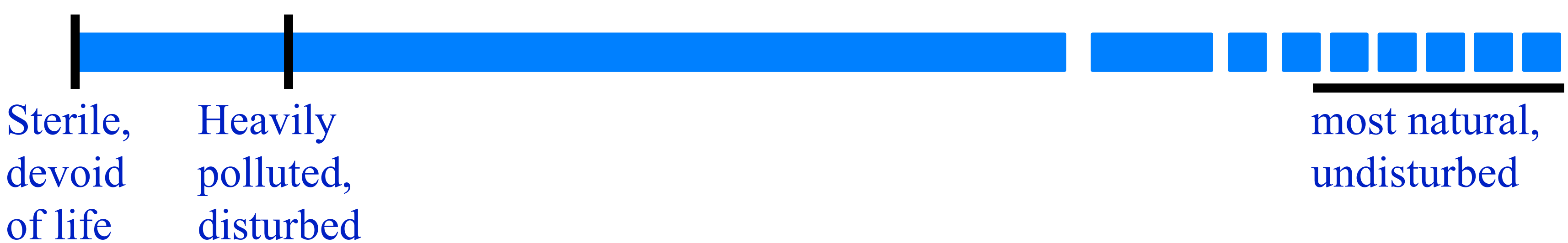
# Characterizing Reference Conditions in Lakes

Jeroen Gerritsen, Tetra Tech, Inc.

# Biological Assessment

- **Biological assessment seeks to assess waterbodies as "good" or "bad" based on their biota**
  - **What is good?**
  - **What is bad?**
- **A scientifically-based system cannot determine "good" and "bad", but it <u>can identify endpoints on a gradient:</u>**



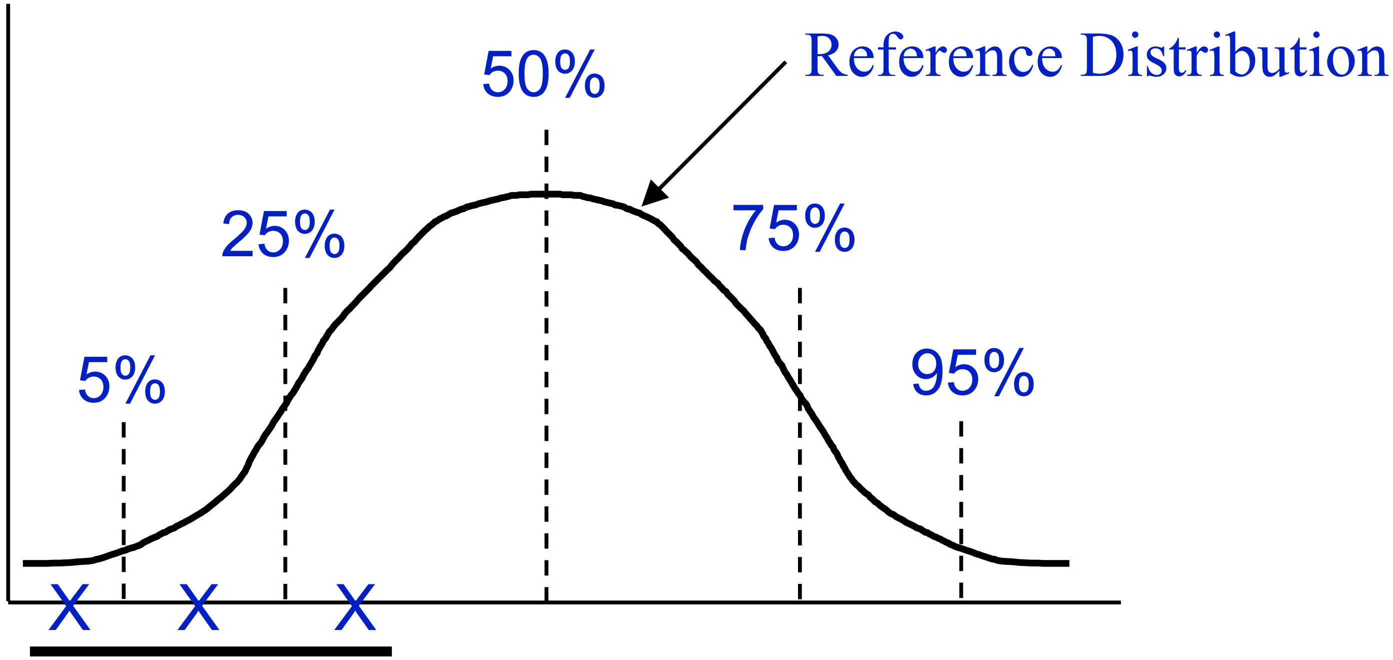
# Reference Conditions

- The primary function of reference conditions is as a measurement standard
- To be useful, a measurement standard must be stable and predictable
  - undisturbed, natural
  - best of available
  - ambient conditions?

