US EPA ARCHIVE DOCUMENT

The use of Conditional Probability Analysis to Derive Nutrient Criteria for Vermont's Lakes and Wadeable Streams

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VT's experience using Conditional Probability

- Water quality standards for nutrients in VT
- Prior approaches to derive criteria
- A common approach using conditional probability
- Verifying the CPROB assessment
- Using different approaches when CPROB does not work well

Why is this so hard?

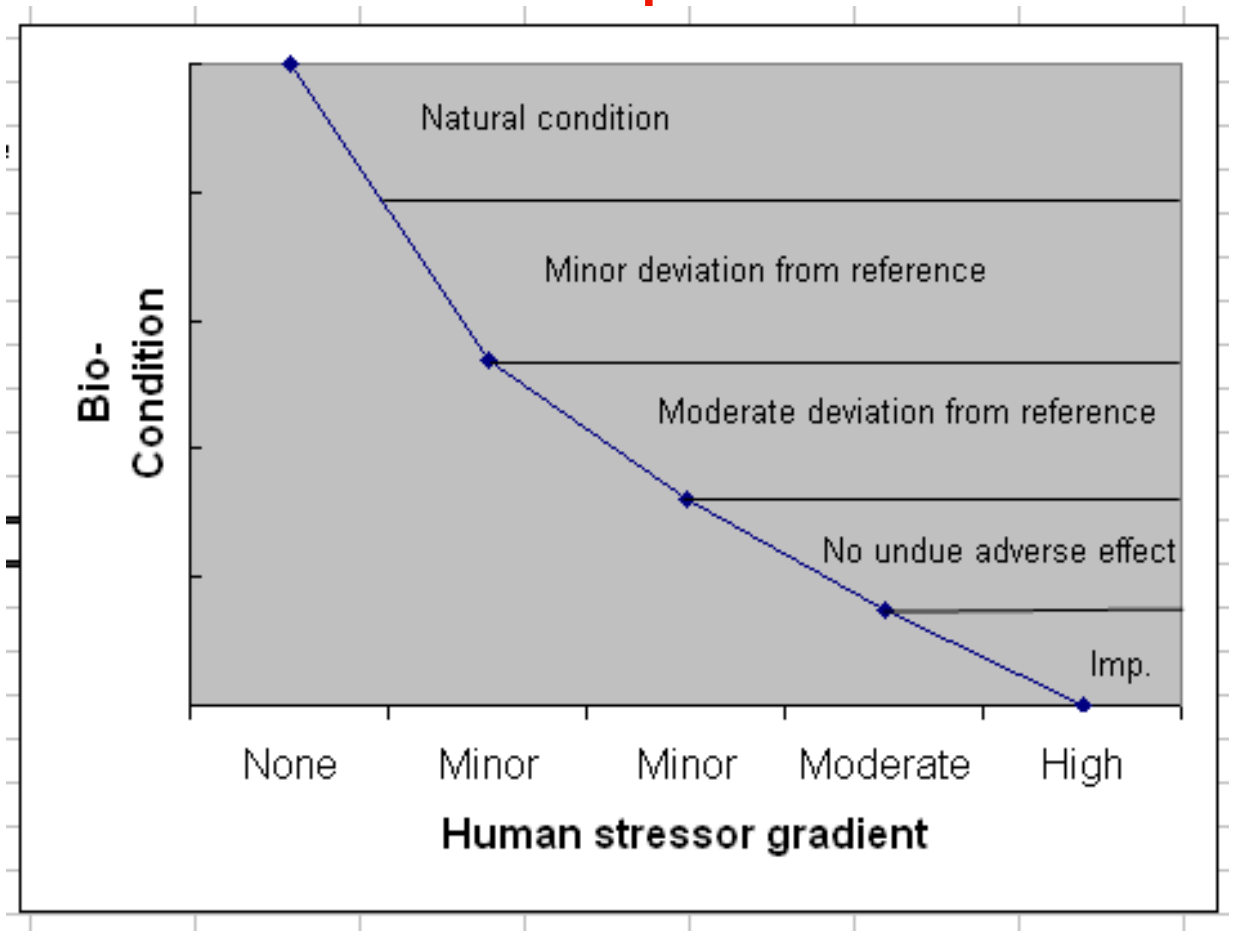
- Response to nutrient enrichment is incremental, without sharp thresholds.
- Biological response to nutrient enrichment is non-linear
- Response to nutrient enrichment is variable among different waterbodies.

VT Water Quality Standards

- Incorporate tiered aquatic life use goals
- Also incorporate tiered aesthetic goals
- Tiers are expressed in narrative
- Challenge is to interpret narratives quantitatively

Vermont Water Quality Standards

Aquatic life use



A(1)

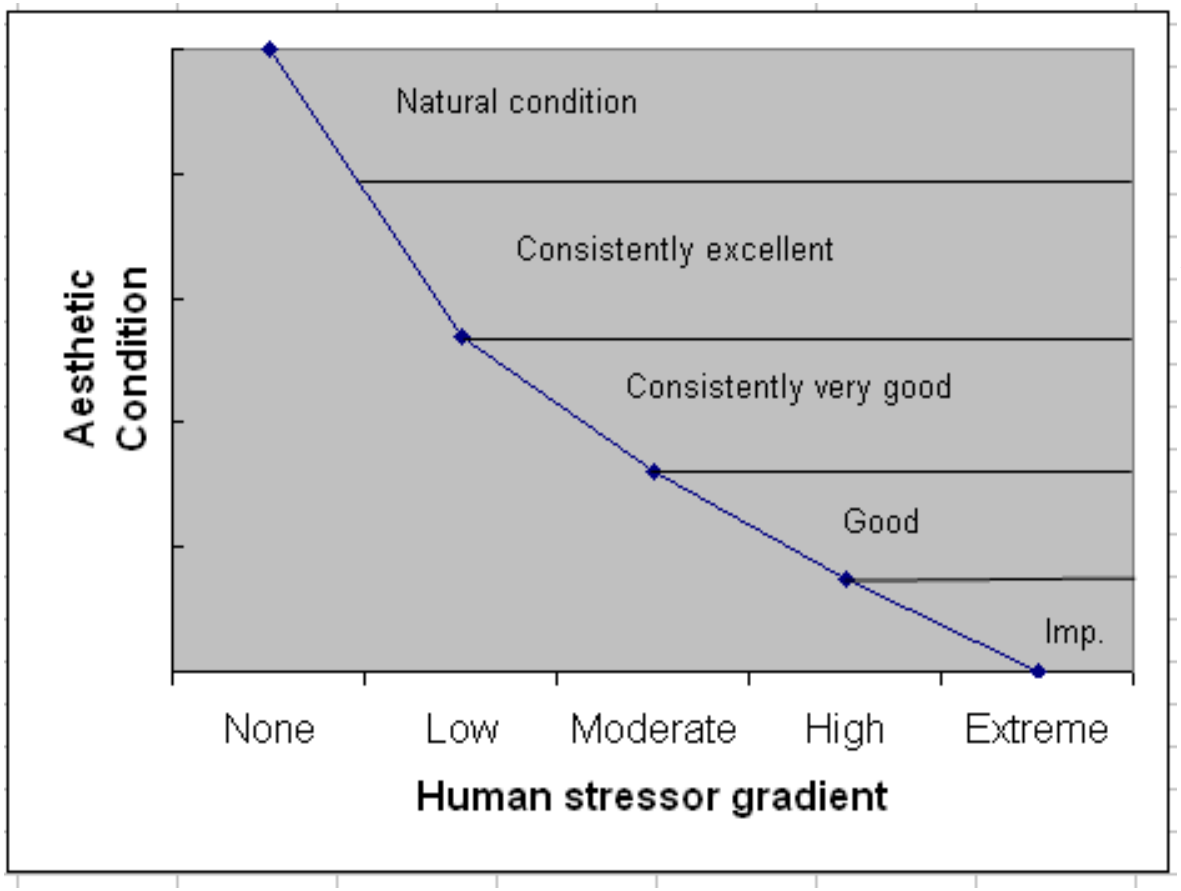
B(1)

A(2),B(2), B(3)

B

Vermont Water Quality Standards

Aesthetics



A(1)

A(2), B(1)

B(2)

B(3), B

Scope of nutrient criteria analysis

- Other uses exist
- Aesthetics and aquatic life are most sensitive to nutrients

	Aesthetics	Aquatic Biota
Lakes	Smeltzer	Kamman
Wadeable Streams	Kamman	Burnham/Fiske

Generic process applied to most analyses

- Define “natural” condition for A(1) waters
- Use conditional probability plots to find possible change-points implying B(1) to B(3) conditions.
- Examine original data to verify or adjust change-points.
- Verify high probability of use attainment.
- Apply knowledge of Vermont lakes and professional judgment.

