Can we still use reference conditions to underpin the WFD?

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Outline

- Definitions of reference conditions
- Approaches used to establish RC
- Loose ends
  - the known unknowns

Definitions of Reference Condition

pre WFD

- The condition that is representative of a group of minimally disturbed sites organized by selected physical, chemical, and biological characteristics (Reynoldson et al. 1997).

- Representing important aspects of 'natural' or pre-Columbian conditions and at the same time, politically palatable and reasonable (Hughes 1995).

WFD's (wordy) definition of RC

Expected background (i.e. reference) conditions with **no or minimal anthropogenic stress** and satisfying the following criteria: (i) they should reflect **totally, or nearly, undisturbed conditions for hydromorphological elements, general physico-chemical elements, and biological quality elements**, (ii) concentrations of **specific synthetic pollutants** should be close to zero or below the limit of detection of the most advanced analytical techniques in general use, and (iii) concentrations of specific **non-synthetic pollutants**, should remain within the range normally associated with background levels (European Commission 2000).

Alternative "definitions" of RC*

Minimally Disturbed Condition

- Absence of significant human disturbance

Historical Condition

- Pre-intensive agriculture (ca. 1850 in UK)
- Pre-settlement (e.g. 1700 in northeastern US)

Least Disturbed Condition

- In conjunction with best available using explicit criteria

Best Attainable Condition

- Equivalent to the ecological condition of (hypothetical) least disturbed sites where best management practices are in use.

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SETTING EXPECTATIONS FOR THE ECOLOGICAL CONDITION OF STREAMS: THE CONCEPT OF REFERENCE CONDITION

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Abstract. An important component of the biological assessment of stream condition is an evaluation of the direct or indirect effects of human activities or disturbances. The concept of a "reference condition" is increasingly used to describe the standard or benchmark against which current condition is compared. Many individual nations, and the European Union as a whole, have codified the concept of reference condition in legislation aimed at protecting and improving the ecological condition of streams. However, the phrase "reference condition" has many meanings in a variety of contexts. One of the primary purposes of this paper is to bring some consistency to the use of the term. We argue the need for a "reference condition" term that is reserved for referring to the "naturalness" of the biota (structure and function) and that naturalness implies the absence of significant human disturbance or alteration. To avoid the confusion that arises when alternative definitions of reference condition are used, we propose that the original concept of reference condition be preserved in this modified form of the term: "reference condition for biological integrity," or RC(BI). We further urge that these specific terms be used to refer to the concepts and methods used in individual bioassessments to characterize the expected condition to which current conditions are compared: "minimally disturbed condition" (MDC); "historical condition" (HC); "least disturbed condition" (LDC); and "best attainable condition" (BAC). We argue that each of these concepts can be narrowly defined, and each implies specific methods for estimating expectations. We also describe current methods by which these expectations are estimated including: the reference-site approach (condition at minimally or least-disturbed sites); best professional judgment; interpretation of historical condition; extrapolation of empirical models; and evaluation of ambient distributions. Because different assumptions about what constitutes reference condition will have important effects on the final classification of streams into condition classes, we urge that bioassessments be consistent in describing the definitions and methods used to set expectations.

Key words: best attainable condition; bioassessment; Clean Water Act; consistency of terminology needed; historical condition; least disturbed condition; minimally disturbed condition; monitoring; reference condition defined.

INTRODUCTION

Human beings, through their great range of activities, have altered the global landscape in a variety of ways. Describing the effects of these activities on the structure and function of aquatic ecosystems and their biota is a fundamental objective of biological assessments, whether the effects are considered singly or in combination, and whether they are local, regional, national, or international. Conducting a biological assessment involves an evaluation of the biota, and should include the environmental factors that have direct and indirect effects on the temporal and spatial variation in the biota. Since the primary focus of a biological assessment is an evaluation of the effect of human activity, a critical element in the process is estimating biological status in the absence of human disturbance.

Most biological assessments are based, either directly or indirectly, on the concept of comparing current condition to natural conditions (structure, composition, function, diversity) in the absence of human disturbance or alteration (i.e., comparison to a pristine, unpolluted, or anthropogenically undisturbed state; Steedman 1994, Hughes 1995, Jackson and Davis 1995, Davies and Jackson 2006). The term *reference condition* has been used to describe the state used to gauge the effects of human activity (Karr and Chu 1999), and the term

