Sources of uncertainty in lake and transitional/coastal water assessment

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With contributions from a great many WISER people working in Modules 3 and 4

- Data collection
- Data management
- Data analysis

Why Ecological Status Assessment?

1. Because the WFD says so?

Why Ecological Status Assessment?

1. Because the WFD says so?

2. The ecosystem has a value in its own right
3. Biological Quality Elements (BQEs) are proxies for ecosystem services
4. The components of the ecosystem integrate the effects of one or more anthropogenic pressures (known and unknown)

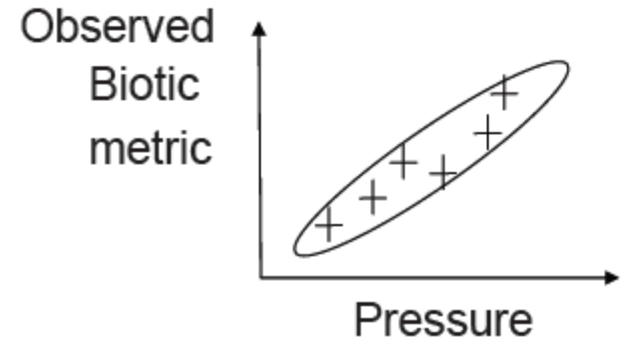
Always remember....

Our BQE based on a biological sample is always an **estimate** of a desired true quantity

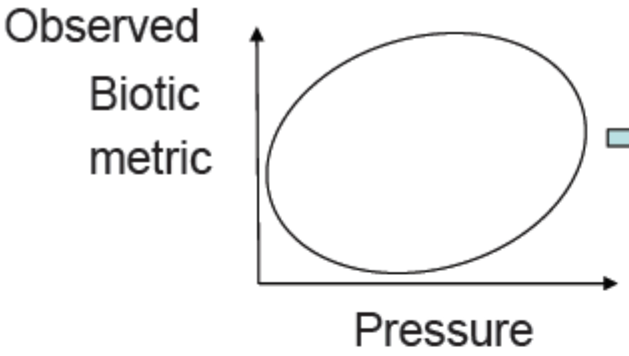
- Two types of uncertainty
  - Scale-related
  - Sampling/processing-related

- Our ideal BQE metric would be the perfect integrator:
  - not changing much in space (within our waterbody) or time,
  - it wouldn't matter how we collected or processed the sample data

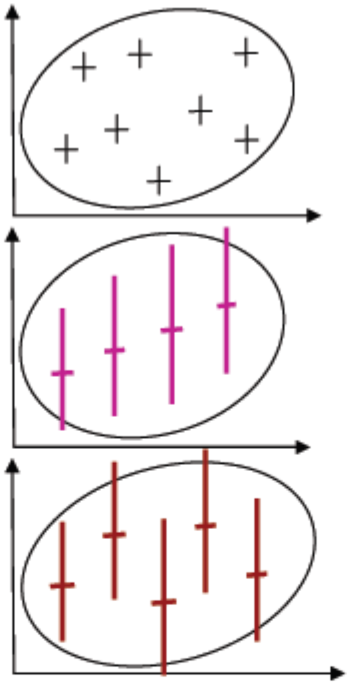
Why Quantify Uncertainty?



Underlying Relationship		Sampling variance of metric
strong	&	low



	Underlying Relationship		Sampling variance of metric
(a)	weak	&	low
(b)	strong	&	high
(c)	weak	&	high



Can only differentiate (a) - (c)

by estimating sampling precision of biotic metric

Uncertainty of status class is due to the combined effects of

- Spatial & Temporal variation within water bodies
- Sampling, sub-sampling & sample processing methods
- Reference condition modelling predictions
- Choice of biological Metrics, conversion to EQRs
- Status class limits and multi-metric multi-BQE rules
- **Hence**
  - Every decision you make can affect the WB assessment and its true uncertainty
  - Uncertainty studies can generally only focus on **some** of these issues at one time

