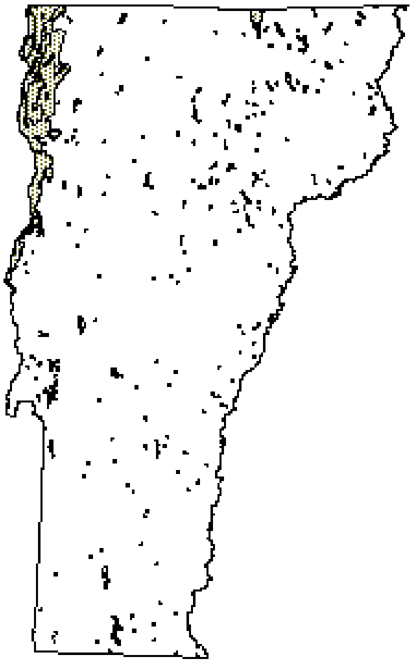

Paleolimnology and Bioassessment of Vermont and New Hampshire Lakes

Status Report, 11/01/99-2/22/2000

Bioassessment Project Component

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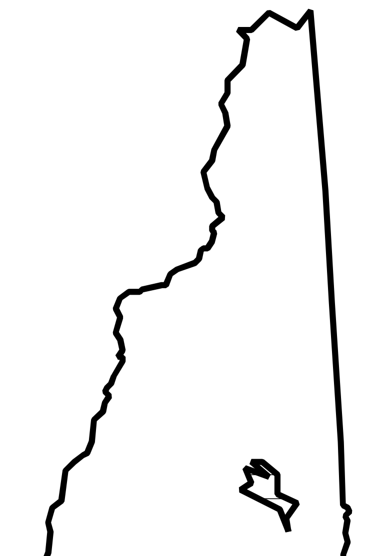

Project: Bioassessment of Vermont and New Hampshire Lakes Project and Development of Biological Criteria for Vermont Lakes Project

Funding Source: § 104(b)(3) of the Clean Water Act and EPA-Office of Water, Biocriteria Program

Reporting Period: 11/01/99-2/22/2000

In the previous quarterly report, a detailed synopsis of the phytoplankton criteria development process was presented. This short report provides an update on the progress in deriving the remaining assemblages' biocriteria.

Macroinvertebrates:
Macroinvertebrate processing from the 1997 field season is now completed and the data are available for analysis. Some preliminary analyses have been performed. A canonical correspondence analysis using percent composition of rocky-littoral habitat macroinvertebrates on reference lakes is presented here (Figure 1). The analysis yielded a similar physico-chemical grouping as was identified with the phytoplankton. Three general groups (low-alkalinity, well-buffered, and large lakes) cluster together, and have characteristic groupings of macroinvertebrates as well. Note, as an example, the occurrence of several taxa which fall on the same gradient occupied by the Low alkalinity lakes (Figure 1). Similar analyses have been performed for the remaining habitat types, as well as with combined reference and test-lake data for the rocky littoral habitat.

