

Evaluation of Data Generated from Lake Samples Collected by Volunteers

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ABSTRACT

Obrecht, D. V., M. Milanick, B. D. Perkins, D. Ready and J. R. Jones. 1998. Evaluation of data generated from lake samples collected by volunteers. *Lake and Reserv. Manage.* 14(1):21-27.

The goals of the Lakes of Missouri Volunteer Program are to involve citizens in the collection of water samples to monitor lake trophic state and to provide outreach education about lake water quality. Results indicate data generated with volunteer help are of the same quality as that generated by a research laboratory. This conclusion is based on three different methods of evaluation: (1) Comparisons of volunteer and University collected samples showed trophic state classifications were the same for 74% of lakes based on total phosphorus, 84% for total nitrogen and 89% for chlorophyll; (2) Agreement between paired chlorophyll filters was assessed to gauge volunteer processing technique; 88% of the filter pairs was considered good or excellent based on a rating scale developed for this program; (3) Split sampling showed no significant differences for total suspended solids, chlorophyll or total nitrogen. Total phosphorus analysis showed a significant difference with volunteer samples being consistently less than University samples. Prior to analysis, volunteer samples for total phosphorus were stored frozen in high density polyethylene bottles while University samples were refrigerated in glass tubes. This difference in storage method may have caused the irregularity in our results.

Key Words: volunteer, lake monitoring, quality control, chlorophyll, phosphorus, nitrogen, nutrients, sample preservation.

In 1992 the Missouri Department of Natural Resources secured a grant from the U.S. Environmental Protection Agency to develop a citizen monitoring program for lakes. The School of Natural Resources at the University of Missouri (MU) was chosen to administer the program. After a review of articles pertaining to citizen monitoring programs (Kishbaugh 1988, Rumery and Vennie 1988, Heiskary 1989, Simpson 1991, Carpenter 1992), the Lakes of Missouri Volunteer Program (LMVP) was created. The ongoing goals of the program are to (1) involve citizen volunteers in the

collection of water samples to monitor lake trophic state and (2) provide outreach education about lake water quality.

Parameters monitored by volunteer helpers are Secchi transparency, surface water temperature, algal chlorophyll (CHL), total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS). Each winter, regional data review sessions are held to present results of the previous sampling season to volunteers. These reviews are also used to teach volunteers about lake ecology, review problems with sample collection and processing, and plan the upcoming sampling season.

As part of the program, we have evaluated the

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reliability of data generated from volunteer collected samples. In an attempt to assess the merit of these data, we will answer three questions in this paper: (1) Were trophic state assessments based on volunteer collected samples dependable? (2) How careful were volunteers when they processed their samples? (3) Did the sample processing and storage procedures used by volunteers influence data? To answer these questions we: (1) Compared trophic state assessments based on volunteer-collected samples with assessments based on samples collected by MU personnel; (2) Evaluated the similarity of duplicate chlorophyll filters to gauge how carefully volunteers processed their samples; and (3) Compared results from lake samples split between LMVP staff and volunteers to determine if processing and storage procedures used by volunteers influenced the data.

Methods

Volunteers generally sampled once every 3 weeks from April through September, for a total of eight collections per season. Sample sites on small lakes were located near the dam while larger lakes (> 1000 acres) had multiple sites. At the sample site volunteers measured surface water temperature and Secchi transparency and collected three surface samples (≤ 0.5 m) with a 1- or 2-L polyethylene bottle. These samples were mixed in a bucket, and the sample bottle was filled from the composite. The sample was stored in a light-tight cooler and processed the same day. Processing involved rinsing and filling a 60-mL high density polyethylene bottle with lake water for analysis of TP and TN. Volunteers used a hand pump with a vacuum flask/filter funnel assembly to prepare duplicate CHL samples on glass fiber filters (Gelman A/E). Volunteers sampling Missouri lakes with high inorganic suspended solids (Jones and Knowlton 1993) also prepared two filters (tared Whatman 934AH) for TSS analysis. All processed filters were placed in a light-tight container with desiccant. This container and the 60-mL bottle were stored frozen. Processed samples were collected from volunteers during mid-season and again at the end of the season. Storage time varied from 1 to 6 months.

All analyses were conducted in the Limnology Laboratory at the MU by LMVP staff. TP was analyzed by the ascorbic acid – color reagent method following persulfate digestion (365.3, USEPA 1979), TN with an ultraviolet scan after persulfate digestion (Crumpton et al. 1992), CHL by fluorometry following heated

ethanol extraction (Sartory and Grobbelaar 1986), and TSS gravimetrically (methods 2540 B and 2540 E, APHA 1989).