# Reference Expectations

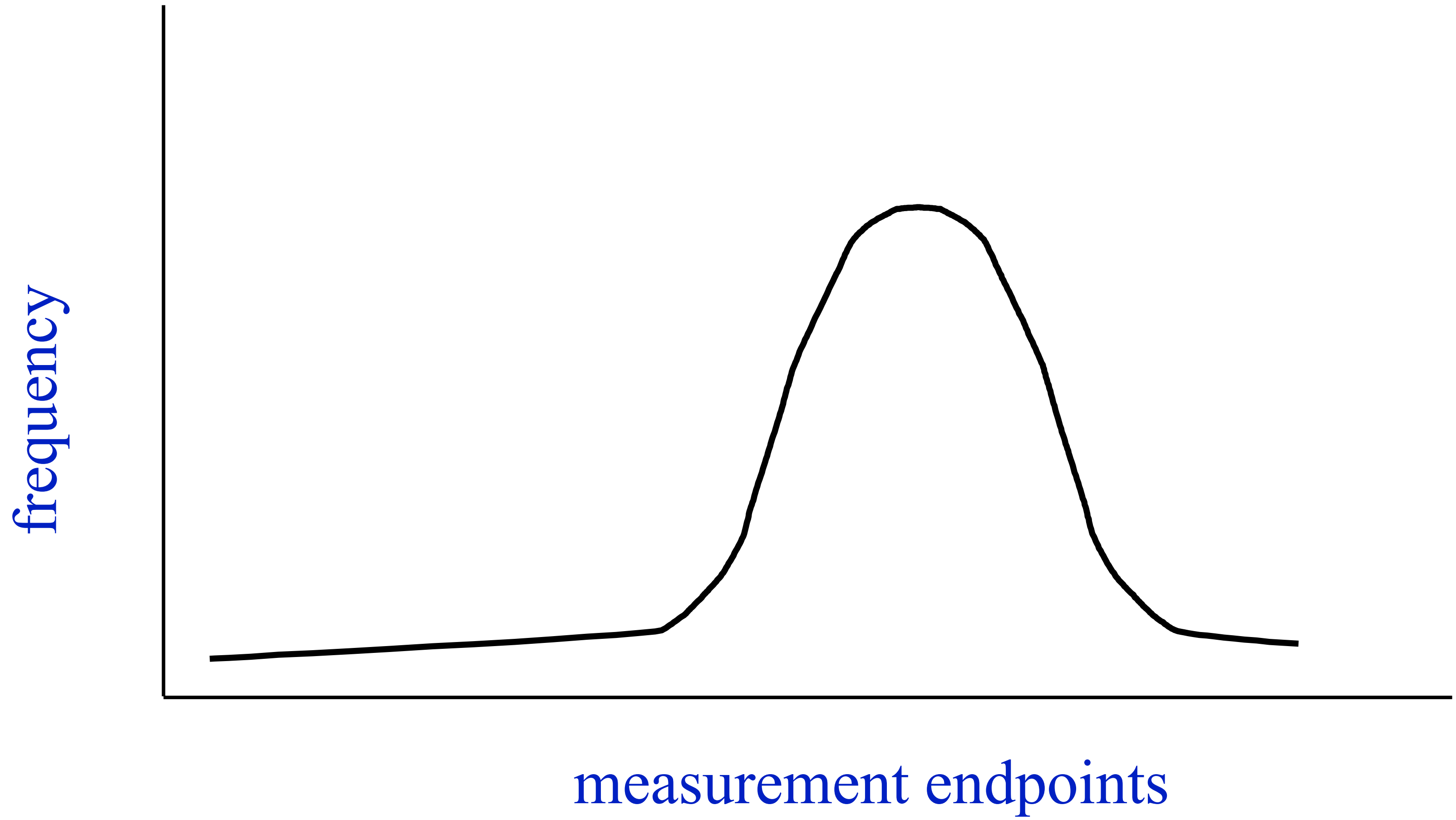
- Bioassessment consists of comparison of a lake or stream to an <u>expected condition that would exist in the absence of severe human influence</u>
  - Good is variable
  - How do we define the expected condition?
  - Where do we draw the line between impairment and non-impairment?

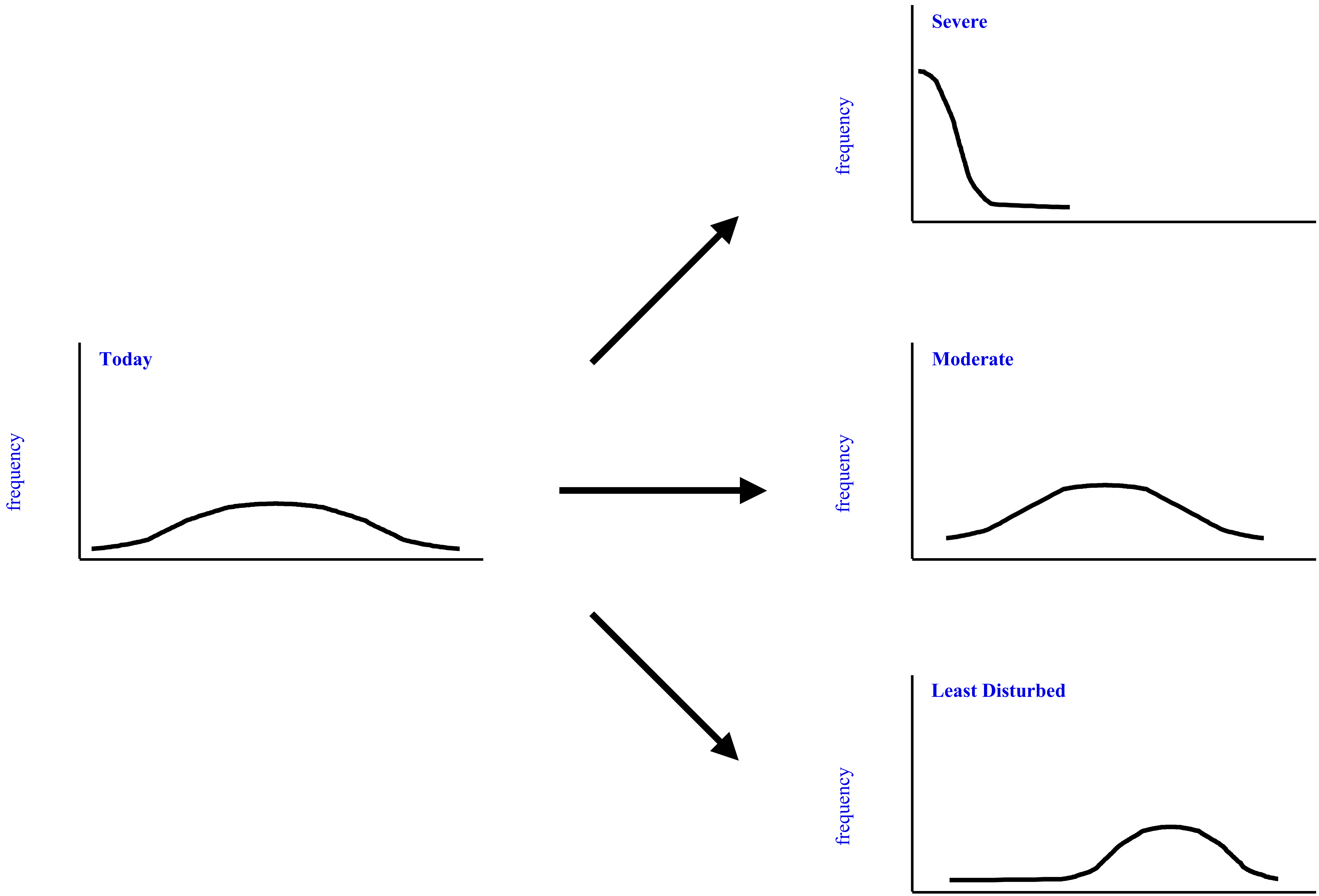
- **To capture variability, we must base expectations on a <u>population of reference sites</u>**