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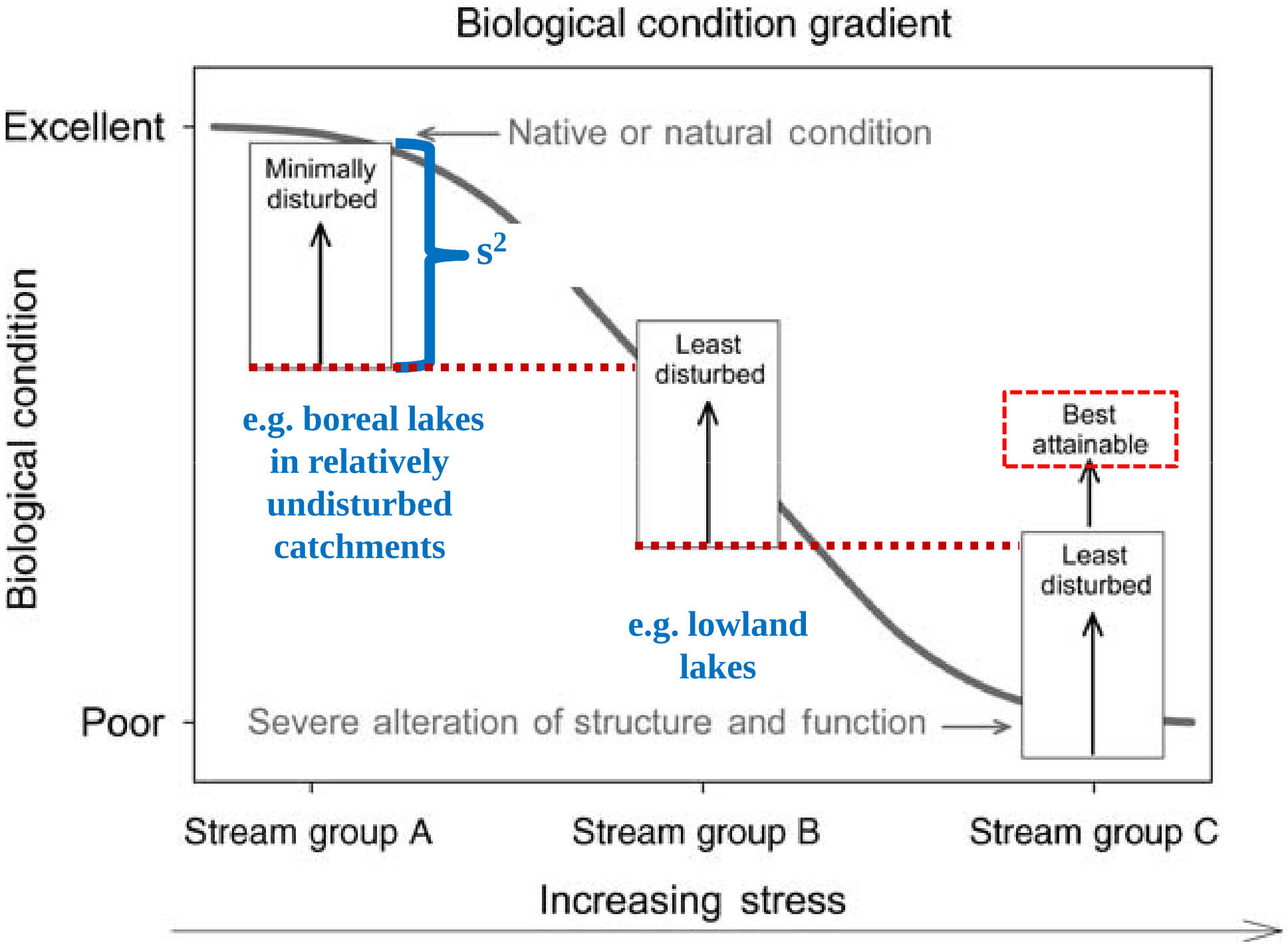
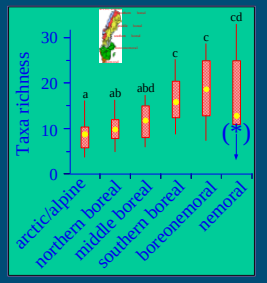
**** Stoddard et al. (2006)***

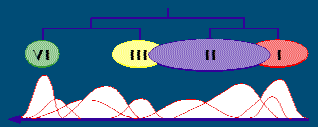

Biological condition gradient
Excellent
Native or natural condition
Minimally disturbed
s^2
Least disturbed
Best attainable
Least disturbed
e.g. boreal lakes in relatively undisturbed catchments
e.g. lowland lakes
Biological condition
Poor
Severe alteration of structure and function
Stream group A
Stream group B
Stream group C
Increasing stress

Approaches for establishing RC

- Spatial (typology) analogues



- Modeling

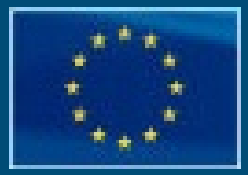


- Historical

  - paleoecological reconstruction

- Curve fitting (stress trajectories)

- Expert judgment



1.3. Establishment of type-specific reference conditions for surface water body types (Annex 2)

(i) "**Type-specific** biological reference conditions shall be established…for that surface water body type at high ecological status…"

(iii) "…may be either **spatially based or based on modelling** …not possible to use these methods…may use **expert judgement**…"