Lakes

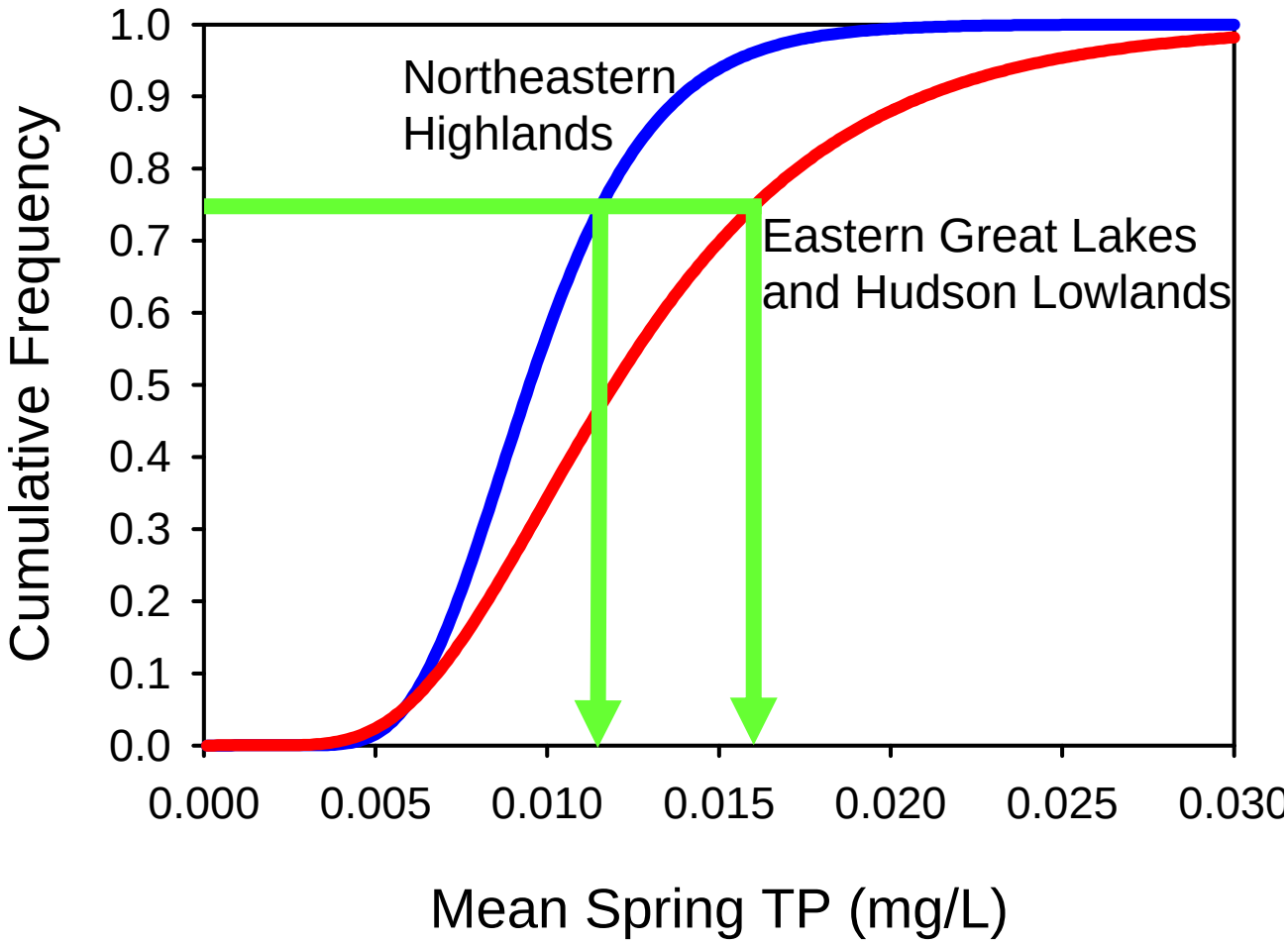
Lake Data Sources and Nutrient Criteria Variables

- Spring Phosphorus Program (TP, TN)
- Lay Monitoring Program (Summer TP, Chl, Secchi, User Survey)
- Vermont Lake Condition Biological Index (VLCBI)
- Vermont Lake Inventory Database (physical factors, land use, ecoregion)

Defining “natural condition”

New England Ecoregions

Spring TP distributions for lakes with minimally developed watersheds



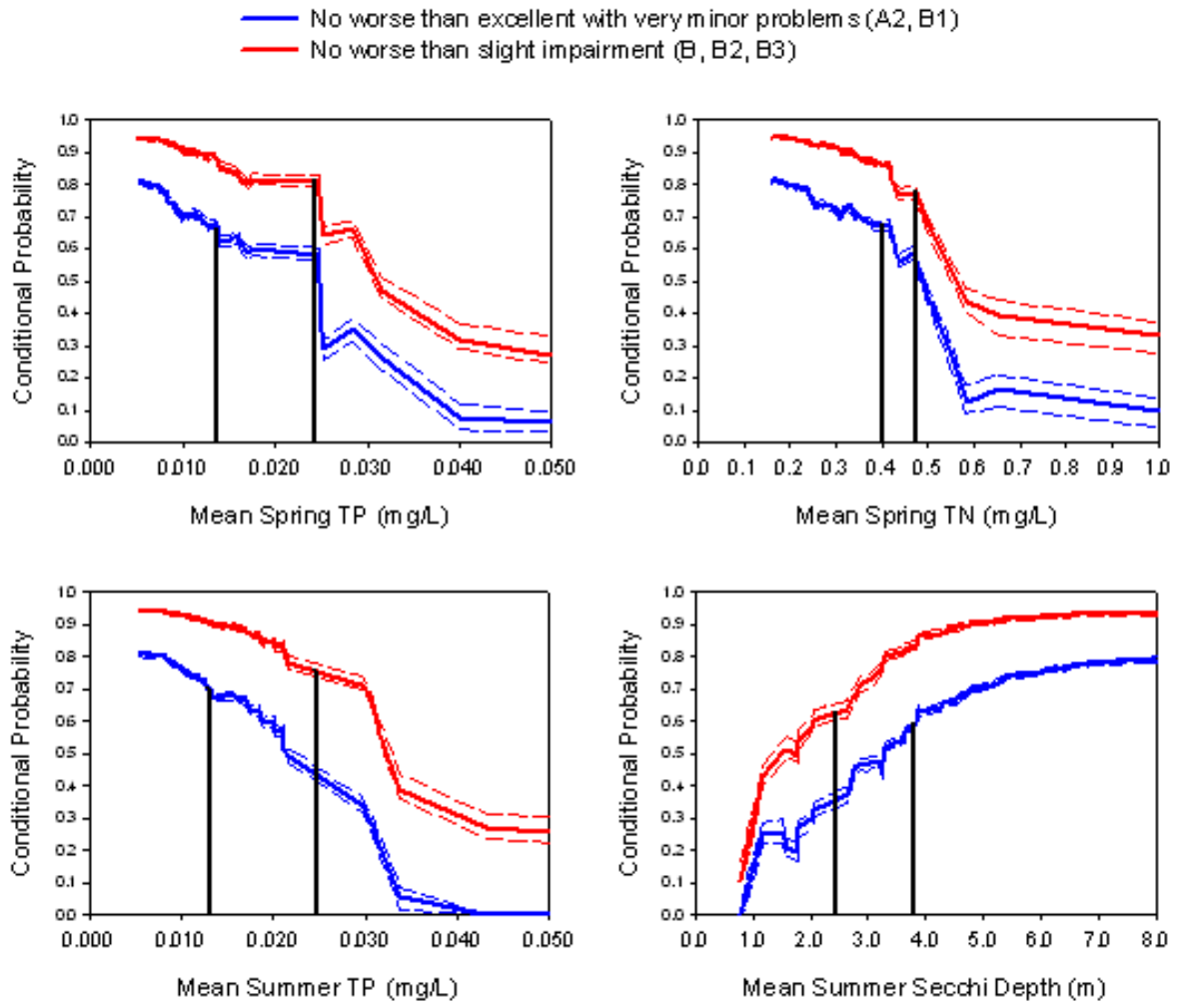
Lakes

Aesthetics

Vermont Lake User Survey

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.

Conditional Probability Analysis



Note: n>5,000 obs.