Results

Trophic State Comparison – Volunteer vs University Data

To evaluate the reliability of trophic state assessments based on data generated from volunteer samples, we paralleled volunteer collections with collections by University personnel during the 1992-94 seasons. University samples were collected on three occasions each year, May through August. To minimize temporal variability in this analysis, volunteer data were limited to the three sample occasions which most closely approximated University sample dates. To reduce problems associated with spatial variability, only sites sampled by both volunteers and the University were compared ($n = 19$). Averages for TP, TN, and CHL were calculated for the three volunteer samples and for the three University samples collected during a particular summer. Trophic state assessments were based on these averages and criteria for Missouri lakes (Jones and Knowlton 1993).

Volunteer and University trophic state classifications were identical for 14 of 19 TP comparisons (74%), 16 of 19 TN comparisons (84%), and 17 of 19 CHL comparisons (89%). Results presented in Fig. 1 indicated that comparisons that did not lead to identical trophic state assessments were similar in terms of actual measured values with the exception of one TP comparison. For those comparisons not resulting in the same trophic state classification, the average difference between the volunteer and University values for TP was $5 \mu\text{g/L}$ (excluding the single outlier), $84 \mu\text{g/L}$ for TN, and $3.8 \mu\text{g/L}$ for CHL.

The TP comparison that exhibited poor agreement occurred in Lake Taneycomo in 1992 when volunteer data showed a much larger average than University data. Knowlton and Jones (1990) found this lake can have a short residence time (<1 day), and TP values were typically around $20 \mu\text{g/L}$ when Table Rock Dam, located upstream, was releasing water. During periods of low or no flow, nutrients from a nearby point source (wastewater effluent) pooled at the sample site. In 1992 our volunteer collected a sample with $123 \mu\text{g/L}$ of TP, suggesting localized influence from this point source. We do not believe this elevated value was a function of the volunteer's ability but a reflection of the dynamics of the system.

Secchi transparency was not used to categorize trophic state because of the influence inorganic suspended solids have on water clarity in Missouri lakes (Jones and Knowlton 1993). Examination of these data indicated that the average summertime Secchi transparencies measured by volunteers were generally comparable to University readings (Fig. 1). University Secchi values ranged from 0.7 to 4.5 m. Deviations between the average volunteer and University Secchi readings ranged from 0 to 2.2 m with a median value of 0.2 m.

No statistical differences were found between University and volunteer summer means for TP, TN, CHL or Secchi using Wilcoxon Rank Sum Analysis at the 5% significance level (Schlotzhauer and Littell 1987).

Chlorophyll Filter Replication

The quality of data generated by volunteers depends on their ability to process water samples with care. In order to gauge volunteer processing technique, we analyzed similarity between paired CHL filters. Ideally the duplicate filters should be the same, with minor differences attributed to the analytical method. Large differences would suggest a problem with volunteer technique. Filter pairs were assessed based on the difference in CHL between the filters defined as a percent of the minimum value of the pair using the formula $100 \times [(M - m) / m]$, where M is the maximum value and m is the minimum value of the pair. A shortcoming of this method was that small differences between filters from samples with low

