activities. Some major areas that need to be included are lake uses that are impacted by aquatic plant, fish and other wildlife population abundances. The surveys also need to be conducted in light of regional potential for each individual lake. Armed with this information lake managers would be able to set reasonable lake management goals that would be supported by the public because the public helped develop those goals.

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