Lake Aesthetics Criteria Summary

	A(1) Natural Condition	A(2), B(1) No worse than excellent	B, B(2), B(3) No worse than good or very good
Spring TP (mg/L)	0.012[a] 0.016[b]	0.014	0.024
Spring TN (mg/L)	0.36	0.40	0.48
Summer TP (mg/L)	0.014	0.014	0.024
Summer Chl (mg/L)	3.8	3.8	2.4
Summer Secchi (m)	0.005	0.009	0.016

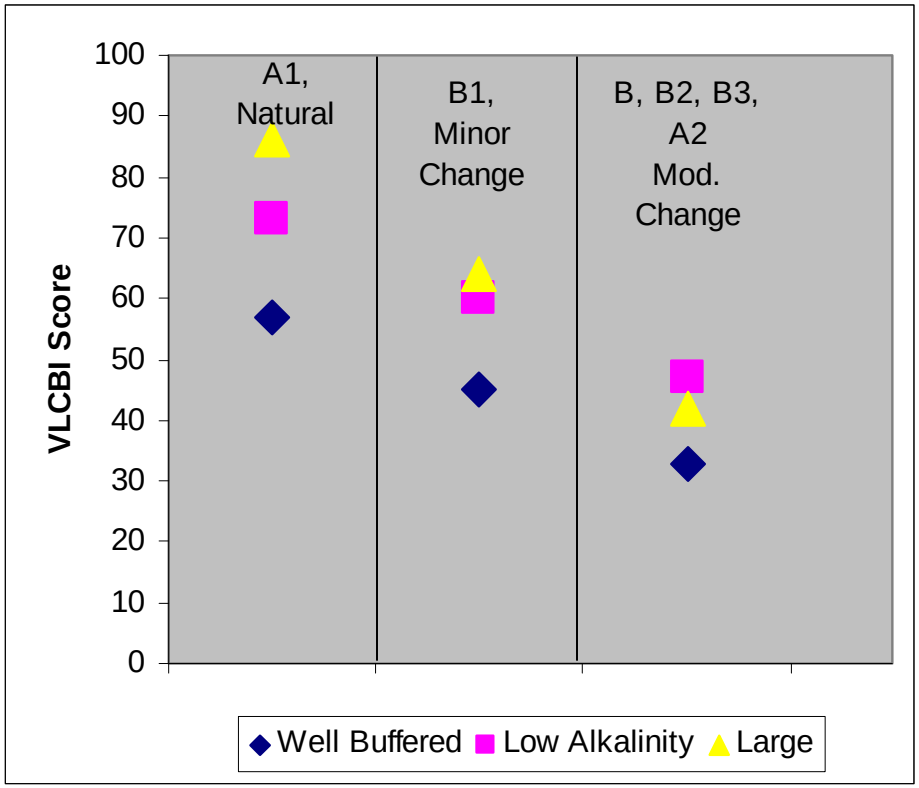
[a] Northeastern Highlands; [b] Eastern Great Lakes and Hudson Lowlands

Lakes

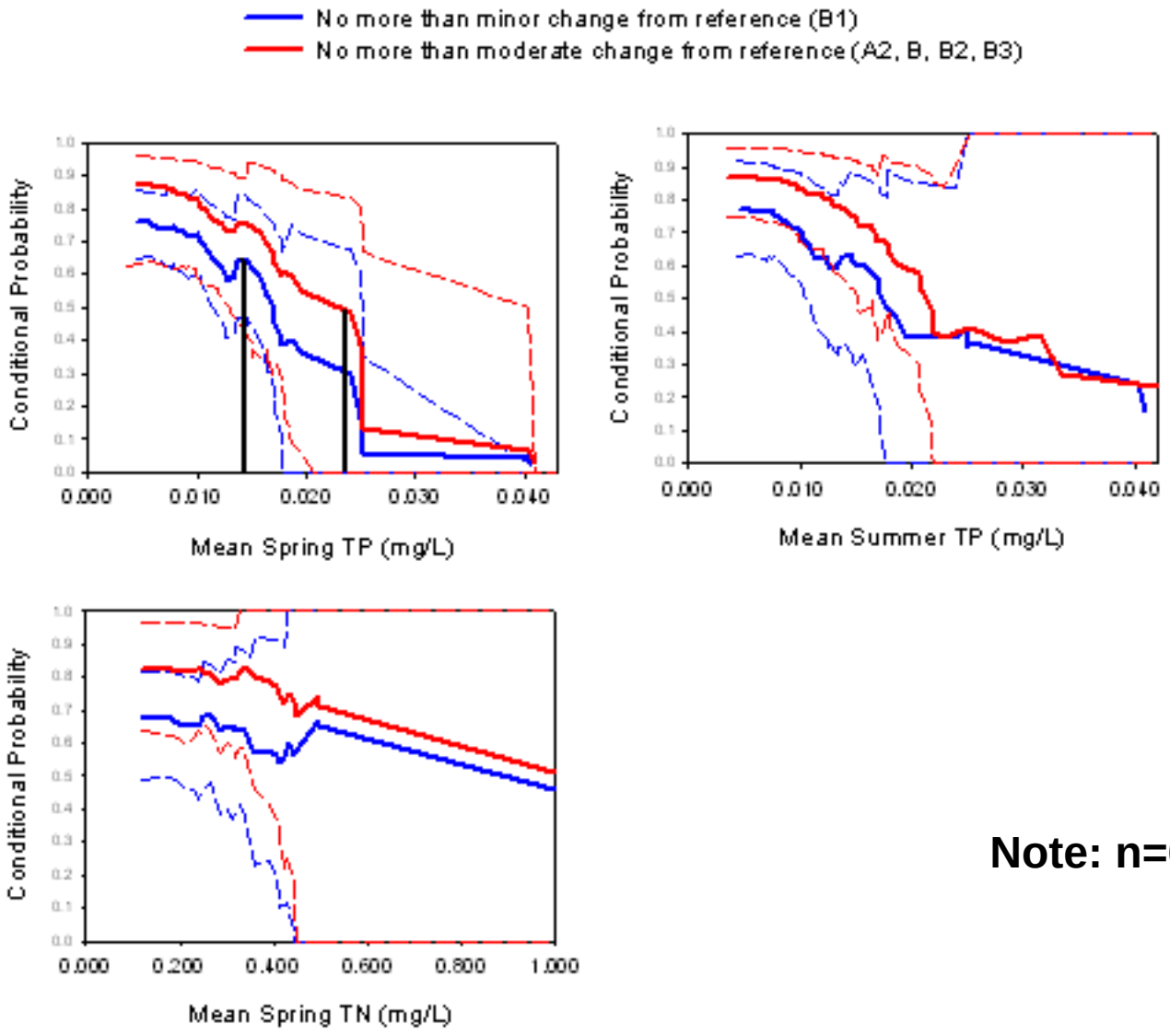
Aquatic Life

Vermont Lake Condition BioIndex

1. Index designed to identify the degree to which biological community deviates from reference.
2. Derived from > 48 VT lakes, phytoplankton and macroinvertebrates
3. Used the VLCBI for phytoplankton.



Conditional Probability Analysis



Note: n=60 obs.

Lake Aquatic Life Criteria Summary

	A(1) Natural Condition	B(1) No more than minor change	A(2), B, B(2), B(3) No more than moderate change
Spring TP (mg/L)	0.012[a] 0.016[b]	0.014	0.024
Spring TN (mg/L)	0.36	--	--
Summer TP (mg/L)	0.014	--	--

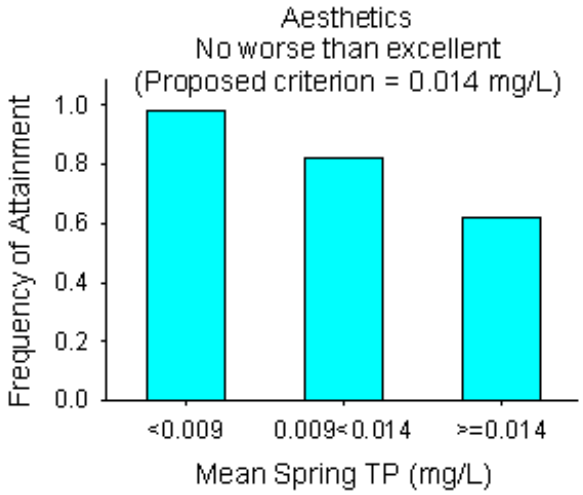
[a]Northeastern Highlands; [b]Eastern Great Lakes and Hudson Lowlands