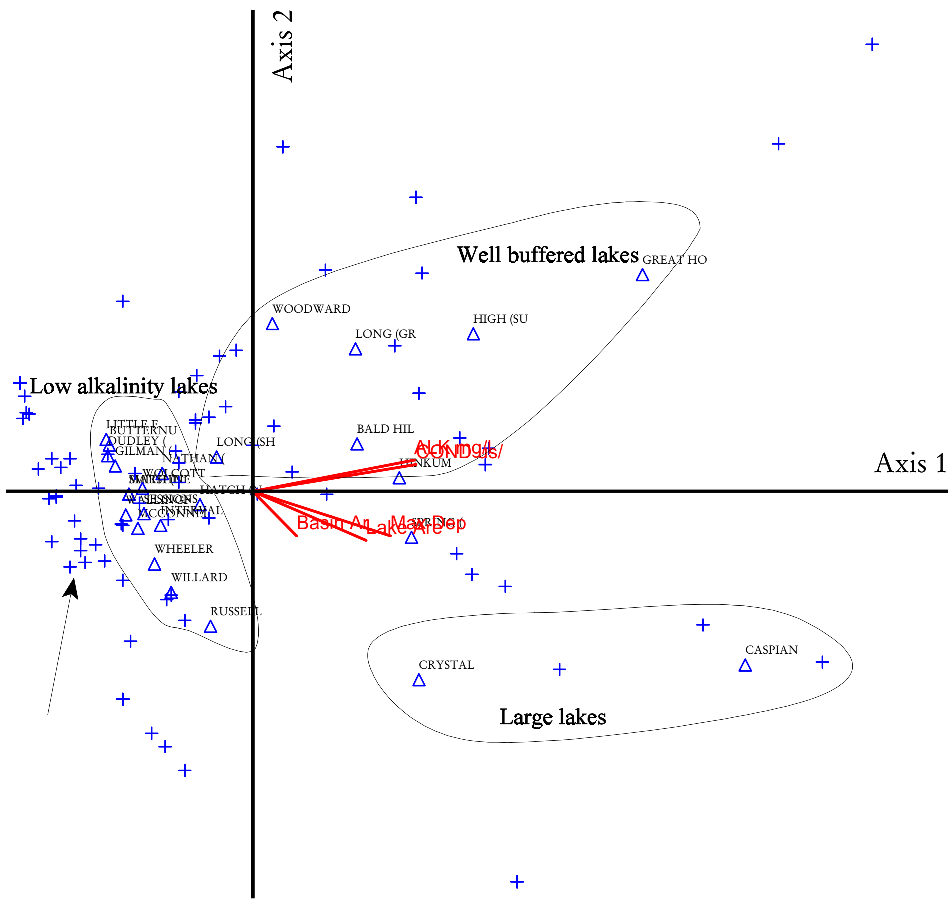

Figure 1. Canonical correspondence analysis of macroinvertebrate taxa percent composition data (+) plotted in multivariate space with reference lake scores (△) calculated as linear combinations of environmental variables. The occurrence of several taxa which fall along the same axis occupied by the low alkalinity lakes (marked by an arrow) is significant. These first two ordination axes comprise 7.5% and 4.5% of the total 16.4% variance explained in this analysis.

When the preliminary phytoplankton criteria were derived for the 1996-1997 lake set, then reviewed with the additional 1998 data, it was found that the additional 10 lakes worth of data exerted significant influence on the ability of the criteria to discriminate reference from unknown/degraded conditions. The same might be expected of the macroinvertebrate information. Accordingly, it seems prudent to await availability of the 1998 data as well in order to reduce duplication of effort. Taxonomy is presently complete for the 1998 samples save dipteran identifications and data entry and validation.

Trophic State Measures:

Trophic state criteria were revisited to incorporate additional 1998 lake data, and a summary of the trophic state criteria is included here. The process of criteria development was as follows: identify and statistically verify a classification; determine (and verify statistically) whether metrics discriminate test from reference conditions within classes; and derive trophic scores.

The three lake-type classification derived from the phytoplankton criteria was used as a starting point. A multivariate analysis of variance (MANOVA) was performed on the reference lakes to determine if variation existed in the mean trophic state scores for Secchi transparency, chlorophyll-a concentration, and algal biovolume across the three lake classes. The mean set of trophic scores varied significantly across the classes (Wilks' $\Lambda = 0.241$, $F = 5.88$, $p = 0.003$). Follow-up ANOVA underscored that this separation was driven largely by TSI_{Cha} ($F = 18.7$, $p = 0.001$). Neither TSI_{SD} ($F = 3.01$, $p = 0.07$), nor TSI_{Biovol} ($F = 0.47$, $p = 0.63$) varied significantly across classes for the reference lakes.

To enhance separation between the classes, the 'large' and 'well-buffered' lake groups were pooled, and compared to low-alkalinity lakes. Both TSI_{SD} ($t = -2.740$, $p = 0.009$) and TSI_{Cha} ($t = -2.575$, $p = 0.014$) varied significantly between groups. Low-alkalinity lakes had higher TSI_{SD} and TSI_{Cha} scores of 5.7 ($\pm$4.2) and 5.2 ($\pm$4.2) trophic state units respectively. No significant difference existed in mean TSI_{Biovol} scores between the pooled large or well buffered and the low-alkalinity lakes.