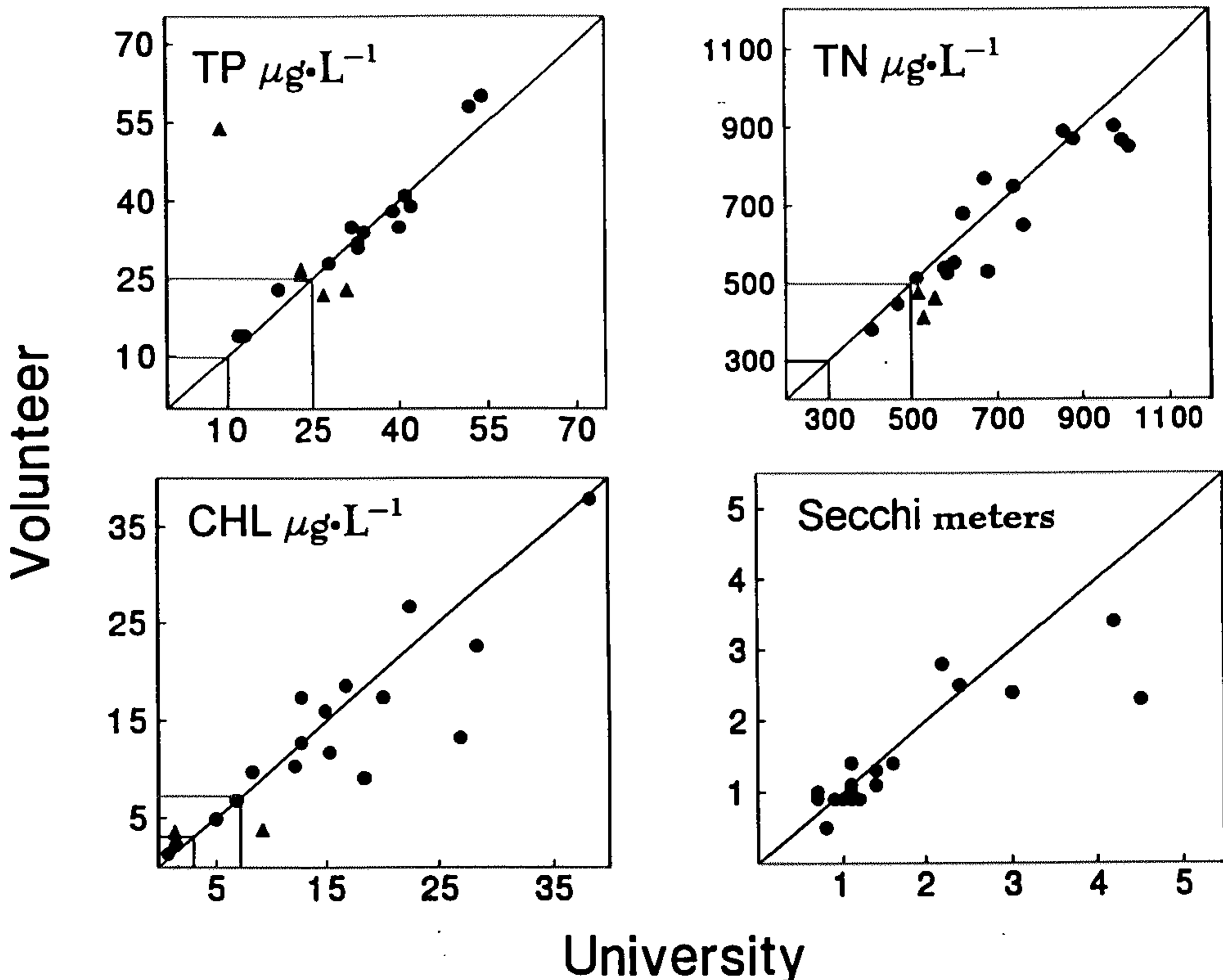


Figure 1.—Comparison of University and volunteer total phosphorus (TP), total nitrogen (TN), chlorophyll (CHL), and Secchi data from summertime sampling, 1992-94. Diagonal lines represent 1:1. Vertical and horizontal lines indicate trophic state cut-points for oligotrophic, mesotrophic, and eutrophic reservoirs according to Jones and Knowlton (1993). Triangles represent University and volunteer data that did not lead to the same trophic classification. Secchi transparency was not used to make trophic state classifications.

Table 1.—Criteria for evaluating the difference between paired chlorophyll filters processed by volunteers.

Difference	Category
≤ 5%	Excellent
≤ 10%	Good
≤ 15%	Fair
> 15%	Poor

CHL concentrations resulted in relatively high differences when measured as a percent. To resolve this problem the formula $100 \times [(M - m) / 5]$ was used for paired filters with an average CHL value $\leq 5 \mu\text{g/L}$. Analysis of a random selection of 60 filter pairs processed in the University laboratory showed that a difference between paired filters of about 5% (for values $> 5 \mu\text{g/L}$) was typical. Using this information, we created a rating system that would indicate in simple

terms the quality of filter replication to our volunteers (Table 1). Results of these comparisons are presented in Fig. 2 and represent all CHL filter pairs collected by individual volunteers during 1992 through 1995. During their first year in the program (Fig. 2A), volunteers as a whole had 87% of their filter pairs categorized as excellent or good. Results were similar for the second and third year while fourth year volunteers had 94% of their filter pairs rated excellent or good (Fig. 2B-D). We have used data review sessions to point out potential problems in technique (sample mixing and measurement, etc.) to those volunteers who had filter pairs in the fair or poor categories.