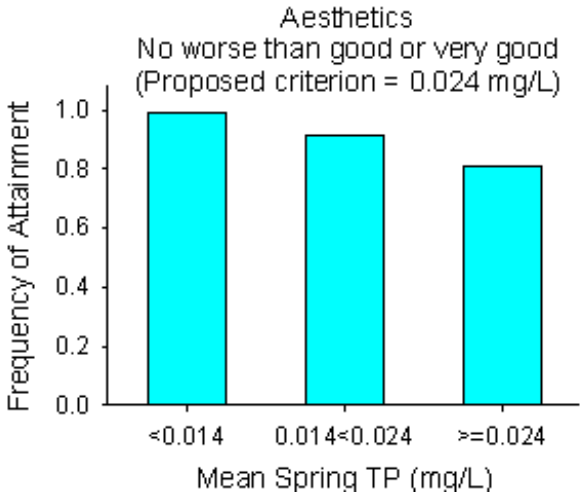
Proposed Effective Criteria for Lakes

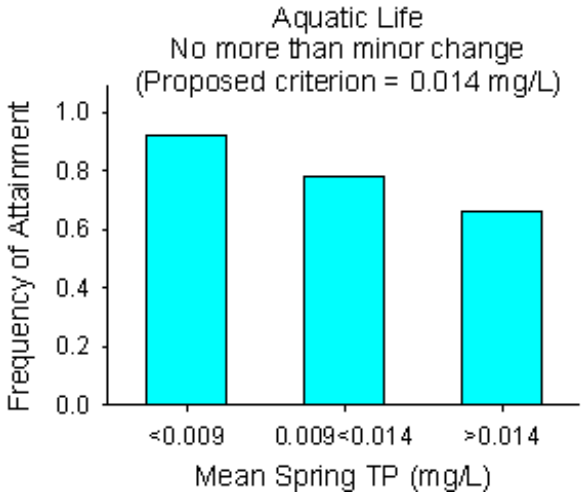
	A(1)	A(2)	B	B(1)	B(2)	B(3)
Spring TP (mg/L)	0.012[a] 0.016[b]	0.014[a] 0.016[b]	0.024	0.014[a] 0.016[b]	0.024	0.024
Spring TN (mg/L)	0.36	0.40	0.48	0.40	0.48	0.48
Summer TP (mg/L)	0.014	0.014	0.024	0.014	0.024	0.024
Summer Chl (mg/L)	3.8	3.8	2.4	3.8	2.4	2.4
Summer Secchi (m)	0.005	0.009	0.016	0.009	0.016	0.016

[a]Northeastern Highlands; [b]Eastern Great Lakes and Hudson Lowlands

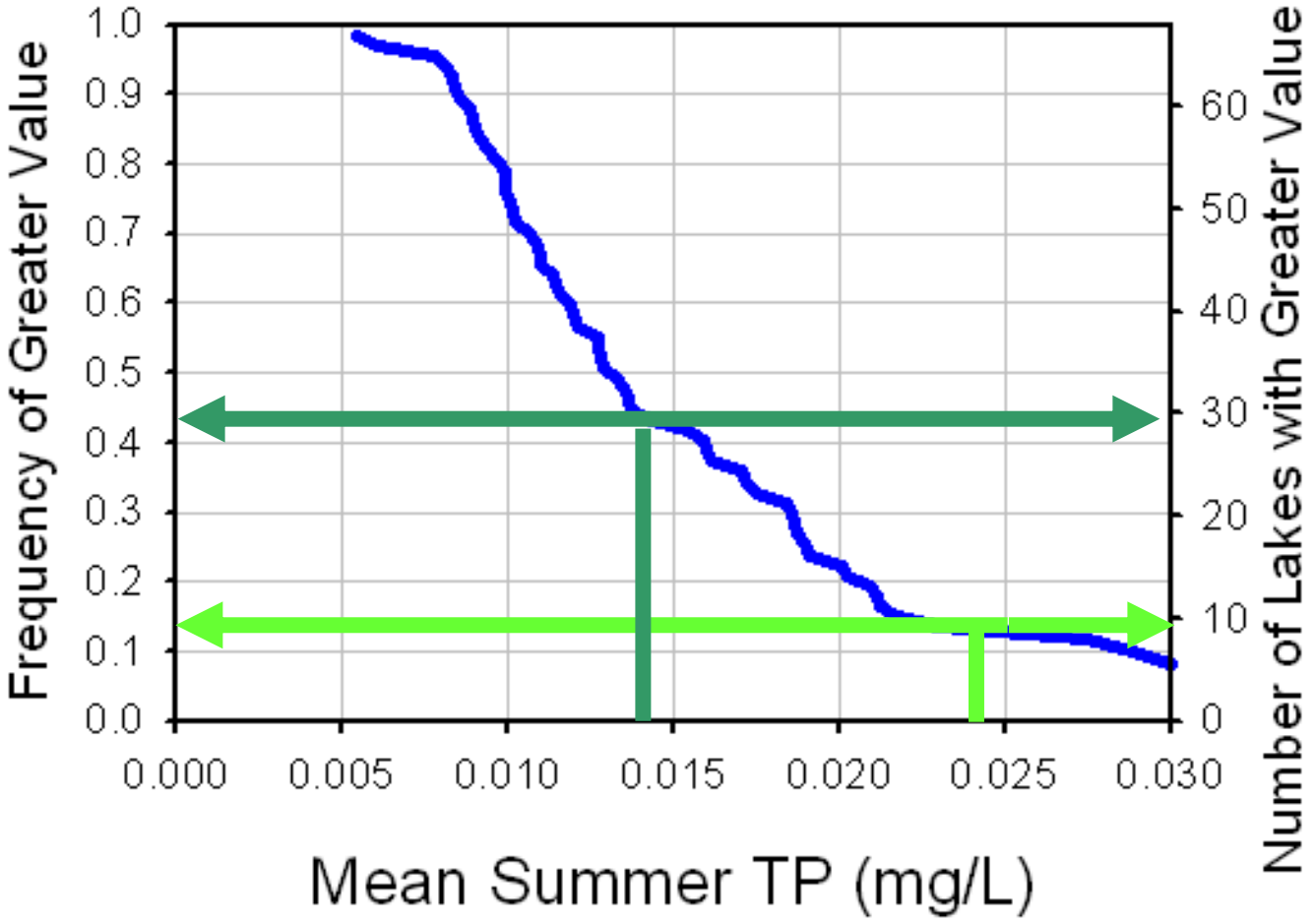
Verifying probability of attainment







Lake Management Implications example using summer TP



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Streams

Stream Data Sources and Nutrient Criteria Variables

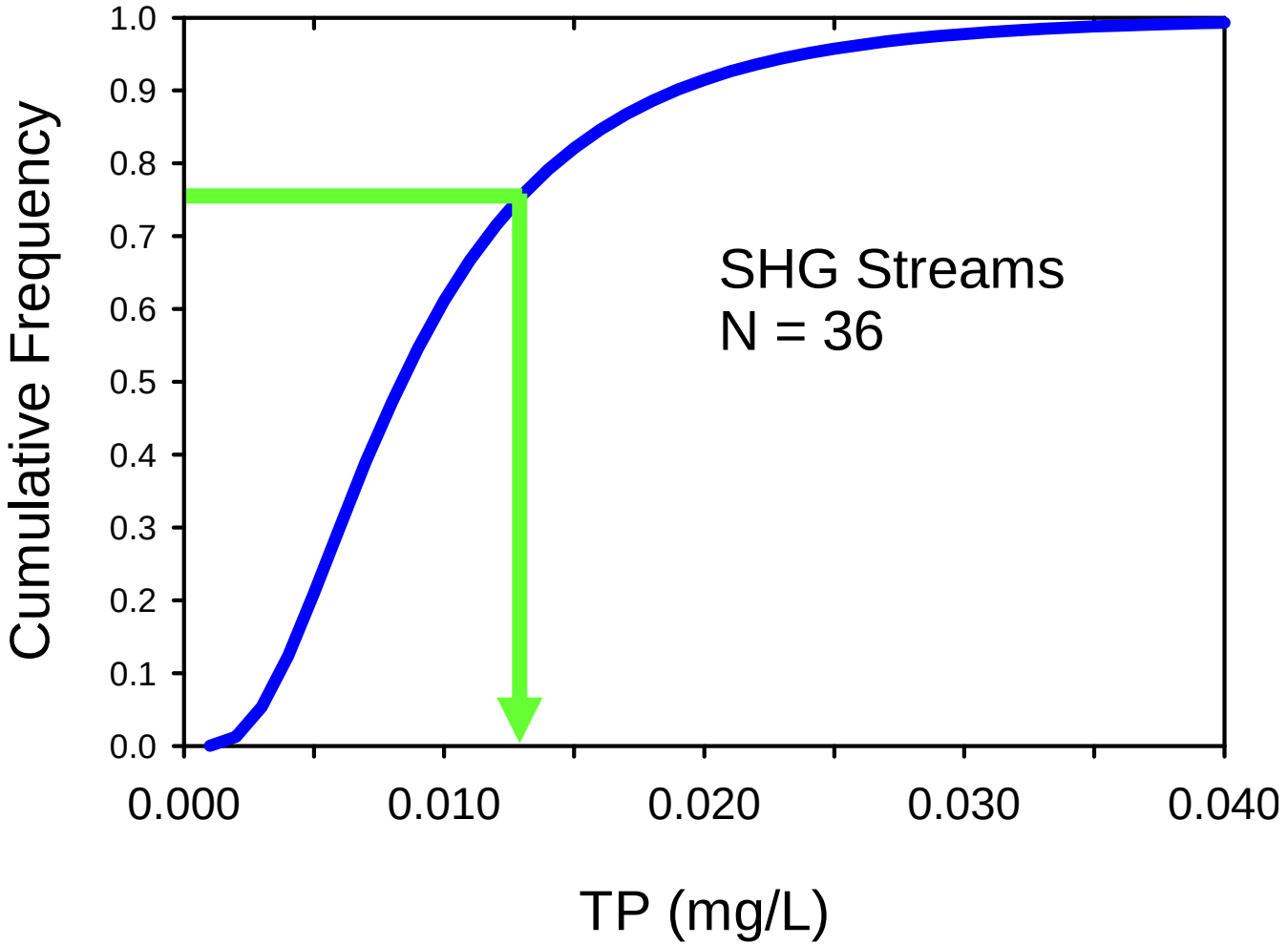
- Ambient Biomonitoring Program
- Vermont Nutrient Criteria Project
- Macroinvertebrate Trophic Index (MTI)
- Low-flow TP, TN
- Micro-algal cover
- Trophic ratings