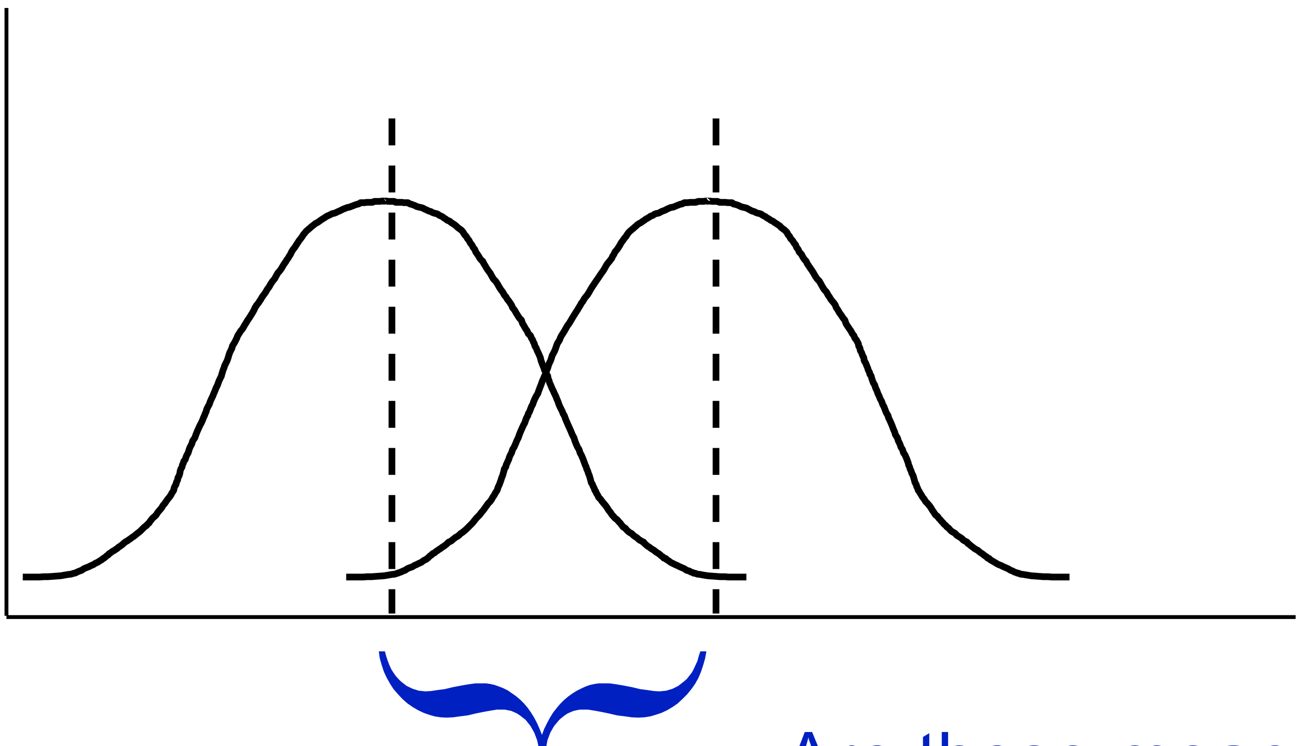

Are these observations different from the reference population?

# Pristine, pre-settlement



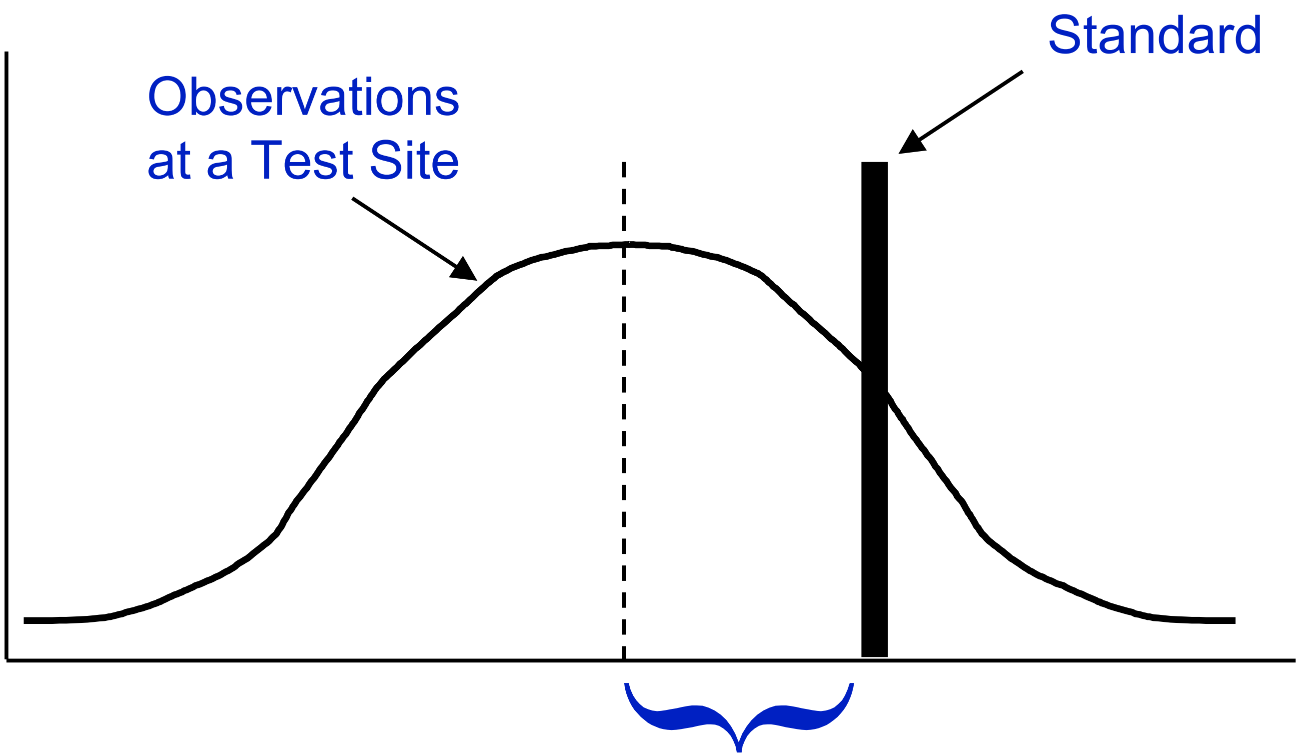

Today
frequency
Severe
frequency
Moderate
frequency
Least Disturbed
frequency

# Traditional Statistical Tests



Are these means significantly different?