Split Sampling

In 1995, LMVP staff took comparisons between University and volunteer data a step further and implemented split sampling as a quality control measure. These results allowed us to compare volunteer

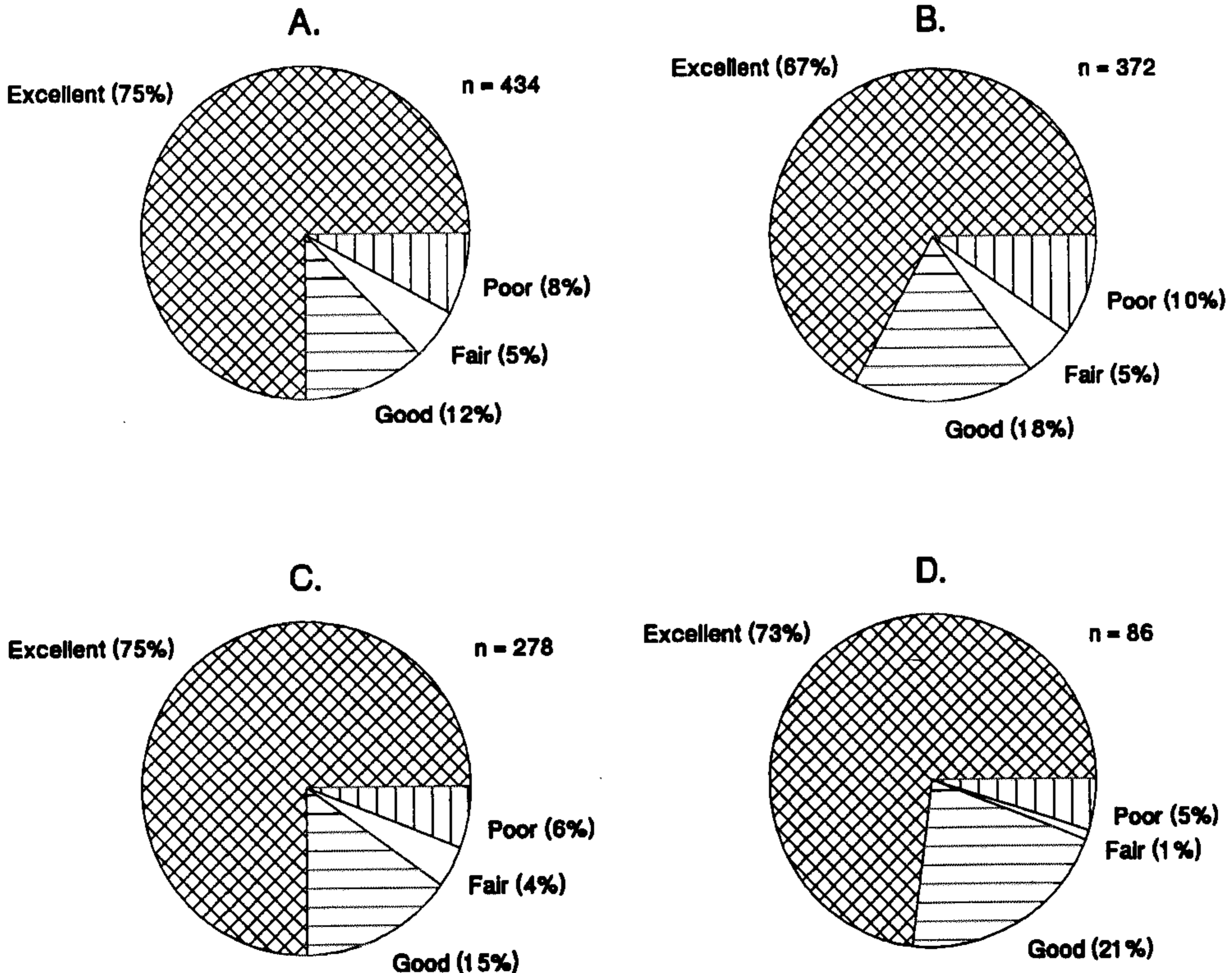


Figure 2.—Results from volunteer chlorophyll filter replication. Panels A, B, C, and D depict results of volunteers after their first, second, third, and fourth years of involvement.

processing and storage methods with those used by the University and to evaluate whether volunteer procedures influenced data.

During the sampling season, a total of 29 split samples were collected from 10 different lakes. Individual lake sites were represented only once, and volunteers who sampled more than one lake site were limited to two split samples from different sites. Sampling was conducted by having volunteers, in the presence of LMVP personnel, follow their usual method of collecting a lake sample. LMVP staff would then fill their sample bottle from the same composite sample. Volunteers were instructed to process their sample as usual. LMVP staff stored their sample on ice and returned it to the University where processing took place. LMVP staff followed routine University Limnology Laboratory procedures for processing, which differed from volunteer methods in that the

CHL and TSS filters were prepared with an electric pump instead of a hand pump, and TP samples were placed directly into glass tubes and stored at 4°C prior to analysis instead of frozen in a polyethylene bottle. Volunteers and LMVP staff followed the same processing and storage procedures for TN samples.