As for the comparison of reference vs. test lakes, no statistically significant differences existed between the mean trophic state scores for any index. Moreover, no significant difference could be extracted even using the highly sensitive multivariate linear discriminant classification procedure. This is likely due to the relatively narrow trophic range existing across VT and NH. The range of trophic state scores is provided in Figure 2.

Trophic state criteria were calculated using the bi-section scoring method, whereby the best 75 percent of the reference range was accorded a score value of 5, and the remaining distance bisected with the resulting ranges being allocated score values of 3 and 1 respectively. Interquartile coefficients were calculated, and these were below or nearly below the critical value of 1 for the pooled large and well buffered lakes. Only TSI_{Cha} had an interquartile coefficient below a value of 1 in the low alkalinity lakes. Table 1 provides scoring ranges and interquartile coefficients for the trophic state criteria.

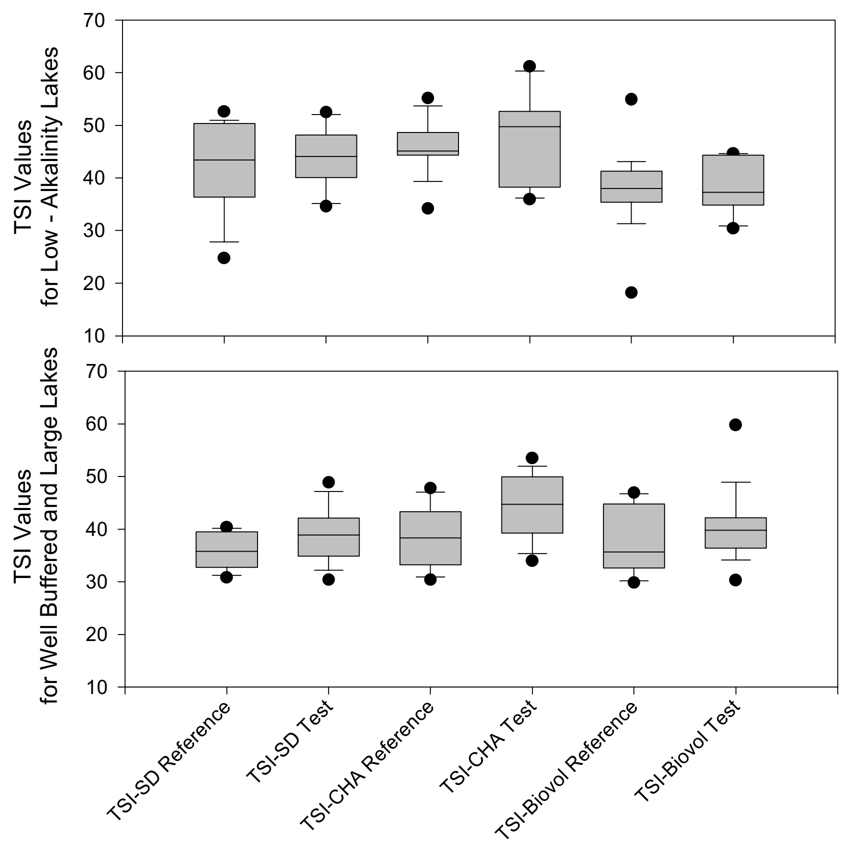

Figure 2. Box-plots of trophic state index values for pooled large and well buffered, and low-alkalinity lakes.

Table 1. Trophic state criteria and interquartile coefficients calculated from 22 reference and 18 test lakes from Vermont and New Hampshire.

Low Alkalinity Lakes				
	Score Attributed:			Interquartile Coefficient
Metric	1	3	5	
TSI_{SD}	-	>50.4	<=50.4	6.4
TSI_{Cha}	>54.9	48.7-54.9	<=48.6	0.3
TSI_{Biovol}	>48	41.1 - 48	<=41	1.6
Large or Well Buffered Lakes				
	1	3	5	
TSI_{SD}	>43	39.5-43	<=39.4	1.0
TSI_{Cha}	>48.9	44.3-48.9	<=44.2	1.1
TSI_{Biovol}	>50.3	41.0-50.3	<=40.9	0.4

An overall trophic state score for each lake was obtained by summing the individual trophic state index scores. Resulting trophic state criteria scores are shown in Figure 3. Since no *statistically* significant difference exists in any mean trophic state index score between reference and test lakes, caution must be exercised in the application of these trial criteria. The bisection scoring method a-priori rejects ¼ of the reference lakes as not actually meeting reference conditions. In areas where a wide trophic gradient exists in lakes, this method may be sound. However, the data presented here indicate that for Vermont and New Hampshire, the method easily results in the error of judging a test lake as not meeting reference conditions when in reality it does.