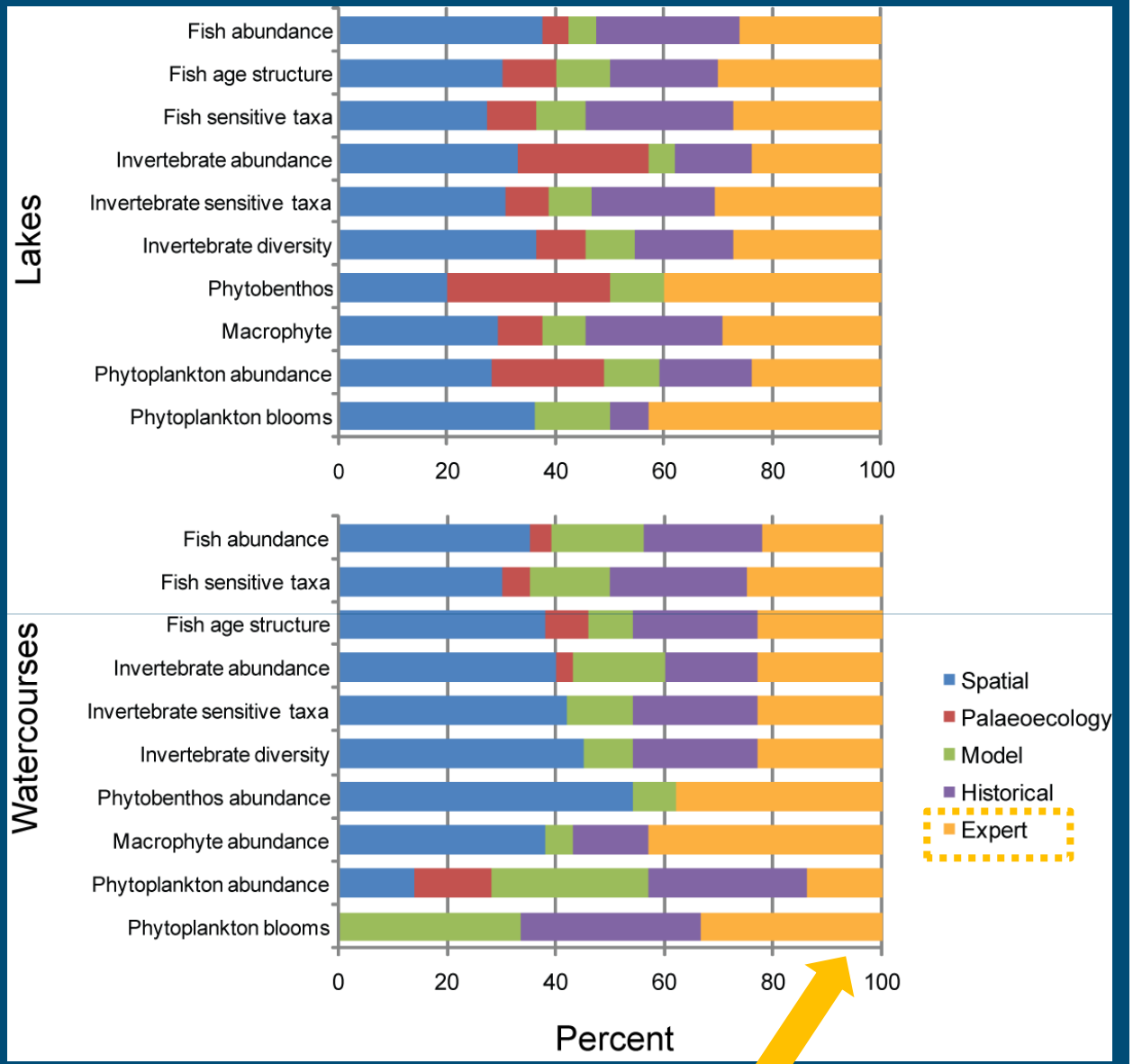
(iv) "For spatially based…**develop a reference network**…to provide a sufficient level of confidence…"

(v) "…reference conditions based on modelling may be derived using either **predictive models or hindcasting** methods…"

(vi) "…not possible to establish reliable type-specific reference conditions…that **element may be excluded**…"

REFCOND*

Methods used by Member States



Need to try and decrease use of "expert" judgment

**Wallin, Wiederholm & Johnson (2003)*

Application of Reference Criteria in Phase I of IC*

- Analysis based on MSs responses to a reference screening questionnaire for macroinvertebrates.
- All GIGs (except NO GIG) used the questionnaire developed by CB GIG
  - major differences in threshold values for agricultural land use (25% NO and 50% CB) and classification of riparian zone and hydromorphology (less focus in NO).

➢ **Poor consistency in how RC were used by MSs**

- need a common guidance of RC criteria

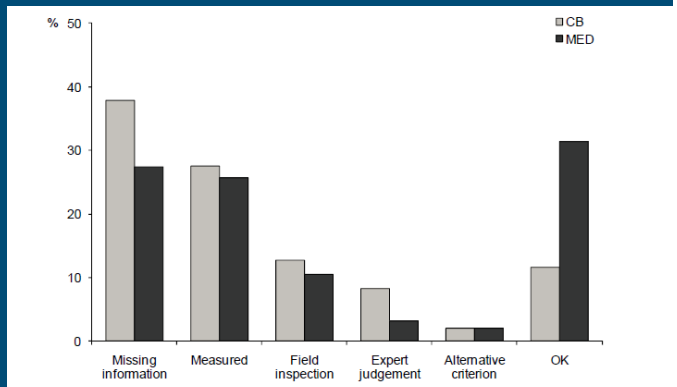


Figure 1. Responses provided by the CB and MED GIGs to the RC screening questionnaire

**** Pardo, Poikane and Bonne (2011) Revision of the consistency in Reference Criteria application in the phase I of the European Intercalibration exercise.***

Example of pressure criteria – Lakes (N-GIG)

NORTHERN GIG					
Criteria	Finland	Sweden	Norway	UK	Ireland
Pressure criteria					
Agriculture*	In data sets at present mainly ≤ 10%	< 10% of catchment	< 5%	< 10% arable or intensive grazing	
Point sources	No major point sources	No major point sources	No major point sources		No major point sources
Urbanised area		< 0.1% of catchment			No urbanisation i.e. villages/ towns < 1%
Population density			< 5 p.e./km2	< 10 p.e./km2	
Other pressures	No significant water level regulation or morphological changes	Annual mean ≥ pH 6		No fish farms	No intensive use of lake i.e. abstractions
Impact criteria					
Total phosphorus		< 10 µg/L, or higher if high colour	< 11 µg/L, or higher if high colour		< 10 µg/L
Chlorophyll			< 4 µg/L (low alk. clear types) (< 6 for other types)		< 4 µg/L
Biovolume phytoplankton					
Paleodata				if available	some sites
Expert judgement	yes, partly	no	yes	yes	yes

* Agriculture: This is mainly judged from visual observation of GIS land use data

Table 6. Reference criteria used by the Lake GIGs for selection of reference lakes

Pardo et al. (2011)