Results of split sampling analysis are presented in Fig. 3. Statistical analysis was conducted using a Paired T-test on differences (LMVP staff - volunteer) between split samples (log transformed data for TSS, CHL, and TP), $\alpha = 0.05$ (Schlotzhauer and Littell 1987). TSS and CHL demonstrated general agreement between LMVP staff and volunteer data (points fall on or near the 1:1 line). No significant statistical difference was found, suggesting that volunteer and University personnel generate similar data.

Values for TN show some deviation from the 1:1 line, likely reflecting variation inherent in nitrogen

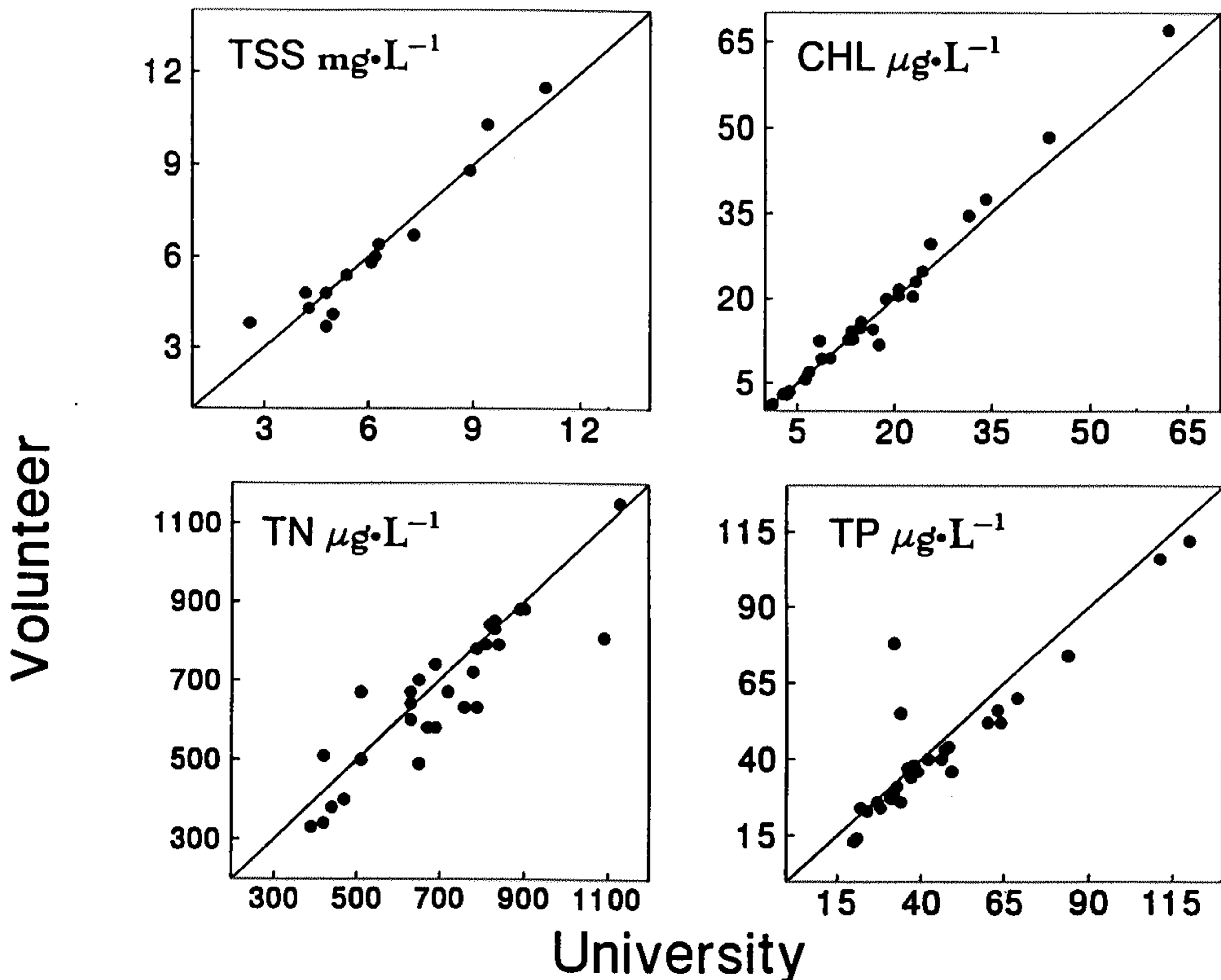


Figure 3.—Results from University/volunteer split samples for total suspended solids (TSS), chlorophyll (CHL), total nitrogen (TN), and total phosphorus (TP). Diagonal lines represent 1:1.

analysis. A statistical difference was found for TN data. However, review of the data indicated one value (difference between LMVP staff and volunteer data) was almost twice as large as the next largest deviation. When this outlier was removed, subsequent analysis showed no statistical difference.