Defining “natural condition”

Three stream types:

- Small, high-gradient (SHG)
- Medium, high-gradient (MHG)
- Warm-water, medium-gradient (WWMG)

Frequency distributions for reference streams



Streams

Aesthetics

Stream aesthetic observations and measurements

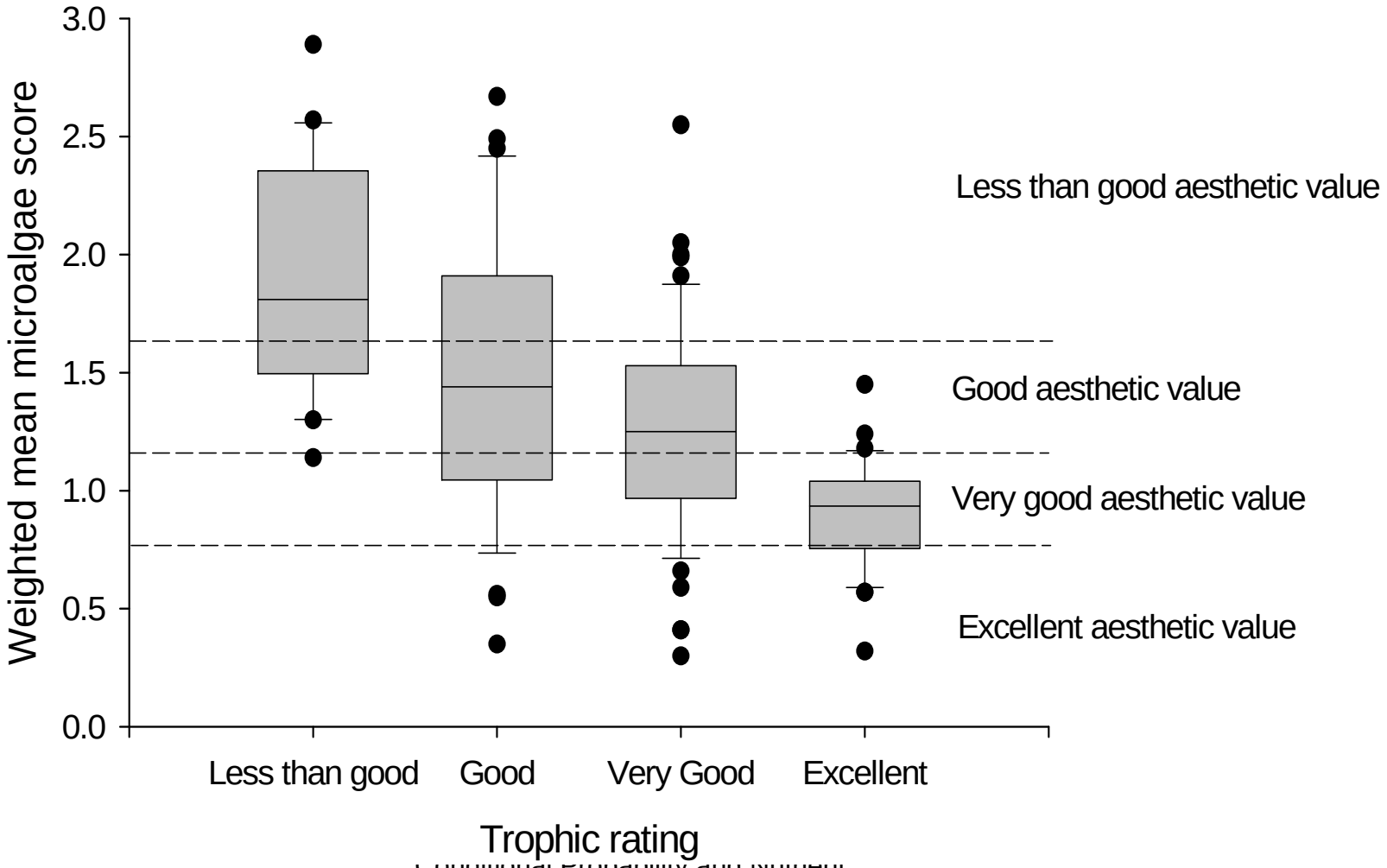
Trophic observation

- Recorded in field by crews after sampling complete
- Scaled trophic appearance from 5 (yuk) to 1 (very clear)