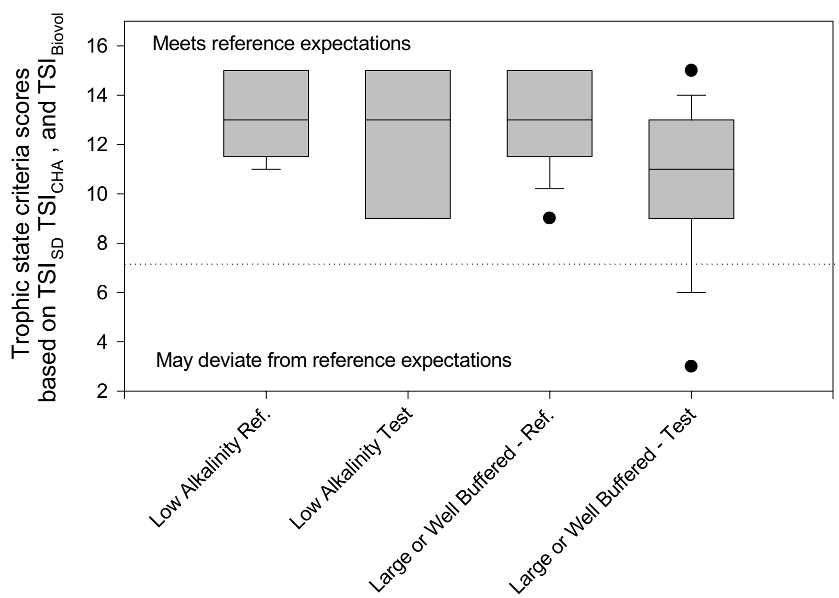

Figure 3. Box plot of trophic state criteria scores for 40 lakes.

Given the high likelihood of misjudging a lake's reference status, it is proposed that only those lakes which score 7 trophic state criteria points or less be identified as not meeting reference conditions. For any lake to receive a score of less than 7 points by this system, no individual TSI score can merit 5 points, and at least one score would have to be a one. In this analysis, nearly all lakes had overall score values which exceeded 7. Indeed, only Lake Carmi, Vermont, which had a score of 3, would be judged as not meeting reference conditions. This is consistent with the fact that Lake Carmi is listed on Vermont's 303(d) list for excessive phosphorus concentrations.

Finally, though these trophic state criteria are limited in their precision, they do have utility in underscoring the extent to which lakes are stressed by nutrients. A comparison of trophic state criteria scores with available total phosphorus data shows a distinct trend of reduced criteria score with increasing total phosphorus concentration (Figure 4). This relationship does perhaps indicate that strict nutrient criteria may better identify nutrient-stressed lakes.

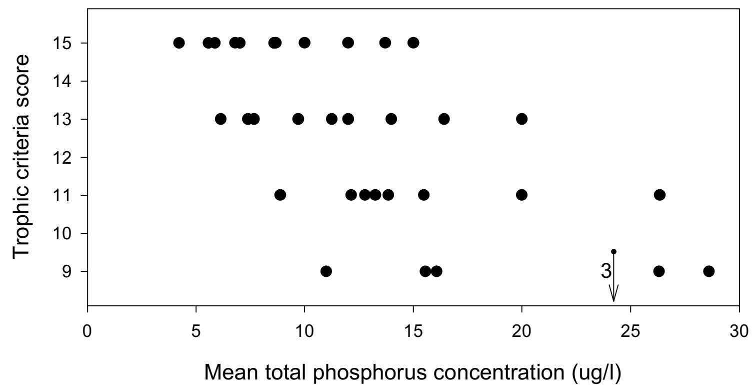

Figure 4. Relationship of mean total phosphorus concentration to trophic criteria score for 40 Vermont and New Hampshire lakes.