# Standards and Criteria




Does the mean significantly exceed the standard?

# Reference Site Criteria

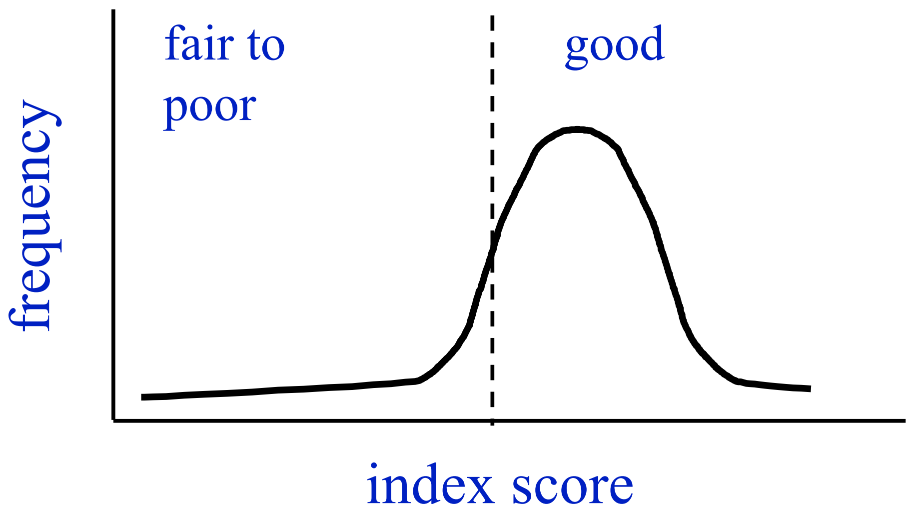
- Most natural unaffected habitat
- Few or no dischargers
- Little or no NPS pollution
- Least fish stocking activity
- Representative of ecoregion, biogeographic province, or lake type.

# Classification and Index Development

- Procedure
  - Define criteria for reference lakes
  - Classify reference lakes
  - Biological survey of reference sites
  - Develop metric scoring from reference distribution

# How a Reference Population is Used

- **Where do we draw the line?**




  - **Usually from a lower percentile of the reference distribution to include effects of natural variability.**

# What if no "Least Disturbed" Sites Exist?

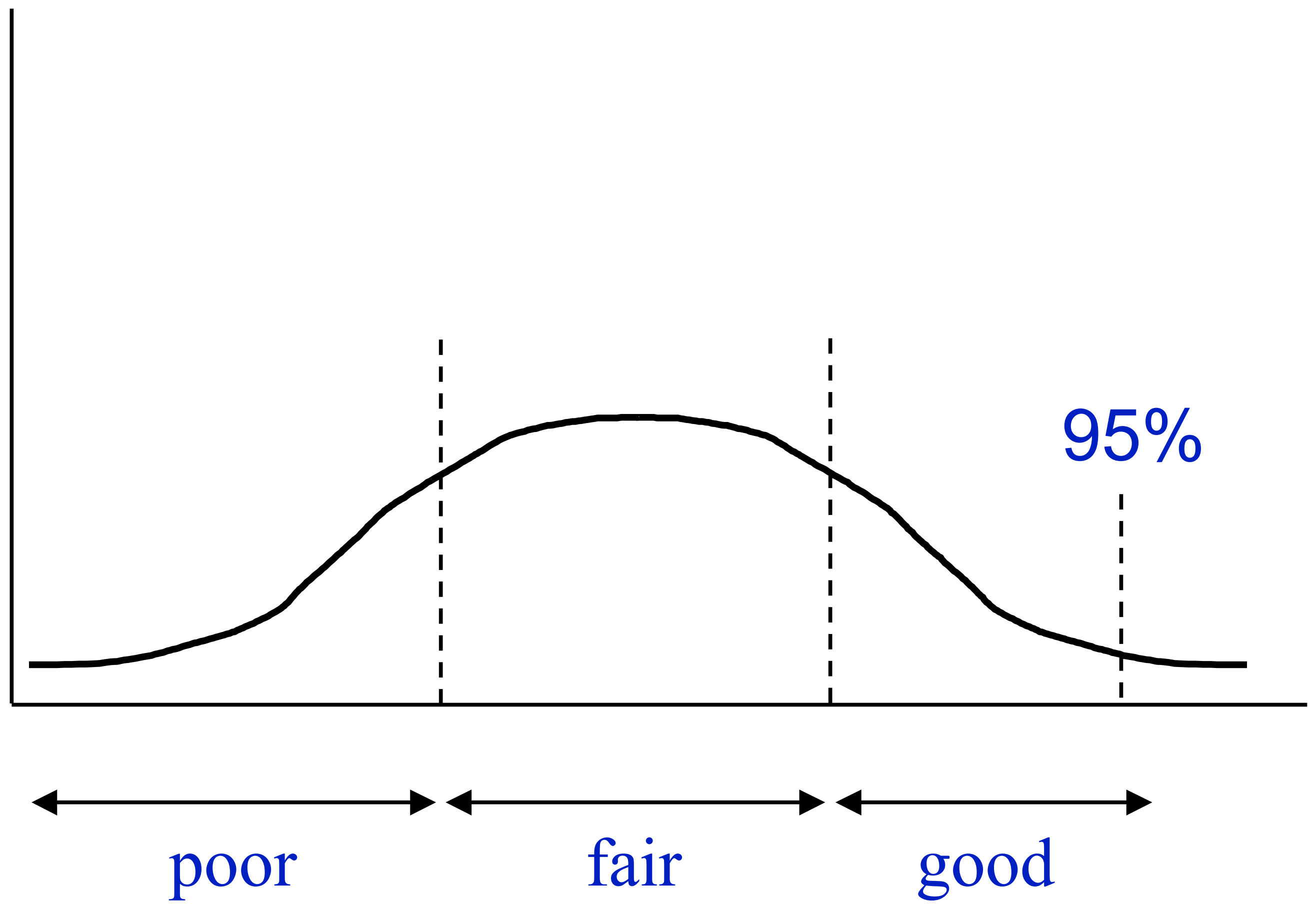
- Too few, or unrepresentative, least disturbed sites
- Man-made environments (canals, reservoirs)
- Heavily altered ecoregions (extensive and intensive agriculture)