3-tiered approach to screening*

Tier 1 – **"True"** reference sites, i.e. sites with no or minimal anthropogenic pressure that fulfill all criteria proposed in RECOND Guidance for all pressures;

Tier 2 – **"Reference condition"** sites or **"Partial"** reference sites, i.e. impacted by some level of anthropogenic pressures but (some) biological communities corresponding to the reference conditions;

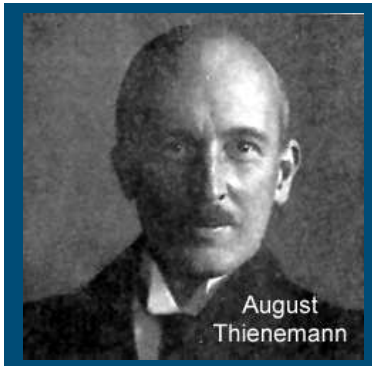
Tier 3 – **"Alternative benchmark"** sites, i.e. sites with some pressure and some level of impairment to biology (can be used for setting benchmark, see EC 2010).

Pardo et al. (2011)

Establishing Reference Conditions

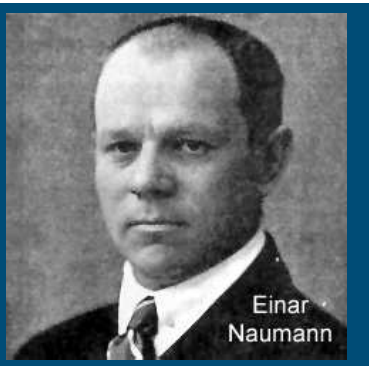
Four case studies:

1. **Spatial typology**
2. **Historical - Observation & Reconstruction**
3. **Typology & Modeling**
4. **Expert judgment**



Lake typology

(13 x in WFD)



Thienemann (1921)

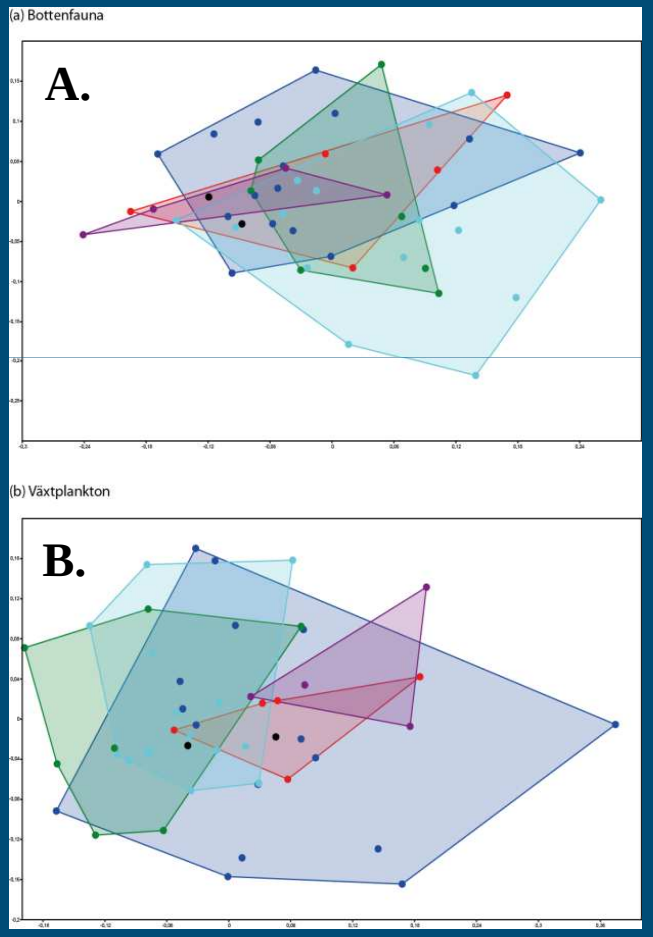
- Classification based on benthic invertebrates (midges) and oxygen concentration

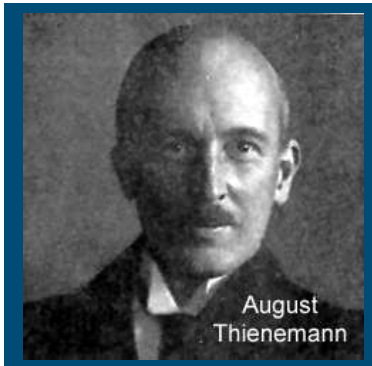
Naumann (1921)

- Trophic state (algal production) determined by many factors, primarily P & N
- Concept of lake ontogeny
- **Regional** variations in production related to catchment geology

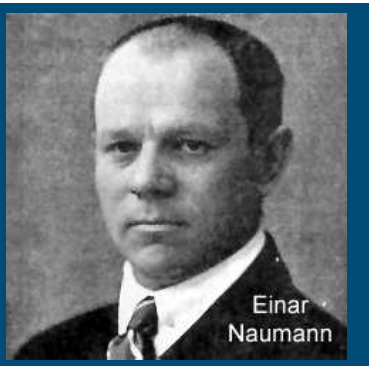
Ex #1: Spatial - Lake Typology (SE)

- ca 270 lake types using System A
- nMDS of littoral invertebrates (A) and phytoplankton (B) in 27 reference lakes sampled in 2012 grouped by six common WFD types
- some significant differences (e.g. ANOSIM) but much overlap
- questionable use in partitioning biological variability





So what did the father's of limnology conclude?



The Naumann-Thienemann classification approach failed because they (i) tried to include too many variables and (ii) it was assumed that there existed distinct sets of lakes that could be easily classified.