The majority of TP data points fell below the 1:1 line, suggesting that volunteer samples consistently yielded lower values. Statistical analysis of the TP data revealed no significant difference. However, two of the data points indicated extreme differences between LMVP staff and volunteer values; indications were that these differences represent isolated instances of contamination during processing. When analysis was conducted without the two extreme data points, a statistical difference was found indicating that LMVP staff and volunteer samples were not equal. We investigated this finding by analyzing additional water samples from lakes and streams in Missouri ($n = 62$) in which phosphorus samples were stored both refrigerated and frozen. Results paralleled the split sample findings in that the majority of data points fell below the 1:1 line. Paired T-test analysis of these data indicated statistical differences between storage methods at $\alpha = 0.05$ (Schlotzhauer and Littell 1987).

To quantify the influences of freezing on phosphorus recovery, we combined the two data sets minus the two outliers from the split sample set ($n = 89$). Because the range of values was large (6 to 120 $\mu\text{g/L}$ for refrigerated samples), we divided the data into two

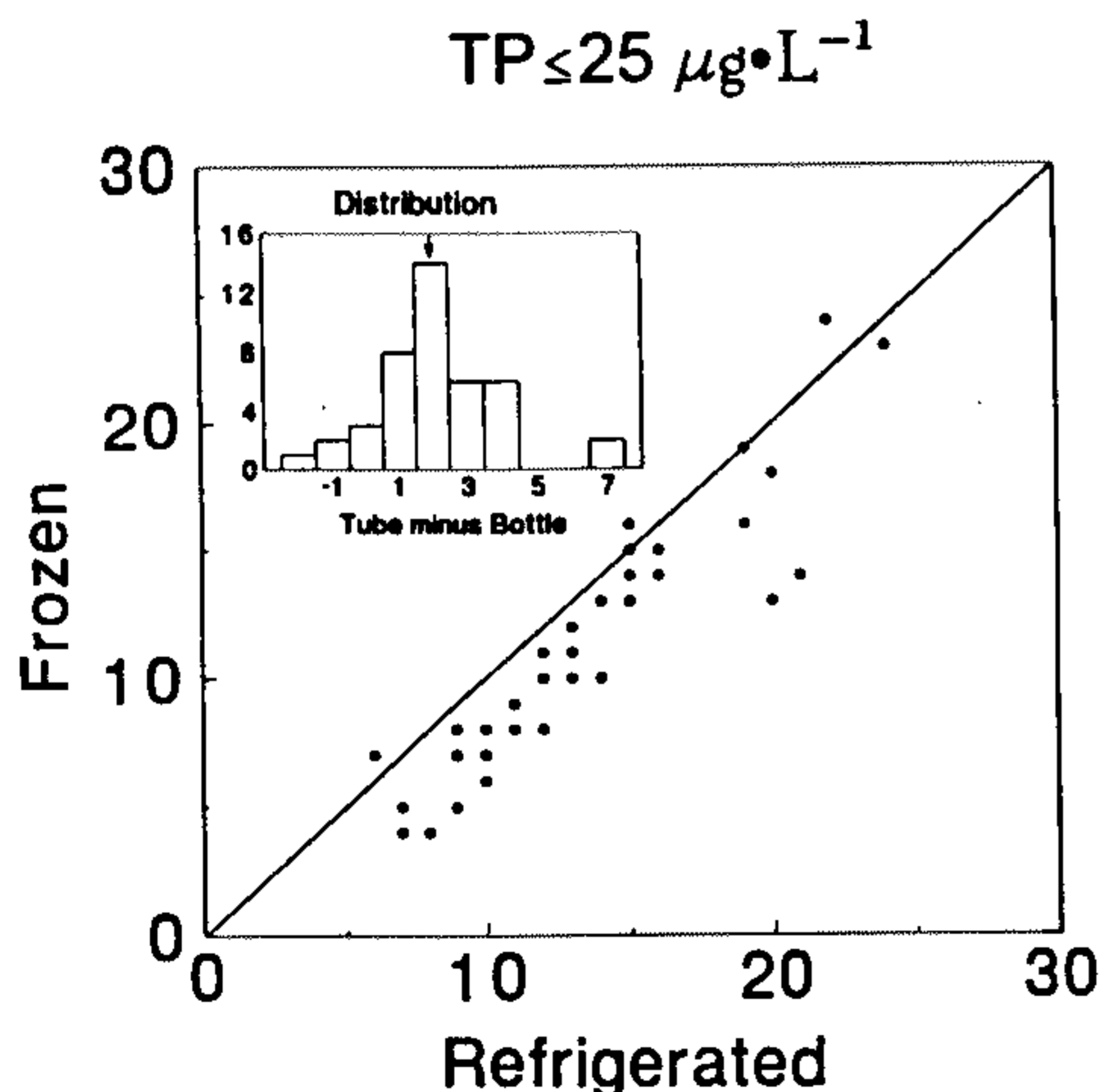


Figure 4.—Scatter plot and distribution plot for phosphorus concentrations $\leq 25 \mu\text{g/L}$ ($n = 42$). Diagonal line represents 1:1. Arrow on distribution plot indicates median difference between frozen and refrigerated samples. Refrigerated samples were stored in glass tubes, and frozen samples were stored in high density polyethylene bottles.

