

Development of phosphorus criteria to protect biological and aesthetic uses in Vermont lakes and wadeable streams

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Introduction:

- Work being conducted in response to the National Nutrient Criteria Initiative
- Vermont WQS contain numeric nutrient standards for Lakes Champlain and Memphremagog, and for Class A(1) streams
 - Criteria include total phosphorus and nitrate-N.
 - Narrative WQS in place for other waters
- Research question: Are there nutrient concentrations beyond which documentable effects would cause violations of WQS?
- Practical question: Are nutrient criteria amenable to VT Water Quality Standards Framework?

VT WQS Criteria:

Class	Aesthetic value	Biological quality
A(1) Ecological	Natural condition	Natural condition
A(2) Water supply	Consistently excellent	Moderate change from reference
B(1)		Minor change from reference
B(2)	Consistently very good	Moderate change from reference
B(3)	Consistently good	
B(other)	Good, variability allowed	No undue adverse effect

Data Sources:

- Lakes: long-term monitoring datasets for TP, Chl-a, Secchi, TN
- Lakes: shorter-term datasets describing biological attainment and user survey responses
- Streams: long-term monitoring datasets for biological attainment
- Streams: shorter-term datasets for TP, TN, numeric aesthetic quality ratings

Analytical Approach:

- For lakes, use 75th percentile of reference sites, by ecoregion, to define "Natural"
- Identify aesthetic endpoints corresponding to "Excellent," "Very Good," etc.
- Identify biological endpoints corresponding to "Natural," "Minor," and "Moderate"
- Determine if nutrient concentrations relate to those endpoints
- To interpret the term "Consistently," identify an acceptable proportion of sites to be maintained by class-specific criteria thresholds
- Identify nutrient concentrations that protect the acceptable proportion of sites.

Analysis - Lakes

Biota

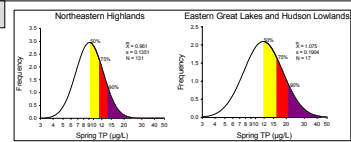


Figure 1. Spring total P by ecoregion for reference lakes

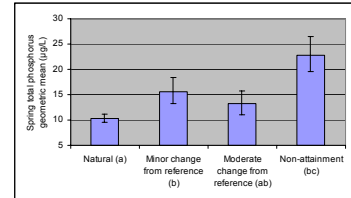


Figure 2. ANOVA: natural-log spring phosphorus concentrations by biological attainment category assessed using the Vermont Lake Condition Index for phytoplankton.

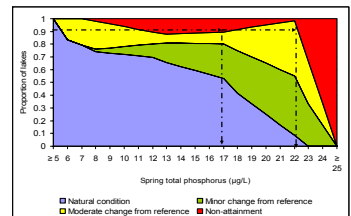
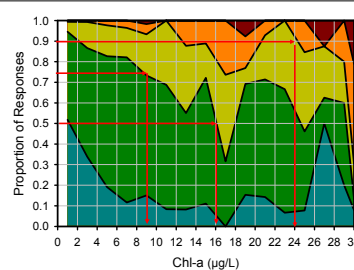


Figure 3. Proportion of lakes attaining biological assessment categories based on Vermont Lake Condition Index scores for phytoplankton, in relation to spring total phosphorus.

Aesthetics



User Survey Response Choices:
 ■ "Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels"
 ■ "Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels"
 ■ "Swimming and aesthetic enjoyment slightly impaired because of algae levels"
 ■ "Very minor aesthetic problems; excellent for swimming, boating, enjoyment"
 ■ "Beautiful, could not be any nicer"

Figure 4. Responses to the Vermont inland lake user survey as a function of the Chl-a concentration measured at the time response was provided.

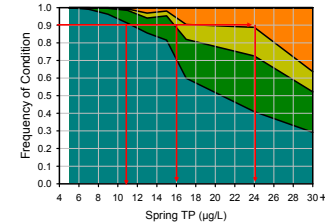


Figure 5. Temporal frequencies of "excellent," "very good," and "good" aesthetic and recreational conditions as a function of spring TP concentration in lakes.

Analysis - Streams

Biota

For stream biota, we derived a benthic index of trophic condition. Trophic index scores were related to TP concentrations, within three described stream assessment types. Nutrient thresholds to protect stream communities within attainment classes were identified as TEC's, MEC's, and PEC's.

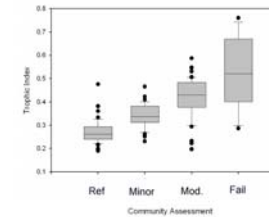


Figure 6. VT Trophic BioIndex values in relation to attainment status for wadeable streams

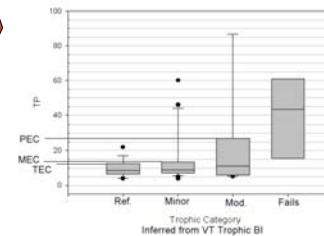


Figure 7. Identification of TEC, MEC, and PEC values of total phosphorus

Aesthetics

This approach was taken using ratings for trophic appearance, aesthetic appearance, and microalgal filament length. Only trophic rating is shown.

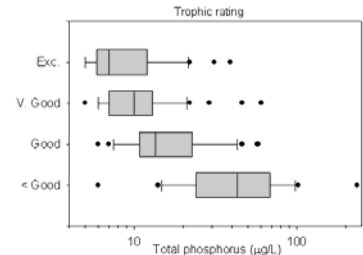


Figure 8. Total phosphorus by trophic rating, for wadeable Vermont streams. Whisker caps are 5th / 95th percentiles, and points show outlier data.

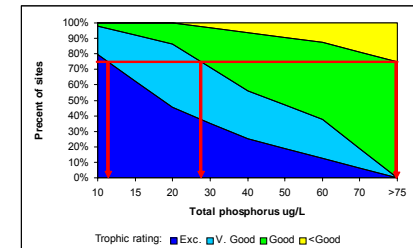


Figure 9. Proportion of sites attaining trophic rating categories based on total phosphorus.

Example criteria recommendations for phosphorus

Class	Lakes - ppb			Streams - ppb		
	Aesthetics	AQL	Functional value	Aesthetics	AQL	Functional value
A(1)	11 ¹ 16 ²		11 ¹ 16 ²	10	10 (TEC)	10
B(1)	11 ³	17	11	10	15 (MEC)	10
B(2)	16		16	26		26
B(3)	30	17	17	62	30 (PEC)	30
B(untyped)	24	22	22			