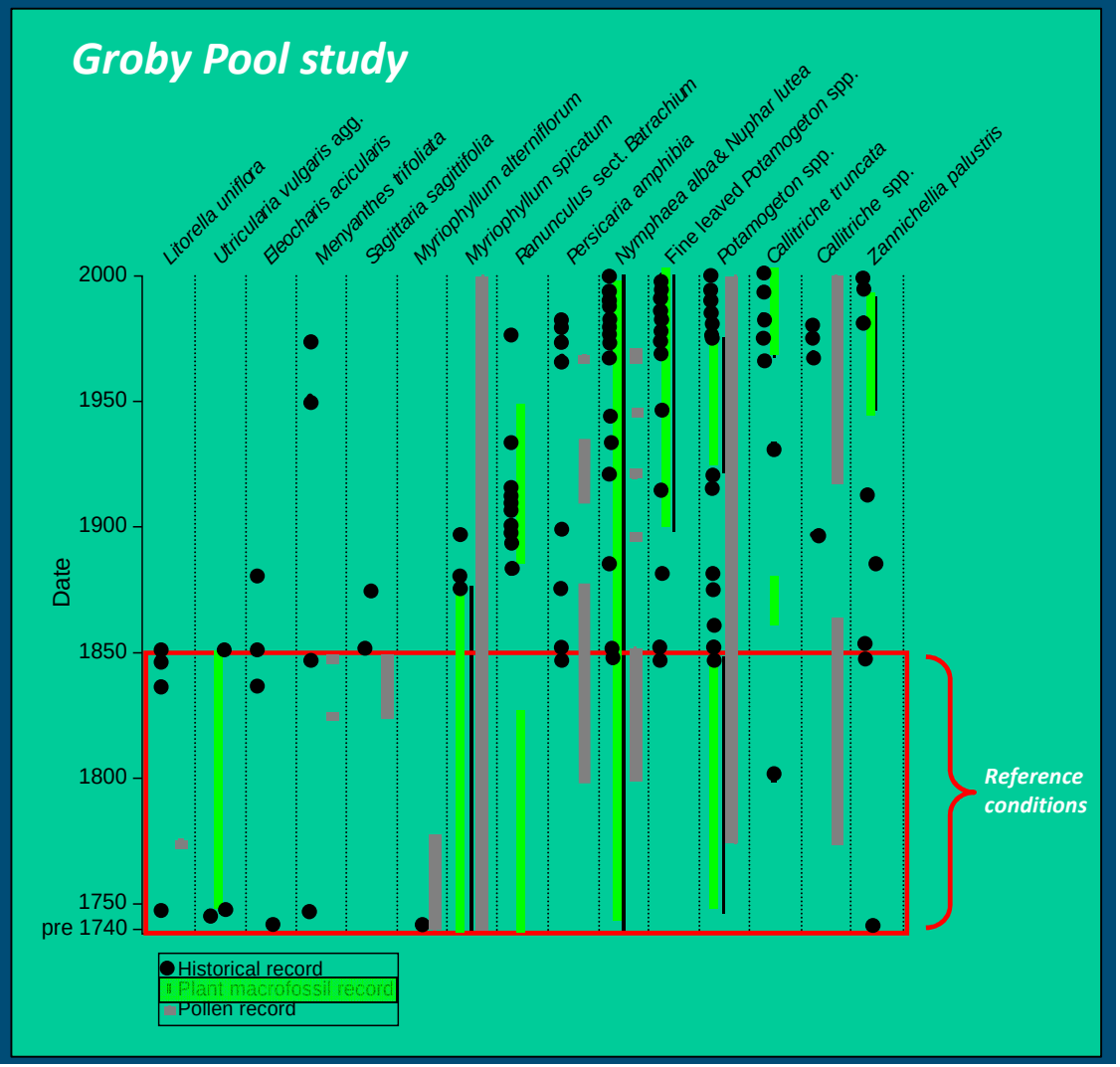
Carlson and Simpson (1996)

Ex #2: Historical - Observation & Reconstruction

- **About 40% of historically recorded taxa represented by macro-remains.**
  - e.g. only 3 of 8 historically recorded *Potamogeton* species found
- **Pollen record revealed**
  - taxa which left no macro-remains,
  - more reliable record of persistence, appearance and loss of taxa.

➢ **Combined macrofossil and pollen provide a reliable indication of temporal change in dominant taxa.**

Davidson et al. (2005)



Euro-limpacs

Ex #3: Spatial & Modeling

RIVPACS models differ from spatial typologies:

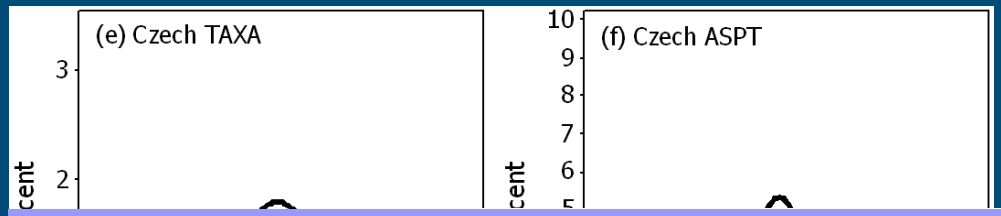
- Biological grouping not abiotic typology
- "Clean" abiotic variables discriminate among groups
- Predict probability of taxon occurrence

Comparison done in:

- Czech Republic
- Sweden
- Great Britain

** Davy-Bowker et al. (2006)*

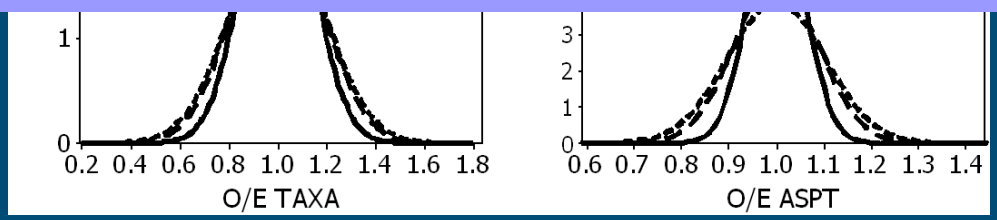
Ex #3: Spatial & Modeling



RIVPACS/SWEPAC$_{SRI}$/PERLA
WFD System-A
A null model

RIVPACS-type models were better at predicting index values than spatially-based approaches.