# Case 2

- Procedure
  - Classify stream
  - Biological survey
  - Develop metric scoring from distribution of "better" streams

# Case 2

- Use upper end of distribution of index score, create arbitrary divisions



# Case 2

- **Advantages and disadvantages**
  - **Advantages**
    - **Can be done anywhere, regardless of existence of least disturbed sites**
    - **Does not require *a priori definition and identification of reference sites***
  - **Disadvantages**
    - **Definition of "good" biological condition is circular**
    - **Natural reference variability is unknown and assumed to coincide with scoring system**

# Regionalization and Preliminary Classification

- The intent of classification is to identify groups of sites that under ideal condition would have comparable biological communities.
- Classification should rely on those characteristics of sites that are intrinsic, or natural, and not the result of human activities.

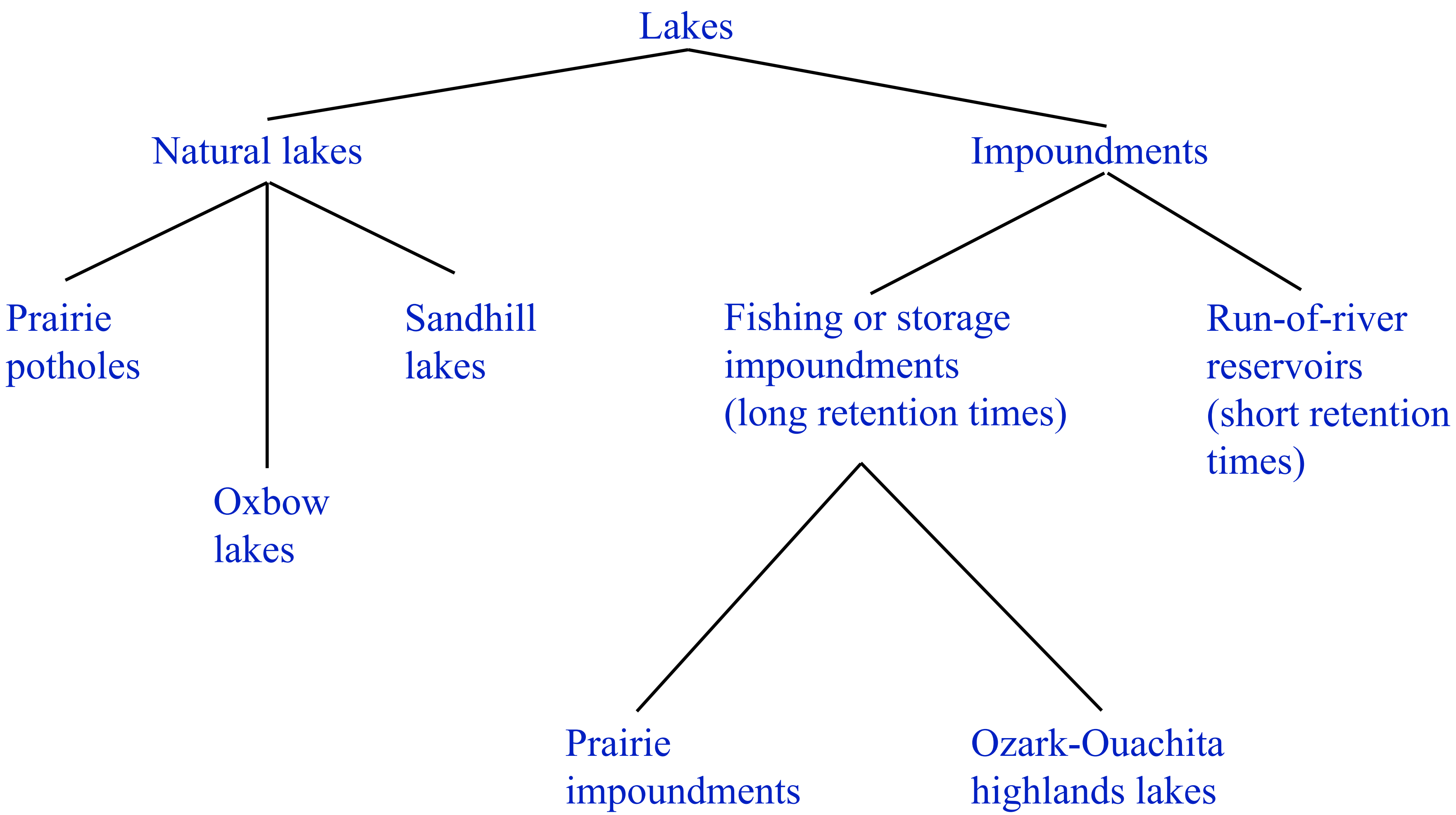
# Classification of Lakes

- **Limit your problem: define the resource**

**e.g.,**

- **area > 10 acres**
- **retention time > 14 days**
- **open water > 50 % of area**