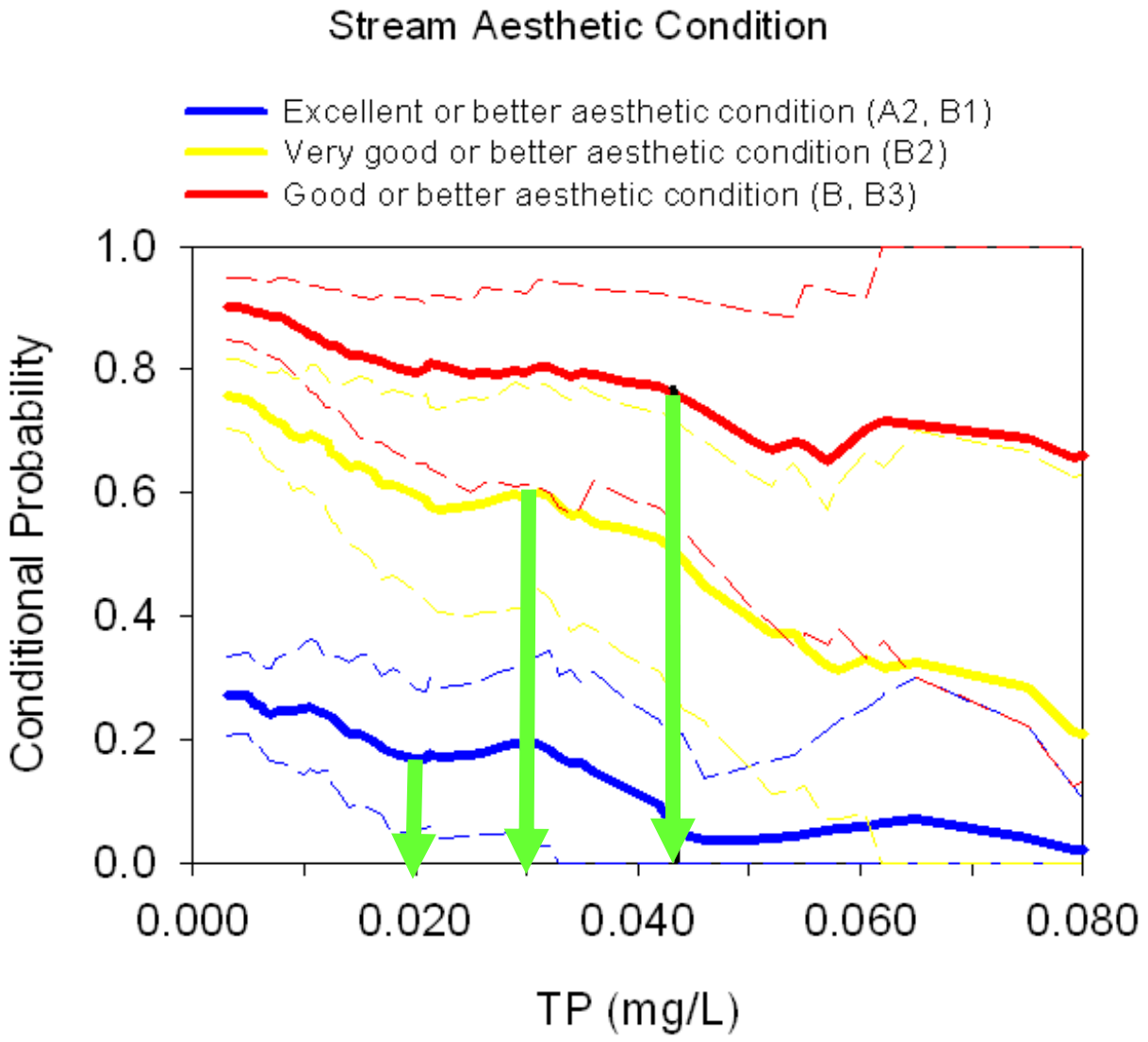
Microalgae measurement

- Assessed using 100 samples of microalgae thickness
- Weighted average value calculated to emphasize importance of “scuzzy rocks.”

Stream aesthetics – measuring vs. observing



Conditional Probability Analysis



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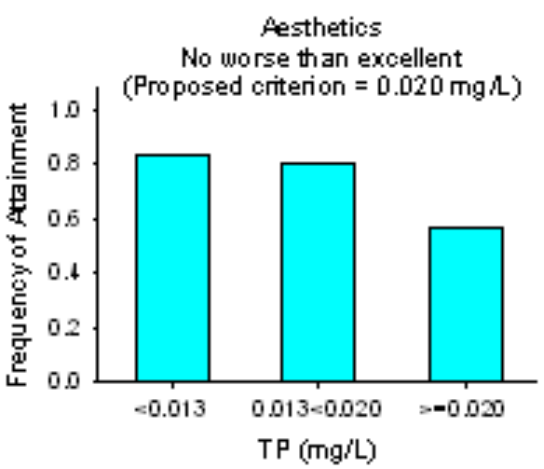
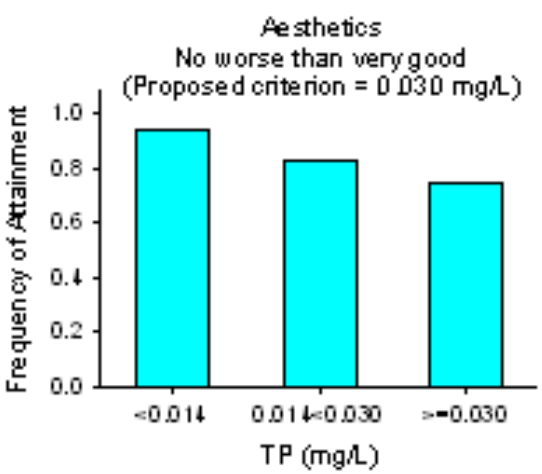
Proposed Aesthetics Criteria for Streams

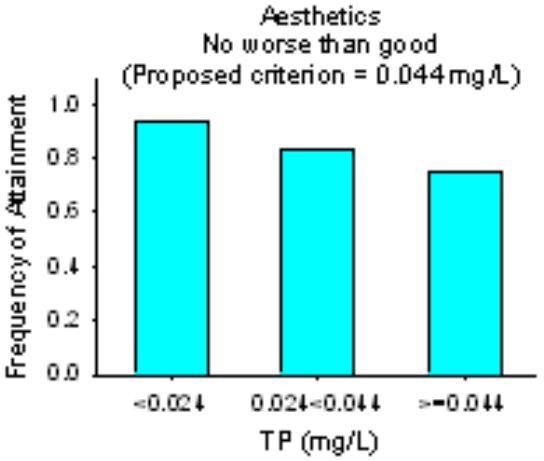
	A(1) Nat.	A(2) Exc.	B Good	B(1) Exc.	B(2) V. Good	B(3) Good
TP	0.010 0.020*	0.020	0.044	0.020	0.030	0.044
TN	0.30	--	--	--	0.50	--