Macrophytes:
At present, analysis of macrophytes is proceeding. Canonical correspondence analysis of macrophyte metrics (Figure 5) identified a distinct separation between low alkalinity, and pooled well-buffered and large lakes, when lake ordination scores were calculated as weighted averages of their macrophyte species assemblages. As with the trophic state criteria, no statistically significant differences existed in mean metric values between the large and well-buffered lake groups, and accordingly, these two groups were pooled.

MANOVA analyses did identify a linear combination of several metrics as producing a significant difference in overall plant community between low alkalinity and large or well buffered lakes (Wilks' Λ = 0.464, F=5.1, p = 0.006). Individual follow-up univariate tests identified three of the metrics as differing significantly between classes. These were % emergent pronate spp. (t=-2.192, p=0.035), % submerged broad-leaved spp. (t=4.692, p=0.001), % submerged mat-like spp. (t=2.530, p=0.016).

A second MANOVA analysis failed to identify a linear combination of the variables which could

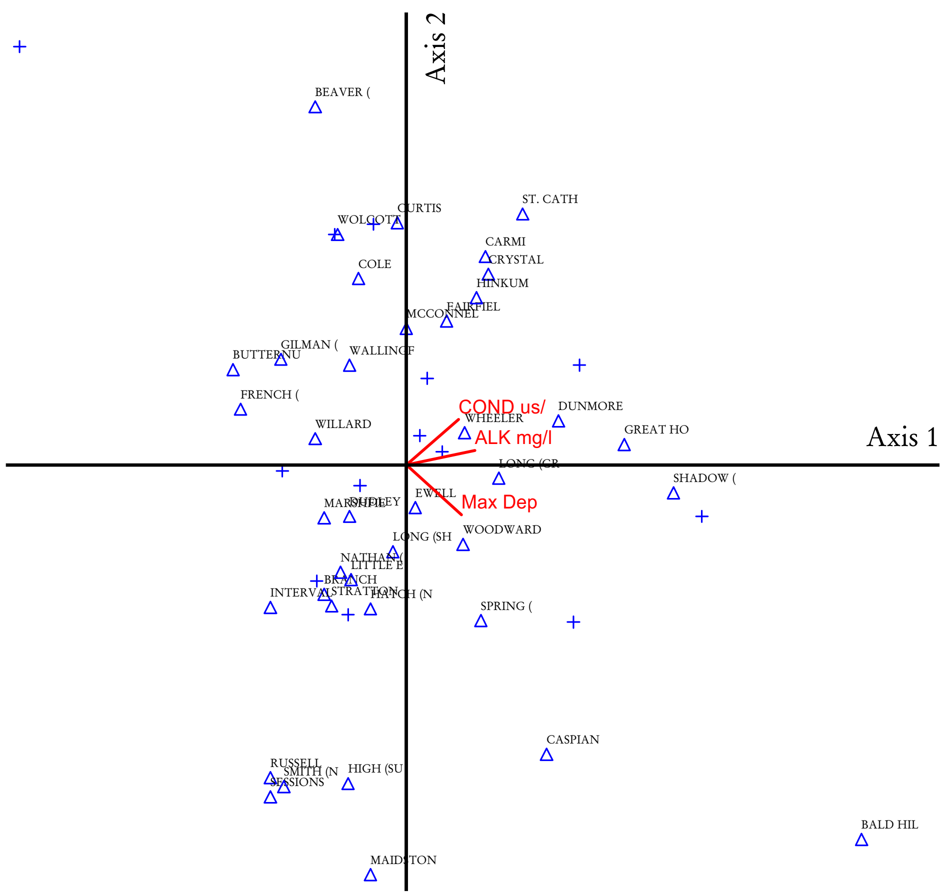

Figure 5. Canonical correspondence analysis of 13 macrophyte metrics (+) plotted in multivariate space with 39 lake scores (△) calculated as weighted averages of the metrics. Lakes falling right of the 2nd canonical axis are either large, or well buffered. Lakes which fall left of the 2nd axis are low-alkalinity. These first two ordination axes comprise 12.1% and 10.5 % of the total 27% variance explained in this analysis.

produce a significant difference between reference and test lakes (p = 0.14). Follow-up univariate t-tests nonetheless identified littoral cover/richness ($t = 2.033$, $p = 0.049$) and % emergent erect spp. ($t = 2.619$, $p = .013$) as having respectively lower and higher mean values in reference as opposed to test lakes. The statistical significance of these reported probabilities should be treated cautiously since MANOVA did not yield a p-value which was significant at the 95% or better level.