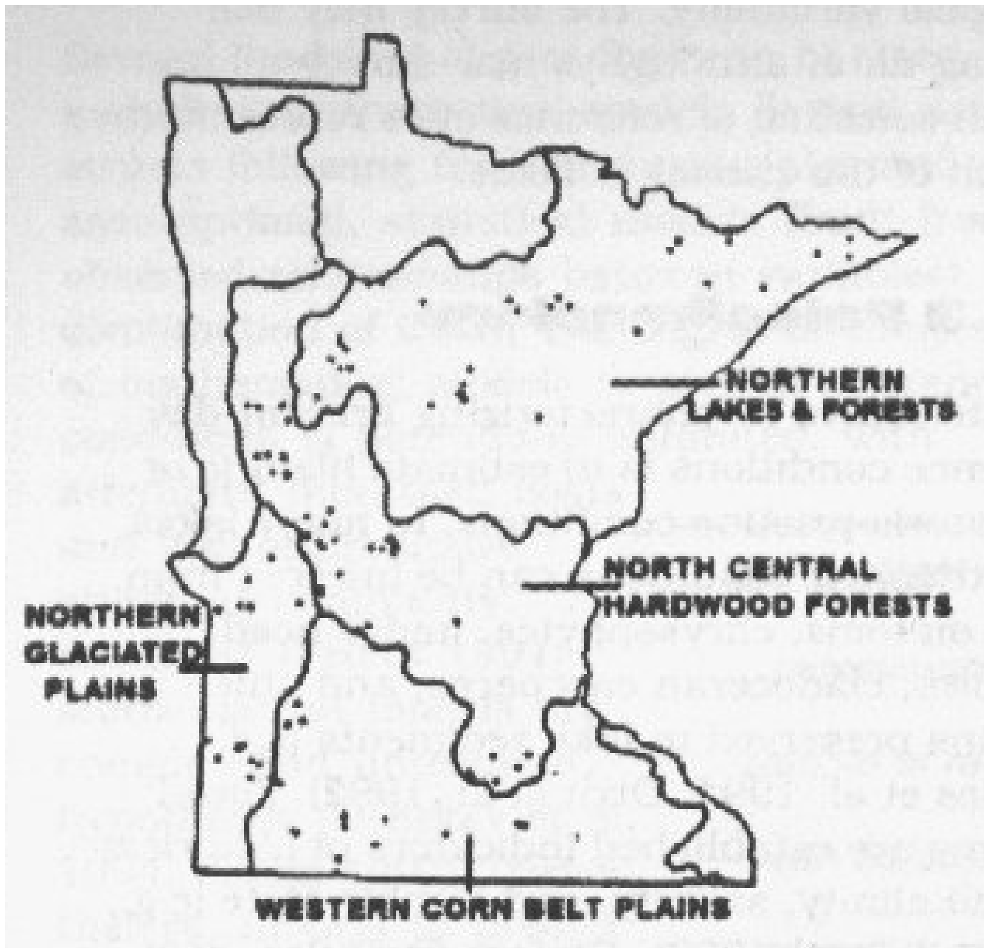
# Classification of Lakes

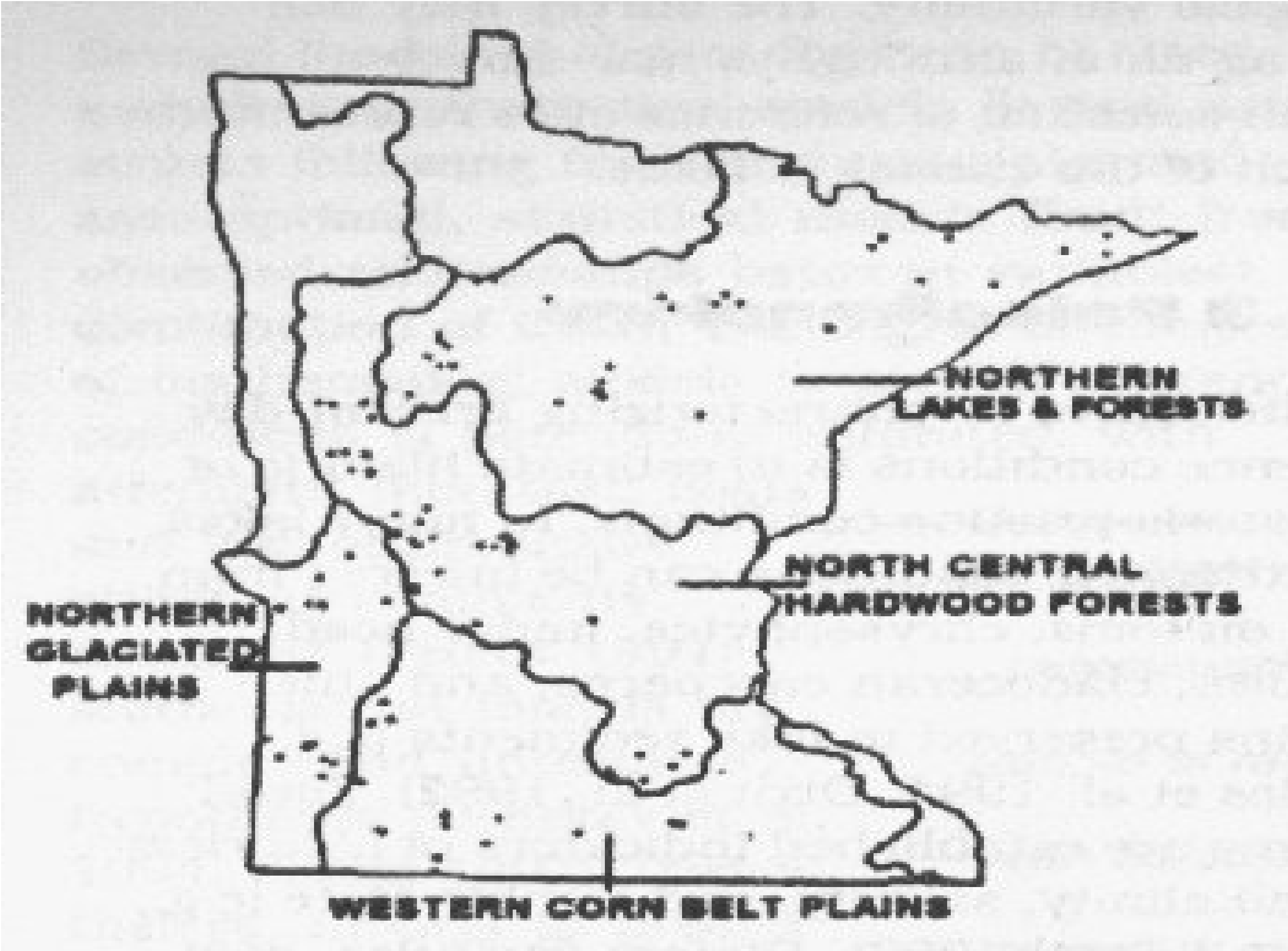


# Identifying Reference Lakes

- Watershed landuse
- Near-shore development and landuse
- Management practices (fertilization, alum, liming, drawdown)
- Discharges

# Case Study: Minnesota Lakes Ecoregions






Chlorophyll *a* concentration of Minnesota reference lakes by ecoregion.