Need more tests of typology vs modelled-based approaches for setting RC.



** Davy-Bowker et al. (2006)*

Ex #3(2): Spatial & Modeling

- **typologies and RIVPACS-models had lower SD(O:E) than null models**
- **varied with geographical extent: at the larger extent, RIVPACS was more precise than typology; at the regional scale, difference was marginal**
- **sensitivity depended on the geographical extent**

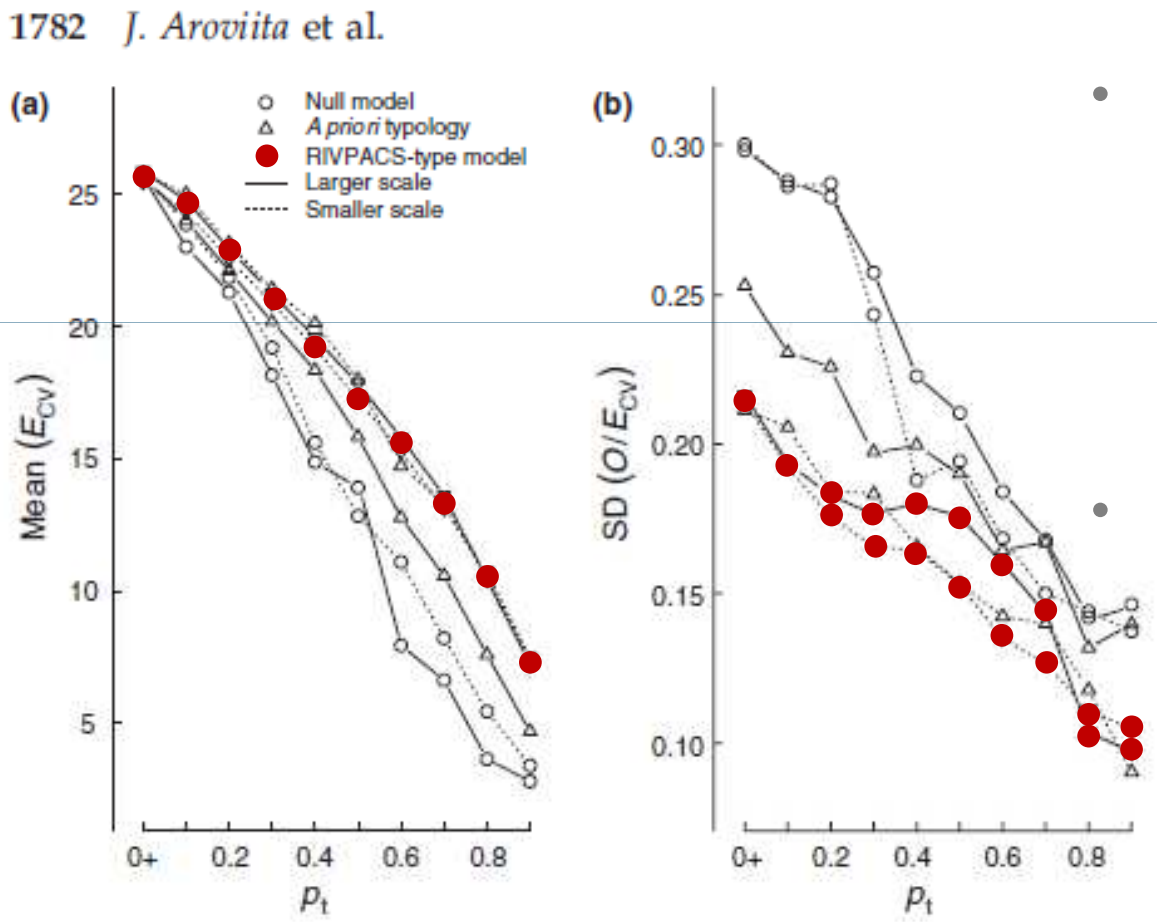


Fig. 3 (a) Mean values of number of expected taxa (E_{CV}, CV = cross-validated) and (b) standard deviation of O/E_{CV} with increasing p_t. See Fig. 2 for explanation of p_t.