*) WWMG Streams

Probability of Attainment example using low-flow TP







Streams

Aquatic Life

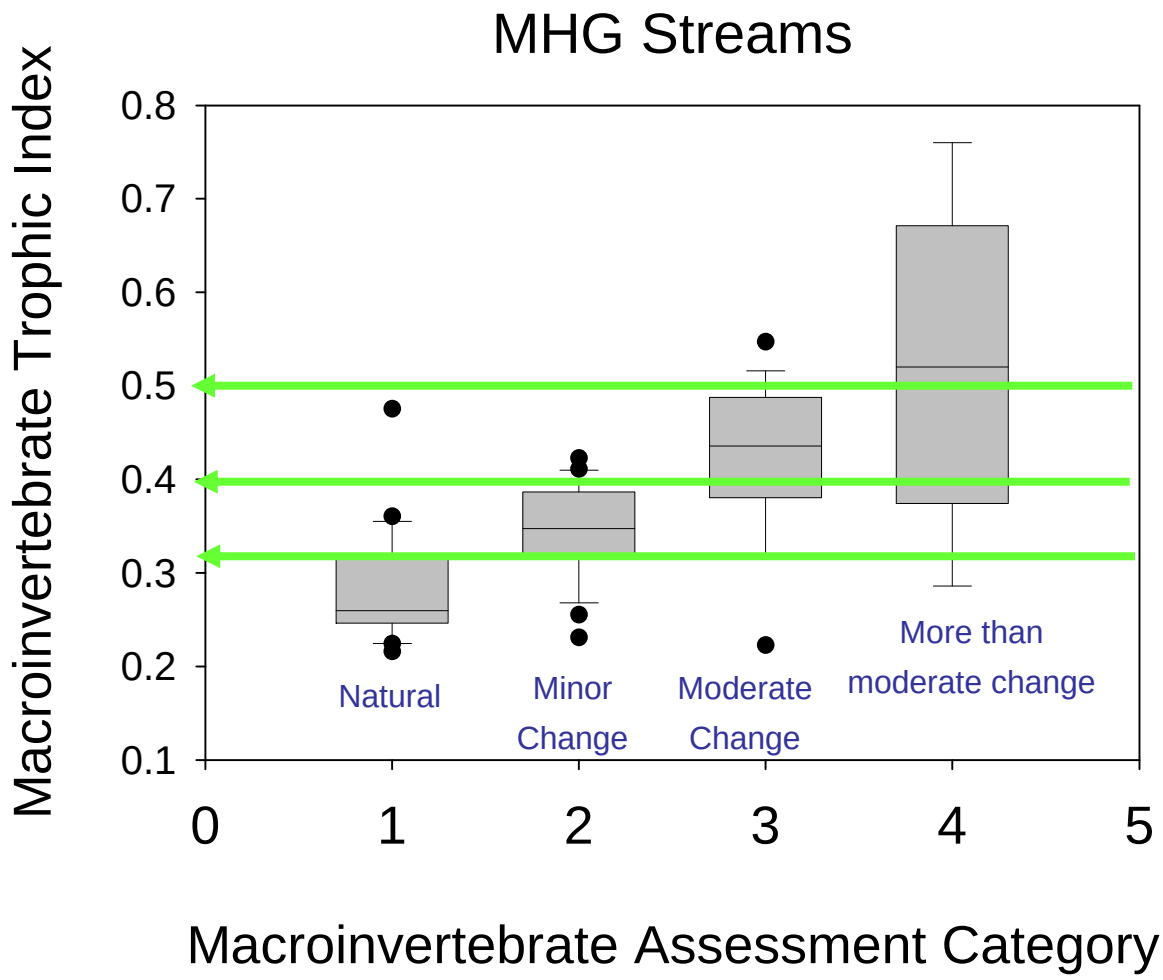
Deriving Criteria for Aquatic Life Uses

Multi-Analysis Approach

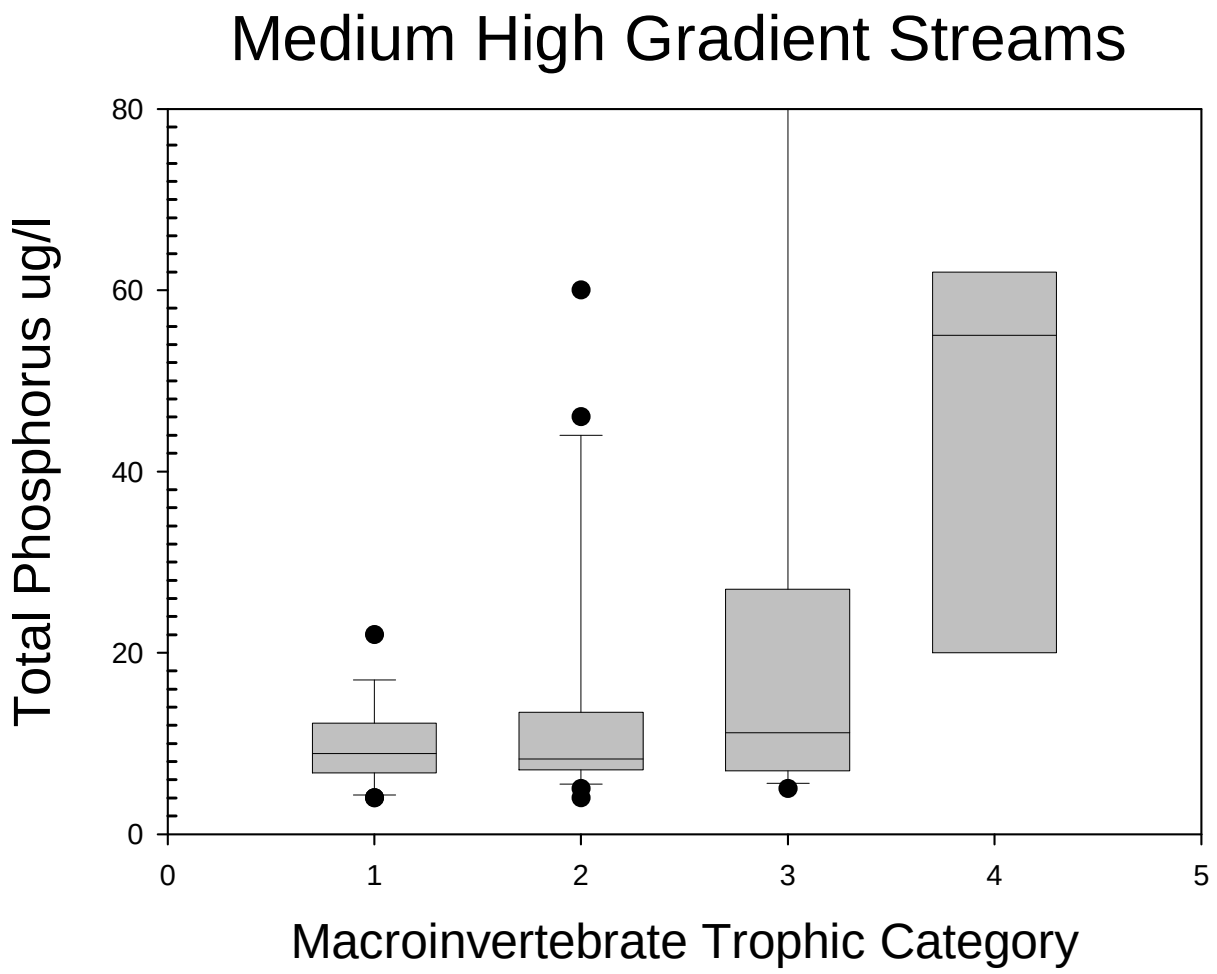
- TP/TN reference frequency distribution;
- Calculate a macroinvert. trophic index (MTI)
- Conditional Probability-MTI Attainment;
- TN/TP Distribution by MTI Category;
- TN/TP vs MTI Regression Intercepts;