# Case Study: Florida Lakes

- Florida water quality standards prohibit nutrient concentrations from being altered so as to cause imbalances of natural populations of aquatic flora or fauna

- Florida DEP developed a stream bioassessment protocol and index by 1995, followed by lake bioassessment protocol and index (in development)

# Overview

- Chemical classification
- Faunal classification of Florida lakes
- Development of biotic index
- Link to nutrient criteria

# Bioassessment Development

- Geographic regionalization
- Sample reference and stressed lakes
- Classification of reference lakes
- Selection of responsive indicators and development of index

# Previous Classifications

- Shannon and Brezonik 1972
  - 4 water types
- Griffith et al. 1997
  - 47 lake regions

# Steps

- Classify lakes by water chemistry
  (Griffith et al. chemical data set)
- Classify lakes by benthic macroinvertebrate community
  (DEP lake biological data set)
- Reconcile

# Water Chemistry

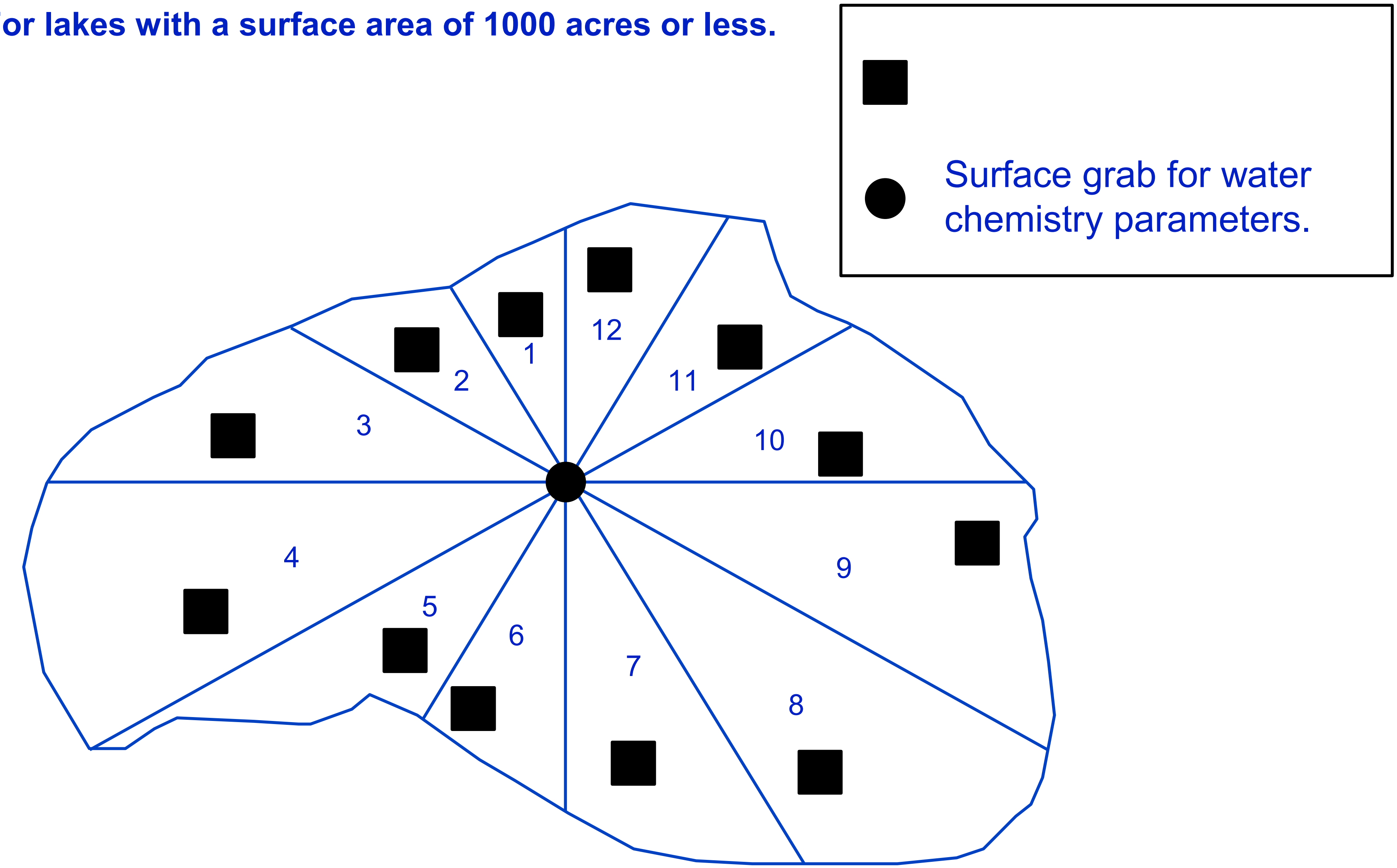
- ~1300 lakes, of which ~500 were complete
  - pH, color, Secchi, total N, total P, chlorophyll
  - PCA analysis of transformed data

## Florida data

# Biological Sampling (>200 lakes)

- **Benthic macroinvertebrates**
- **Chlorophyll *a***
- ***Water chemistry***

**For lakes with a surface area of 1000 acres or less.**



# Conclusions - Water Chemistry

- Confirm Shannon and Brezonik's 4 basic types:
  - acid, clear
  - acid, colored
  - alkaline, clear
  - alkaline, colored
- Most lake regions are predominantly 1 lake type
  - exceptions

# Macroinvertebrate Classification

- Species composition <u>and metrics</u>
- <u>Water chemistry augmented by Griffith data if missing</u>
- <u>DCA and NMDS showed similar patterns throughout (DCA shown)</u>