Aroviita et al. (2009)

Ex #4: Expert judgment

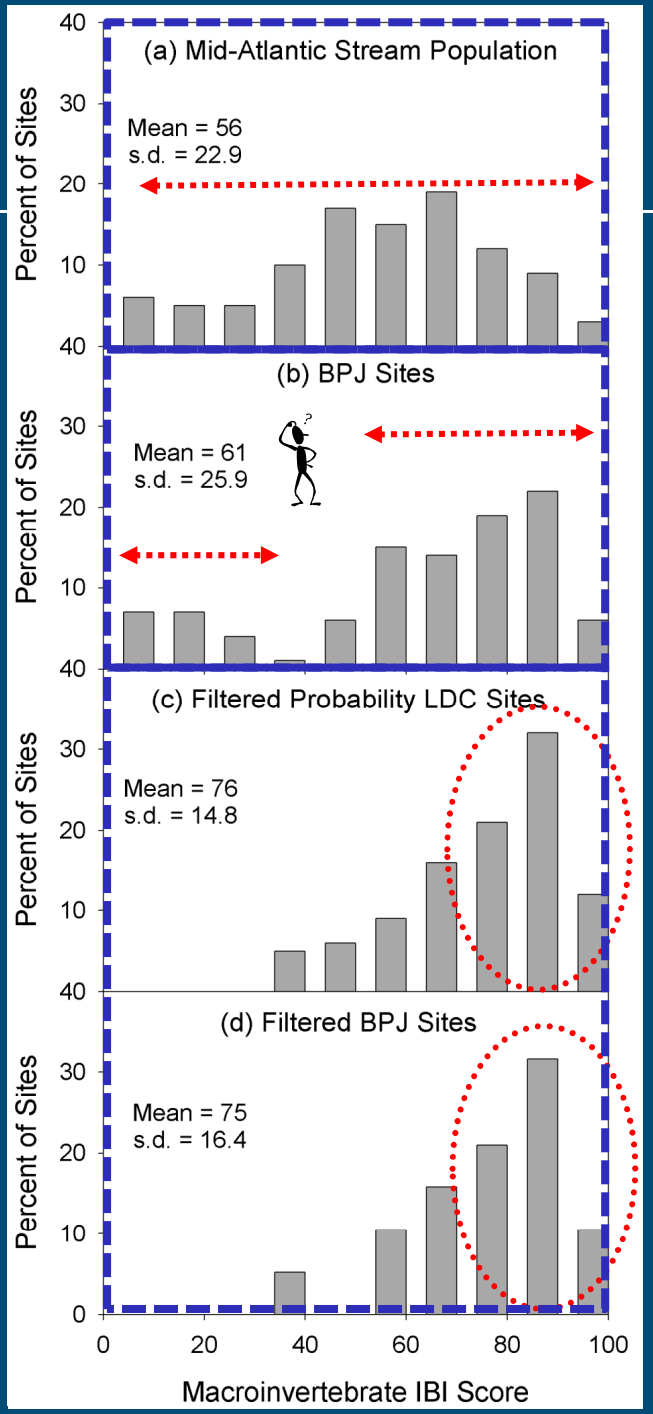
Biotic index - IBI macroinvertebrate scores

(a) **regional population** of streams in the Mid-Atlantic region of the U.S.A.;

(b) set of Least Disturbed Condition sites chosen through **best professional judgment (BPJ)**;

(c) set of LDC sites identified *a posteriori*, **by filtering** the probability data shown in *a*;

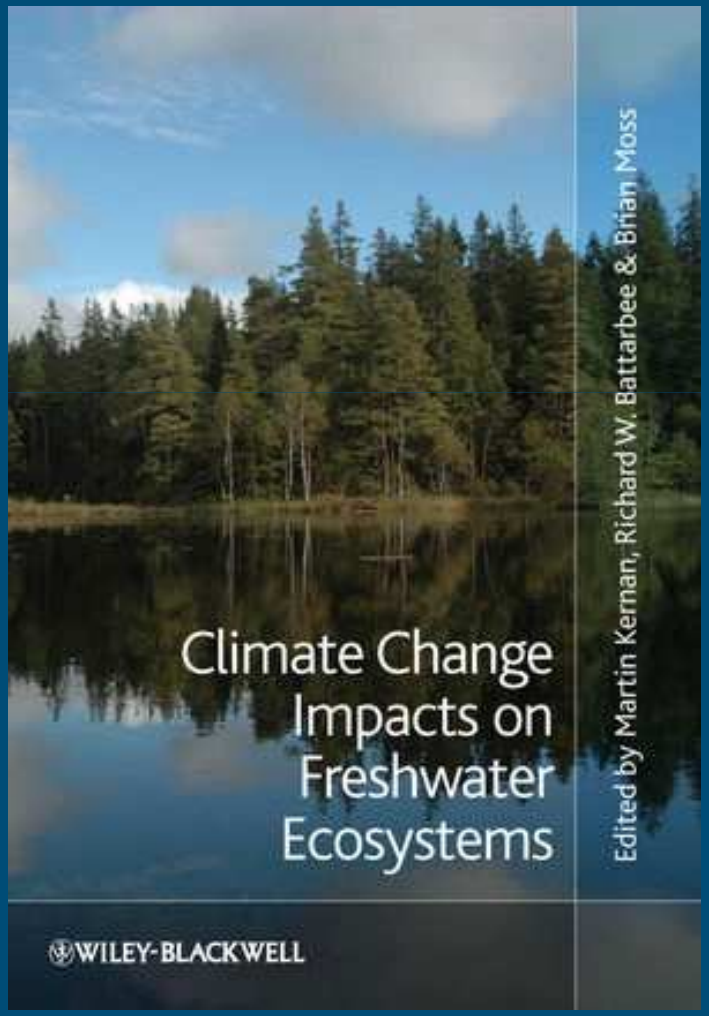
(d) set of LDC sites identified *a posteriori*, **by filtering** the BPJ data shown in *b*.



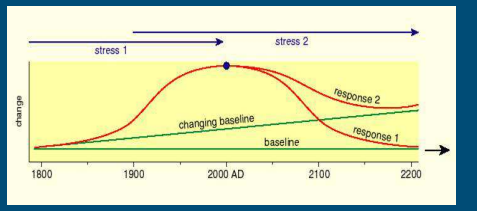
Changing baselines

- how will (European) freshwater ecosystems respond to future climate change directly and indirectly, through interactions with hydromophology eutrophication, acidification and toxic substances?