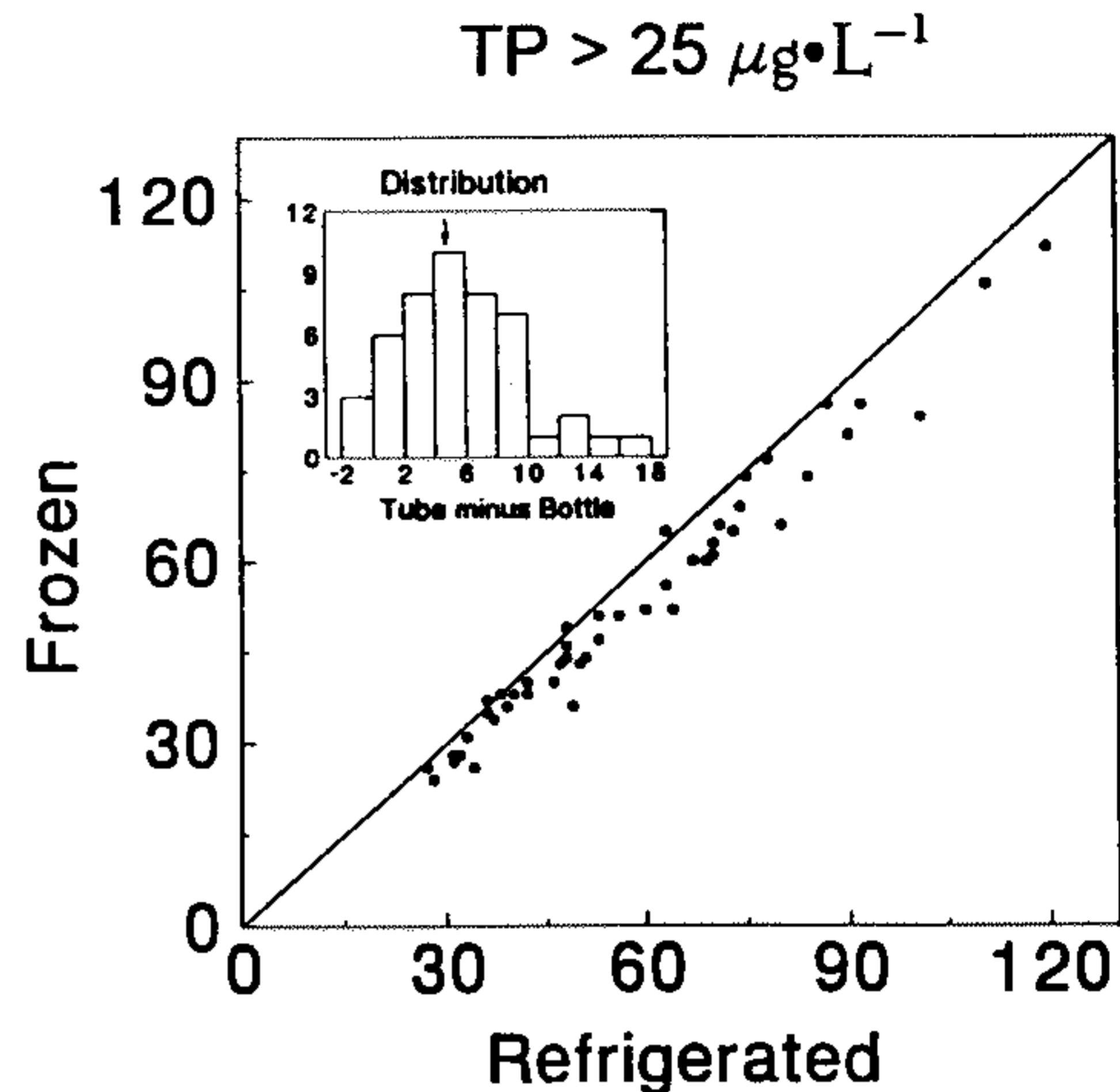


Figure 5.—Scatter plot and distribution plot for phosphorus concentrations $> 25 \mu\text{g/L}$ ($n = 47$). Diagonal line represents 1:1. Arrow on distribution plot indicates median difference between frozen and refrigerated samples. Refrigerated samples were stored in glass tubes and frozen samples were stored in high density polyethylene bottles.

subsets (Figs. 4 and 5). The first subset contained values $\leq 25 \mu\text{g/L}$, levels that would include oligotrophic and mesotrophic lakes (Jones and Knowlton 1993). The average difference between storage methods for this data set was 2.1 $\mu\text{g/L}$, with a standard deviation of 1.8 $\mu\text{g/L}$ and a range of -2 to 7 $\mu\text{g/L}$. The second subset contained values from eutrophic or hypereutrophic lakes ($> 25 \mu\text{g/L}$), and the mean difference between the two storage methods was 5.1 $\mu\text{g/L}$, with a standard deviation of 4.1 $\mu\text{g/L}$ and a range of -2 to 18 $\mu\text{g/L}$. These results suggest there was a consistent bias in the TP values generated from frozen samples.

Discussion

Overall, the preceding analyses support the belief that data generated from volunteer collected samples are similar to data generated from University collected samples.

Analysis indicated that trophic state assessments made from volunteer collected samples generally concur with those of the University. Evaluation of replicate filters for chlorophyll measurements suggests that volunteers process their samples carefully. Split sample comparisons indicated that volunteer processing and storage procedures resulted in values for total suspended solids, chlorophyll, and total nitrogen that match data generated by our research laboratory.

Volunteer total phosphorus values were consistently lower than University values.

Our findings regarding TP differ from those of previous studies. Griesbach and Peters (1991) and Lambert et al. (1992) reported no detectable changes of TP concentrations in samples stored frozen in polyethylene bottles for 1 year and 6 months, respectively. The volume of our frozen samples (< 60 mL) was small compared to those of previous studies—1 L for Griesbach and Peters (1991) and 250 mL for Lambert et al. (1992), making the volume to surface area of the bottles quite different. It seems possible that the problem is related to binding of phosphorus on the walls of