Subsequently, box plots of the distribution of all metrics were examined, and these are provided in Figure 6. Based on the results of the statistical analyses, and of the examination of the box-plots, several metrics have been identified to generate trial criteria. These are shown in Table 2.

Table 2. Suggested macrophyte metrics to be used to construct macrophyte criteria for Vermont and New Hampshire lakes.

Metric	Reason for retention
-Mean Littoral Cover/Richness	Statistically significant difference between reference and test lakes, has ecological significance
-Number Potamogeton spp.	Statistically non-significant between lake classes, but an ecologically significant difference between reference and test lakes in the large or well buffered lakes group is apparent in the box-plot
% Emergent Erect spp.	Statistically significant difference may exist between reference and test lakes, has littoral-zone ecological significance
% Emergent Pronate spp.	Statistically significant between low-alkalinity and large or well buffered lakes, may have ecological significance
% Submerged Broad-leaved spp.	Statistically significant between low-alkalinity and large or well buffered lakes, may have ecological significance
% Submerged Mat-Like	Statistically significant between low-alkalinity and large or well buffered lakes, may have ecological significance
% Submerged Whorled spp.	Statistically non-significant between the lake classes, but an ecologically significant difference between reference and test lakes in the large or well buffered lakes group is apparent in the box-plot
Number (or % composition) Non-native Nuisance Spp.	Not shown in Figure 5, but the ability of non-native nuisance macrophytes to displace native plants renders this a potentially useful metric.

Reporting:

No new reporting (beyond quarterly) is presently available. A comprehensive analysis and writeup of all project data is in progress.

Synopsis of Progress:

Activities undertaken in conjunction with the Bioassessment component of this bi-state initiative are behind schedule. The following is a list of Bioassessment component milestones (a ✓ indicates completion of task):

✓*Task 1)* *Review and reassess the lake classification and biological metrics employed by the 1995 104(b)3 lake bioassessment.*

✓*Task 2)* *Review and tailor methods presented in the draft Lake and Reservoir Bioassessment and Biocriteria Technical Guidance Document to be appropriate for Vermont and New Hampshire lakes.*