- how can European freshwater systems thereby be better managed, e.g. with respect to the EU Water Framework Directive?

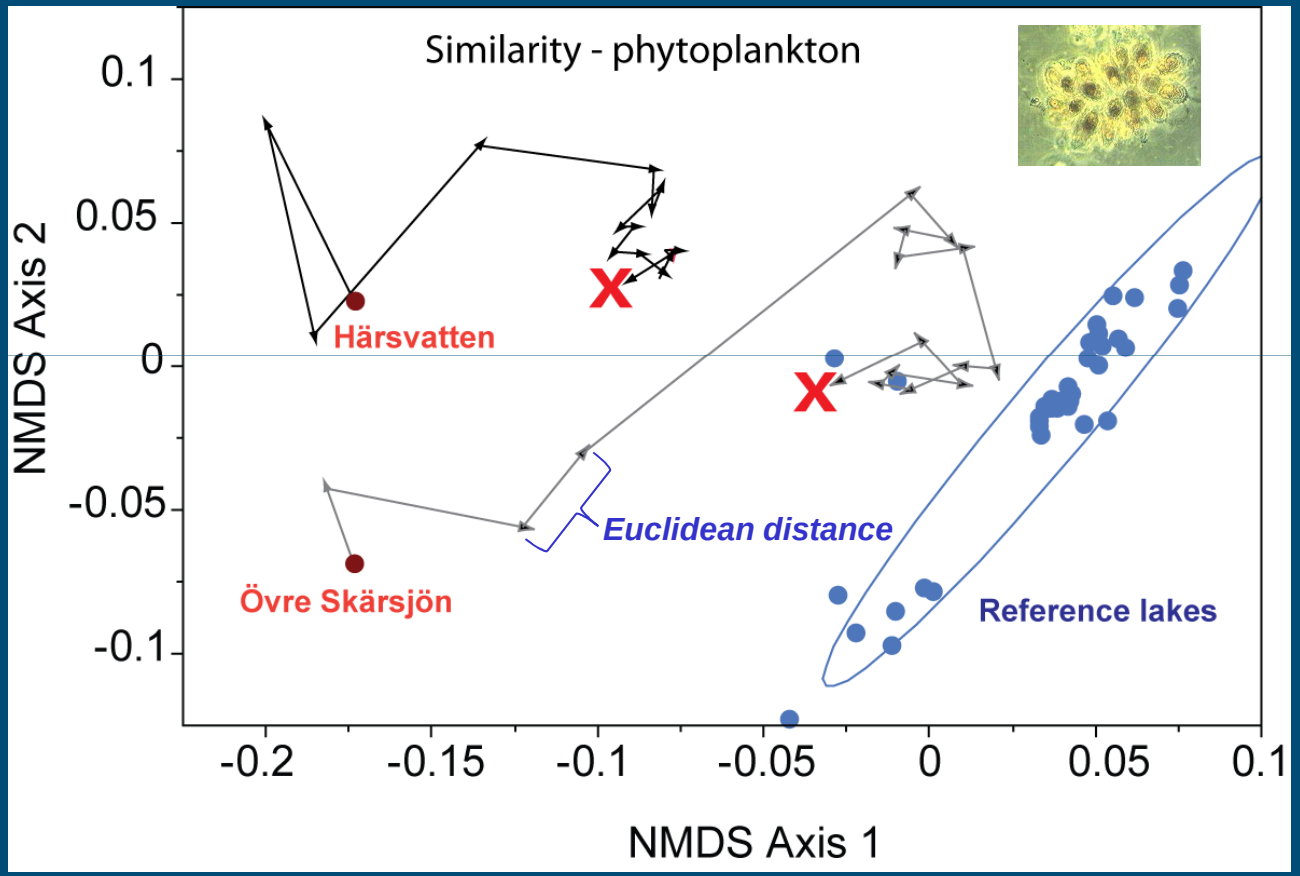


Among-year shifts in phyto-plankton assemblages



Two main drivers:

- Temperature (-0.34)
- pH (-0.32)



Johnson & Angeler (2010)

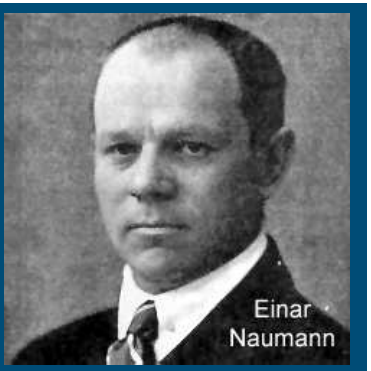
The known unknowns

- the accuracy and variance associated with methods used to establish reference conditions
- response to natural (e.g. climate) drivers and importance of scale
- misclassification errors & socioeconomic consequences (e.g. for sites with < high status)

Before we throw…

- **Establish a common framework and harmonize the use of reference criteria across MSs**
- **Develop reference concepts for all BQEs**
- **Evaluate the use of different approaches for establishing RC and their uncertainty**
  - **typology – modeling – historical**
  - **use of shared reference sites**
  - **better understanding of structure ⟷ function ⟷ resilience**

Message from a founding father of limnology



*"The advancement of the science of **water-types** —and of **regional limnology** as a whole—is of course **dependent upon the collection and comparison of as abundant data as possible from different countries**...In this respect our special journals could greatly further the advance of limnology by making it an absolute condition for publication that contributions should **provide the data in question** without which, indeed, most such communications are quite worthless for comparative purposes."*

Naumann 1929 (cited in Carlson and Simpson, 1996)