# Conclusions

- Ordination of species composition suggests community divisions by water color and seasonal changes
- Examination of metrics suggests different values by ecoregion and pH
- 6 classes

# Metric Testing and Evaluation

- Invertebrate metrics
  - Total taxa
  - Shannon diversity
  - OET taxa
  - HLCI (Hulbert Lake Condition Index)
  - % OET
  - % Diptera
  - % Dominant taxon
  - % Surface (head up) collectors
  - % Suspension feeders

# Metric Testing and Evaluation

- **Water column metrics**
  - **Log Secchi depth**
  - **Log Chlorophyll *a***
  - ***Log Algal Growth Potential***

# Index

- **7 metrics:**
  - **Total taxa, OET taxa, HLCI, % Dominant taxon, % OET, % Diptera, % Surface collectors**
- **Metric scoring**
  - **All metrics are standardized as a percentage of the best (usually maximum) value for the entire dataset (not standardized by region or water type)**
- **Index is average of metric scores; each region/lake type has separate assessment criteria**

# Index Performance

- Indexes work in 4 of 6 classes
  - R75 clear acid: no test samples
  - R65 color anomalous results
    - status of reference and test sites?
- Macroinvertebrate index may be more sensitive in clear lakes, Trophic index may be more sensitive in colored waters?

# Traditional Lake Quality "Criteria"

| Description | Nutrients | Value |
|---|---|---|
| Oligotrophic | Low P | Good |
| Mesotrophic | Medium P | OK |
| Eutrophic | High P | Bad |

# Conclusions

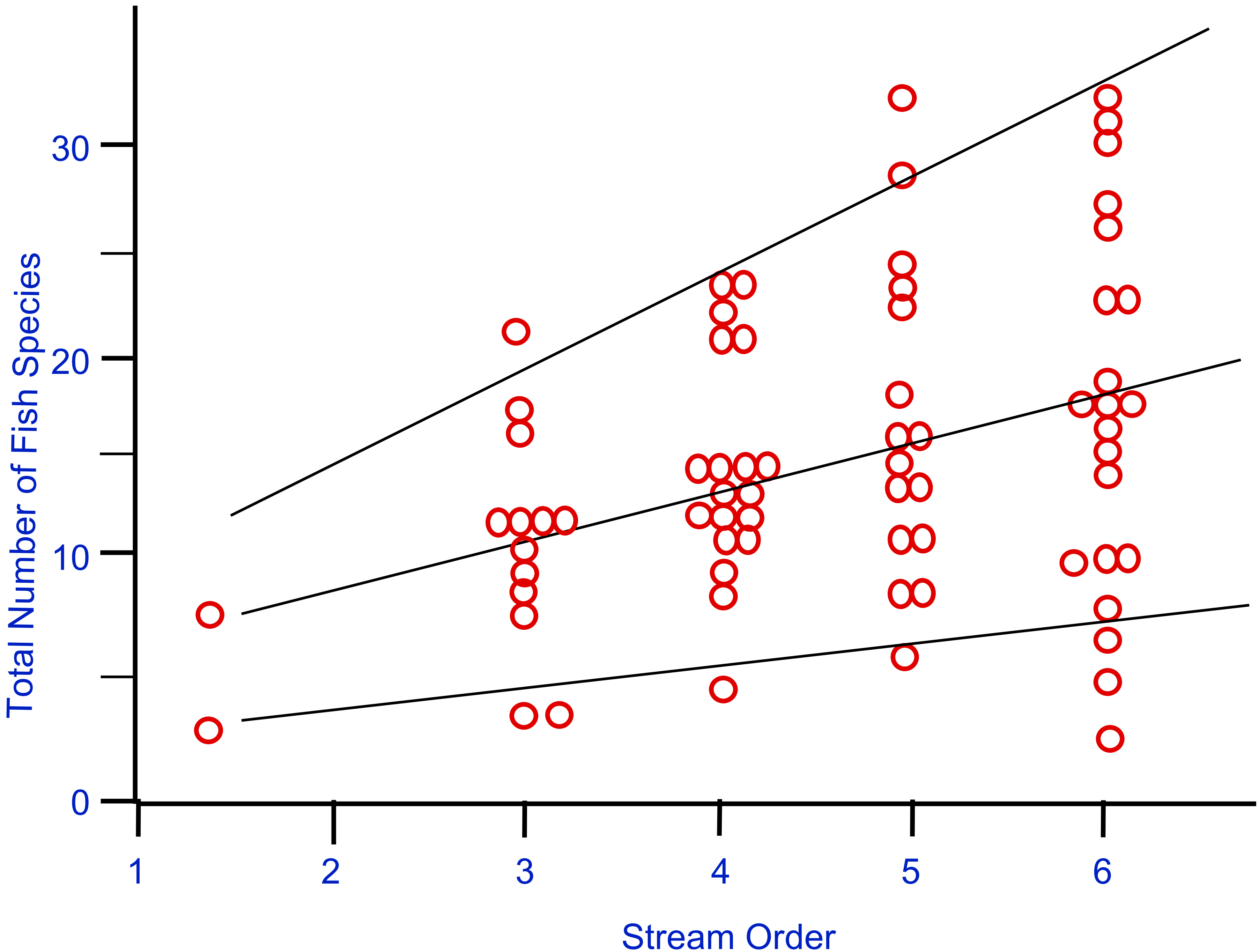
- Nutrient concentrations vary by region and lake type
- Response to enrichment varies by lake type
- Nutrient criteria should reflect this

# Summary: Model System for Nutrient Criteria

- Characterization of biological potential of least stressed lakes
  - classification of least stressed lakes
  - reference characterization creates context
- Linkage of biocriteria and nutrient criteria
  - biological criteria reflect valued endpoints for aquatic life use
  - criteria can be quantified on a regional basis
  - biological response to enrichment

# Classification Approaches

- **Two fundamental approaches exist for classification: *a priori and a posteriori***
  - ***a priori consists of developing logical rules for classification based on observed patterns in the characteristics of the objects (e.g., classifying lakes on ecoregion, surface area, and maximum depth)***
  - ***a posteriori develops groups from a database of observations from the sites and is restricted to those sites in the database***



30
20
10
0
Total Number of Fish Species
1
2
3
4
5
6
Stream Order