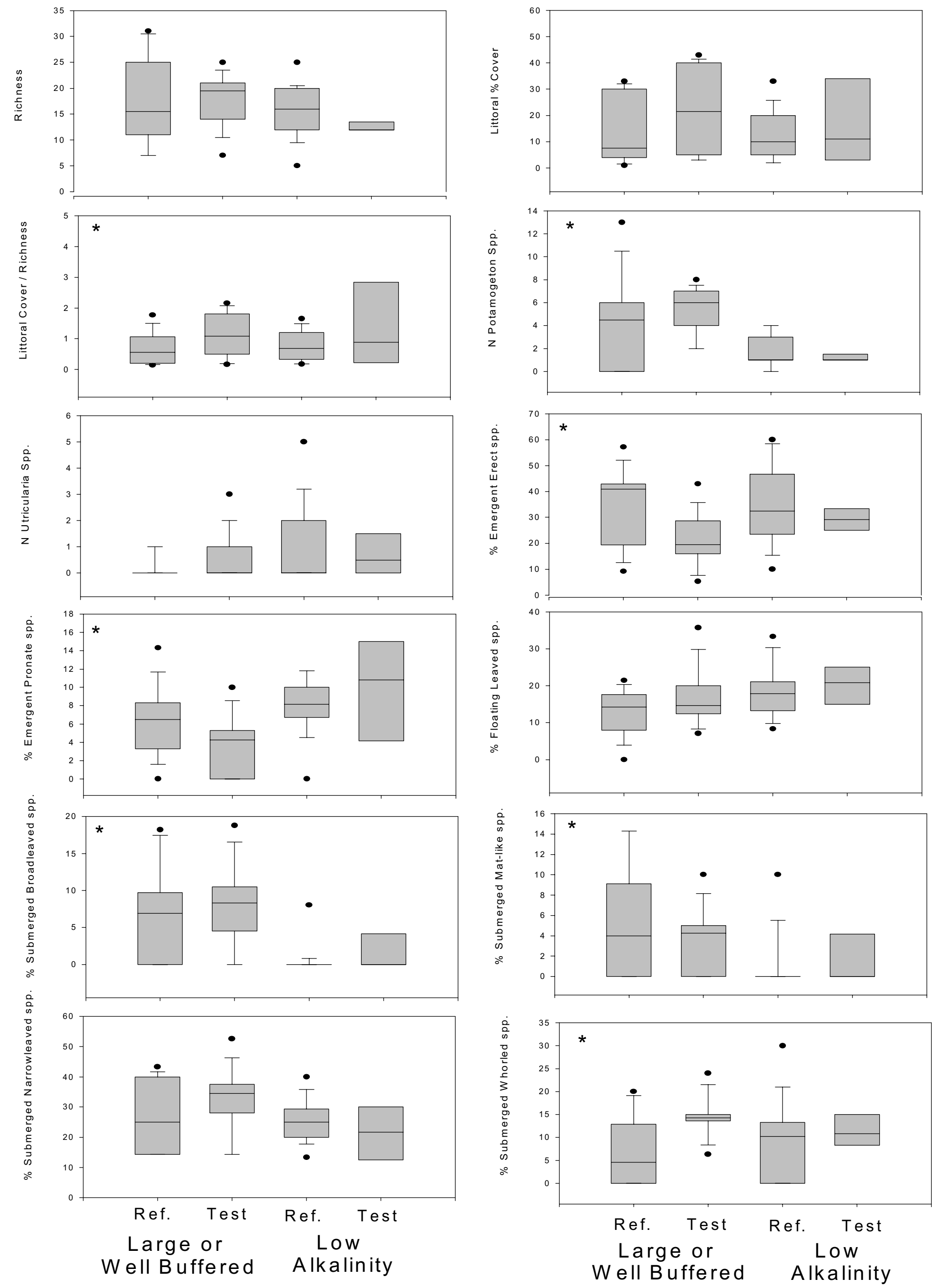

Figure 6. Box-plots of macrophyte community metrics for 39 Vermont and New Hampshire lakes. Metrics which have been identified as potentially useful to build macrophyte criteria are marked with an asterisk, and are described in Table 2.

✔*Milestone: Preparation of workplan detailing specific sampling methodologies and biometrics under evaluation. Completed workplan submitted to EPA Region 1 project contact (Peter Nolan). Expected date of completion 6/15/96. Completed 6/25/96*

✓Task 3) Conduct biological and chemical sampling on six lakes/State in 1996, an additional six lakes/State in 1997, and 10 Vermont lakes in 1998.

✔Milestone: Conduct field bioassessment operations. Expected date of completion for year 1, 10/01/96. Expected date of completion for year 2, 10/01/97. Expected date of completion for year 3, 10/01/98. Year 1 completed 10/3/96; Year 2 completed 10/17/97.

Task 4) Pick(✔), sort(✔) and identify benthic macroinvertebrates to lowest taxonomic level as determined under task 2 (above). Identify phytoplankton to lowest taxonomic level as determined under task 2 (above). Calculate biometrics for all biological data. Analyze physico-chemical data(✔) and calculate appropriate physico-chemical metrics(✔).

Milestones:
- *Macroinvertebrate taxonomy -1996 lakes, completed 10/1997* ✔
- *Macroinvertebrate taxonomy - 1997 lakes* ✔
- *1996 mid-project presentation, completed 3/1997* ✔
- *1997 mid-project presentation, completed 3/1998*✔
- *Trial criteria development, 1996-1997 lakes, completed 3/1998* ✔
- *Redraft phytoplankton criteria, completed 10/1999* ✔
- *Redraft of macrophyte criteria (partially complete)*
- *Redraft of trophic criteria* ✔
- *Draft trial macroinvertebrate criteria* □

Task 5) Prepare a Bioassessment Component comprehensive final report.