Results used with BPJ to derive weight of evidence values

Macroinvertebrate Index Categorization

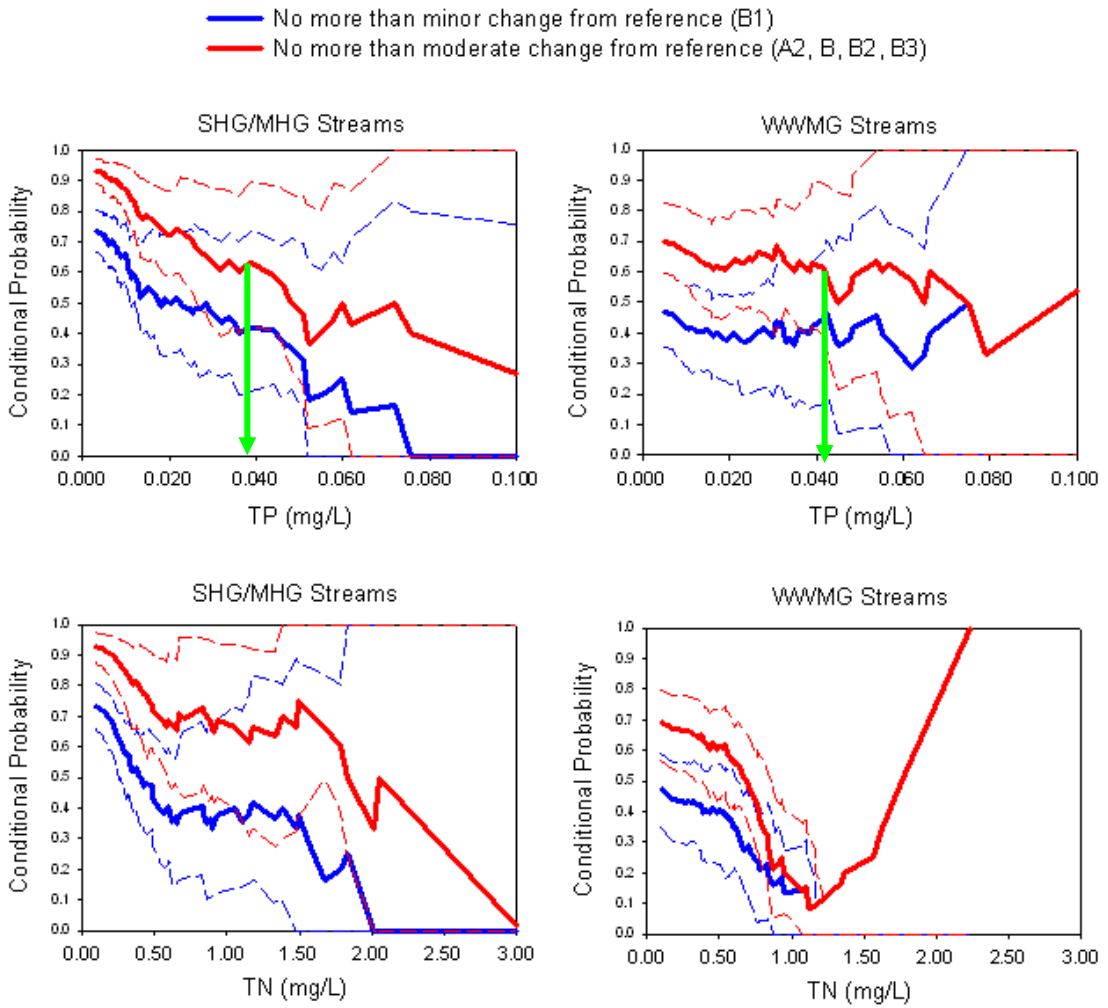


Distribution evaluation

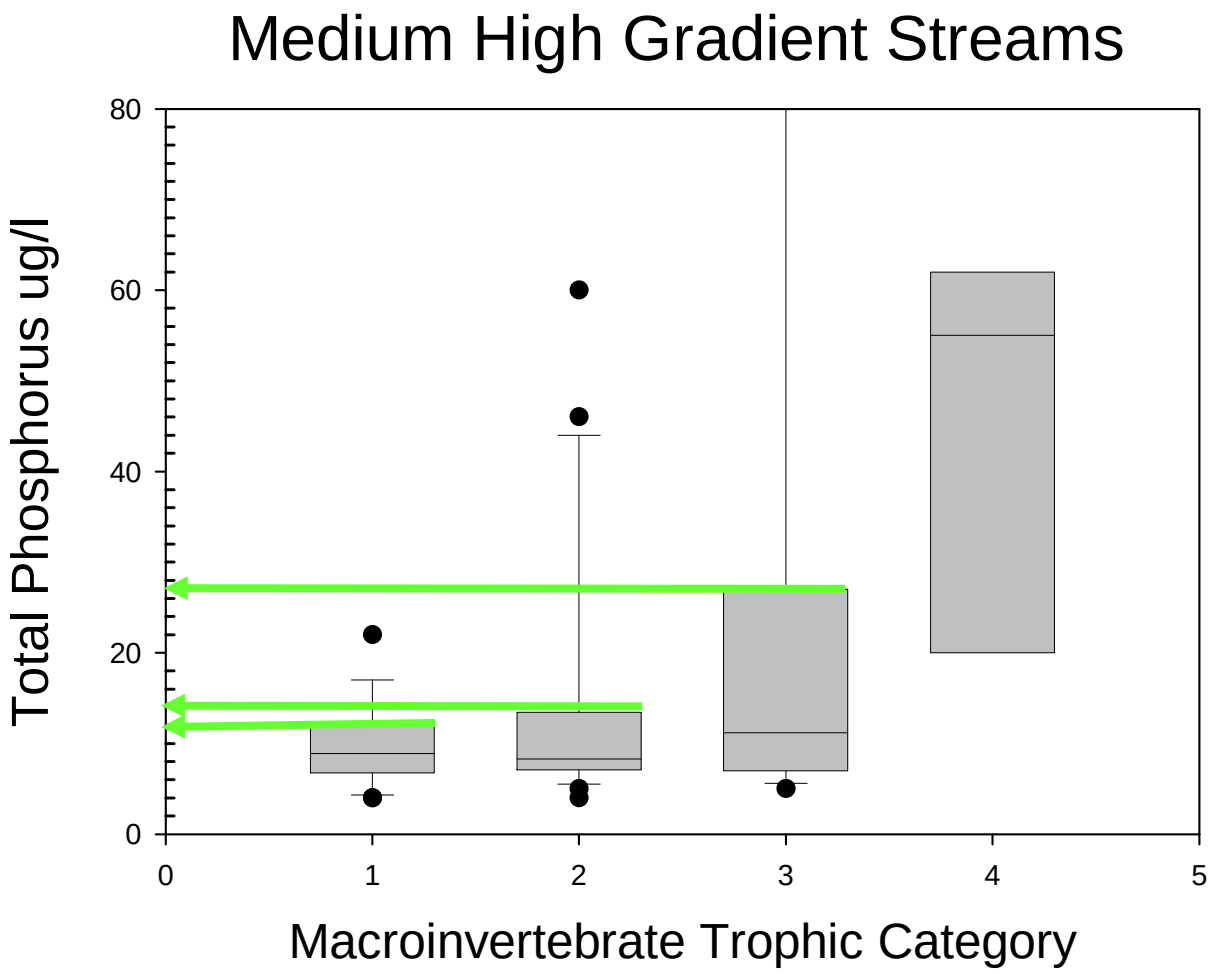


Conditional Probability Analysis

- N sites moderate (>200)
- CL's are wide
- Thresholds yield criteria > those evident from distributions
- B1 thresholds not evident
- This is due to overlap among TP's within MTI's



“Box and Whisker” Analysis

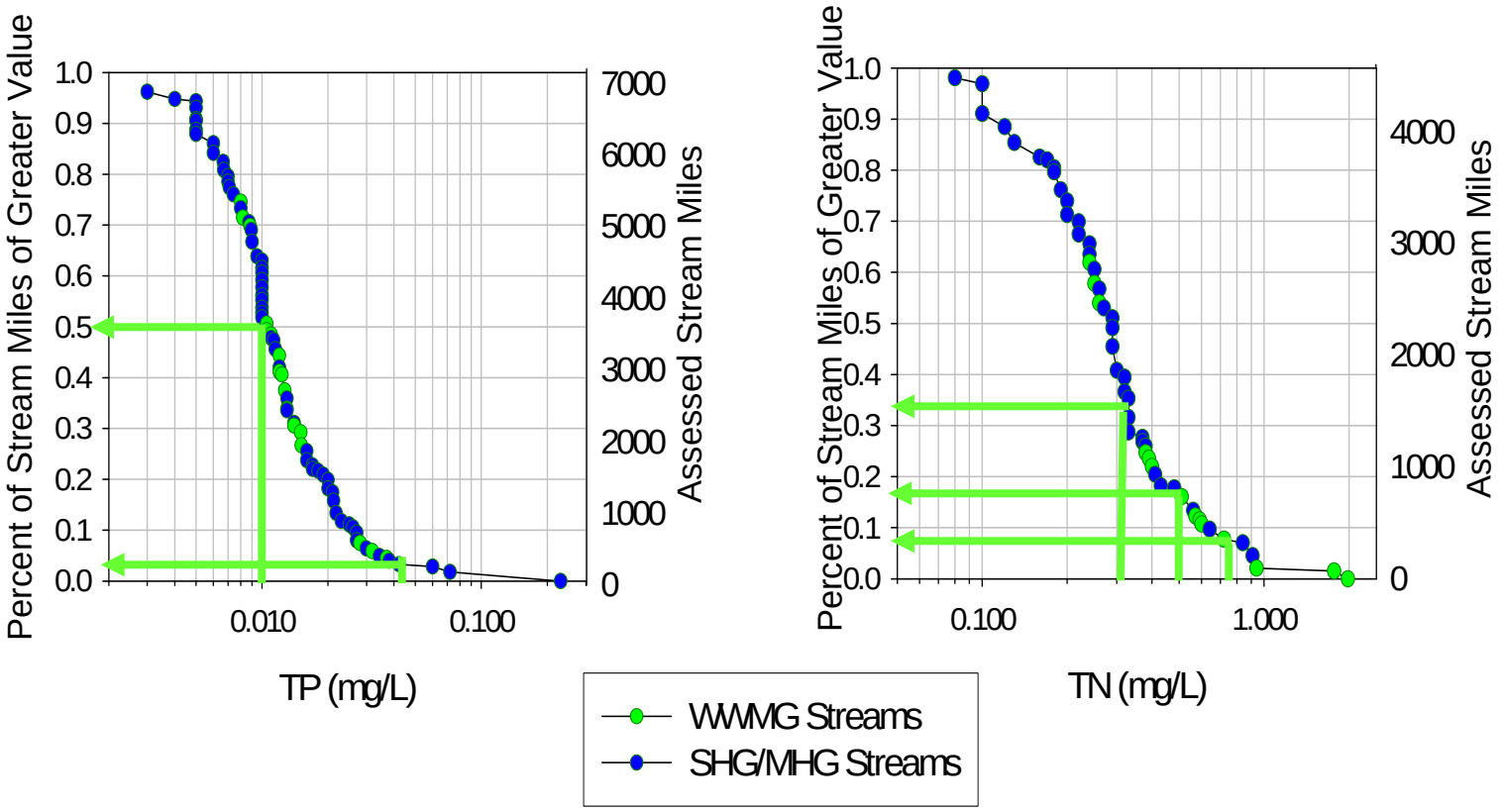


Proposed Effective Criteria for Streams

		A(1)	A(2)	B	B(1)	B(2)	B(3)
TP	SHG	0.010	0.020	0.035	0.020	0.030	0.035
TP	MHG	0.010	0.020	0.035	0.020	0.030	0.035
TP	WWMG	0.020	0.020	0.044	0.020	0.030	0.044
TN	SHG	0.30	0.75	0.75	0.50	0.50	0.75
TN	MHG	0.30	0.75	0.75	0.50	0.50	0.75
TN	WWMG	0.30	0.75	0.75	0.75	0.50	0.75

Numbers in Red derived from aesthetic thresholds; numbers in black from aquatic life thresholds.

Stream Management Implications



Cumulative frequency distributions of low-flow TP and TN in Vermont streams from the probability-based Vermont Streams Survey. Sites were segregated by stream ecotype. Note that the TN assessment applied to only 65% of the total estimated ~7,200 stream miles in VT (1:100,000 scale).

Some observations about CProb

- Width of CL's is a function of sample size and signal:noise in the data.
- Optimal results are evident when n is high, and there little overlap in stressor distributions across response categories.
- If S:N is good but n is low, then changepoints are evident, but CL's are poor
- If S:N is low and N is low, use another technique!

Hierarchy of Lake Criteria

1. Spring TN (lowest)
2. Spring TP
3. Summer TP
4. Summer Secchi Depth
5. Summer Chl (highest)

Implementation Considerations for Streams

- Compliance locations
- Flow conditions
- Application of criteria