the plastic bottles. Alternatively, it may be that in our bicarbonate waters, phosphorus precipitates during the freezing process and these precipitates were not being fully recovered in our subsamples or oxidation step. Identification and elimination of this source of variance is a future goal of the program. At this point, we conclude that the convenience of having volunteers freeze their samples outweighs the reduced yield of phosphorus associated with this storage method. Losses were not large enough to influence trophic state assessment in the majority of cases or impair the data for most other uses.

Conclusion

Public response to the Lakes of Missouri Volunteer Program has been excellent. The number of lakes, sites, and volunteers involved has increased each year. In 1992, we started with 6 lakes, a total of 27 sites and 25 volunteers, and in 1996 more than 70 volunteers were sampling 14 lakes at 51 sites. Most volunteers have remained with the program and requested additional responsibilities. The use of volunteers in the collection of water samples augments our ability to monitor water quality. With training and sufficient reference materials, volunteers are capable of collecting, processing, and storing water samples that produce quality data. Use of volunteers, instead of University personnel, to collect water samples offers many advantages. A volunteer's proximity to the lake allows for frequent sampling without the cost associated with travel and labor. Another benefit is that volunteers can monitor weather events and activities in the watershed that affect water quality. The LMVP also provides University personnel

with an opportunity to educate the public about water quality. The collection of useful data by citizens educated in lake ecology, who have a vested interest in the resource, is an efficient and rational means of fostering effective lake management.

ACKNOWLEDGMENTS: We would like to thank the Missouri Department of Natural Resources for ongoing funding of this project and the Center for Environment, Science and Technology for supplemental support. Special thanks to all of the volunteers who were involved in the program, the Jackson County Parks and Recreation Department for all of their cooperation, Sandy Clark for editorial assistance, and Dr. Melvin George for comments concerning filter replication analysis.

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