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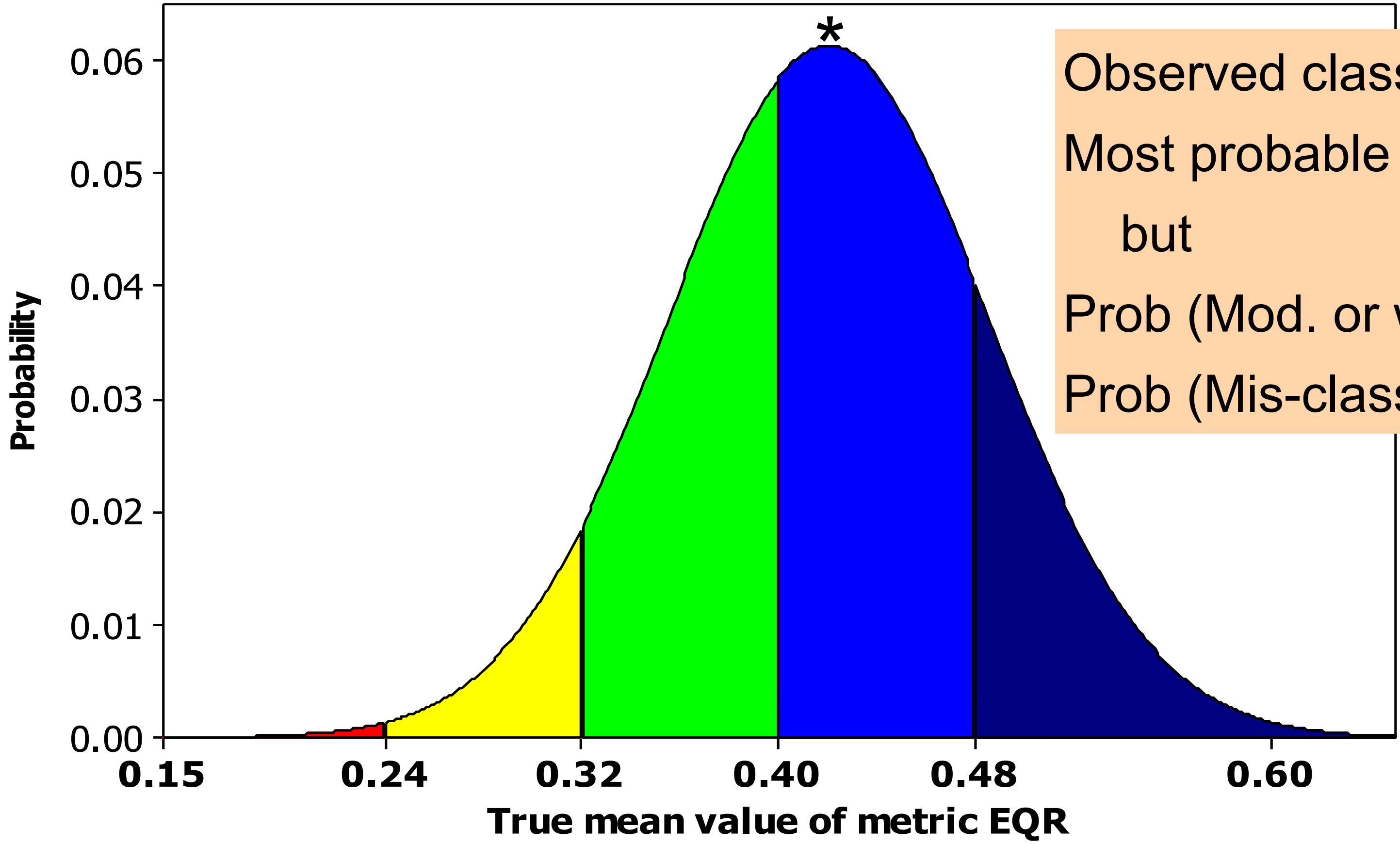
Confidence of status class and Risk of Mis-classification

Observed value = 0.42 * (Good)   Estimated Uncertainty SD = 0.065

Bad	Poor	Mod.	Good	High
0.3%	6%	32%	44%	18%



Observed class = Good

Most probable = Good (44%)

but

Prob (Mod. or worse) = 38%

Prob (Mis-classified) = 56%

Uncertainty assessments with WISER data

- Apologies in advance
- "**Foreground**" and "**Background**" data
- Methods
  - Variance components analysis
    - Derive estimates of sampling uncertainty
  - WISERBUGS
    - Simulate implications of uncertainty for status class assessment
- Comparison across BQEs and waterbody types

- Spatial
- Temporal
- Processing/laboratory/ gear/method

WISER foreground

WISER background

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Uncertainty often hierarchically structured

- (Countries), waterbodies, stations within waterbodies, transects, replicates within stations
- Represent samples of a wider population to which we are interested in generalising
- This is often called a random effect
- It is ALWAYS a categorical variable

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WISER BQEs

• Phytoplankton	Water Column
• Macrophytes/algae	Attached to bed
• Macroinvertebrates	On bed (possibly mobile)
• Fish	Mobile: both

WISER BQE metrics

- Taxonomic compositional analysis
  - Richness (+evenness etc)
  - Functional type (e.g. percentage scrapers)
  - Weighted average metrics (ASPT/Ellenberg type)

- Non-taxonomic analysis, e.g.
  - Maximum growing depth for macrophytes/algae
  - chlorophyll a for phytoplankton
- Multimetrics (can be combinations of the above)

Basic protocol to derive variance components

- **Decide on response metrics** and sources of uncertainty to be investigated
- Collate data (e.g. WISER background data)
  - Or
- Collect data (e.g. WISER foreground data) to a **specific sampling design**

- Biological quality elements
- Abiotic - covariates/”environmental”)
  - E.g. salinity, depth, modification type
- (Abiotic -pressure)
  - E.g. Nutrient concentration, hydromorphological status
- (Reference values for metrics -> EQRs)
- (Status class boundaries for EQRs)

Needed for WISERBUGS

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Basic protocol to derive variance components

- Check, code, enter data
- Graph data, check again (and again)
- Seek out missing data
- Throw away samples where missing data cannot be found
- Identify sources of uncertainty coded as categorical variables ("random effects")
- Additional explanatory variables can be continuous or categorical

WAIT….

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Basic protocol for an uncertainty analysis

- Calculate variance components for sources of uncertainty for null model
  - Preferably using mixed models approach
  - But random effects ANOVA is also possible (with limitations)
- Compare with other models with various explanatory variables
  - E.g. WB phosphorus concentration, lake type, latitude, longitude
  - Sample depth or salinity
  - Month, year etc
- Summarise results

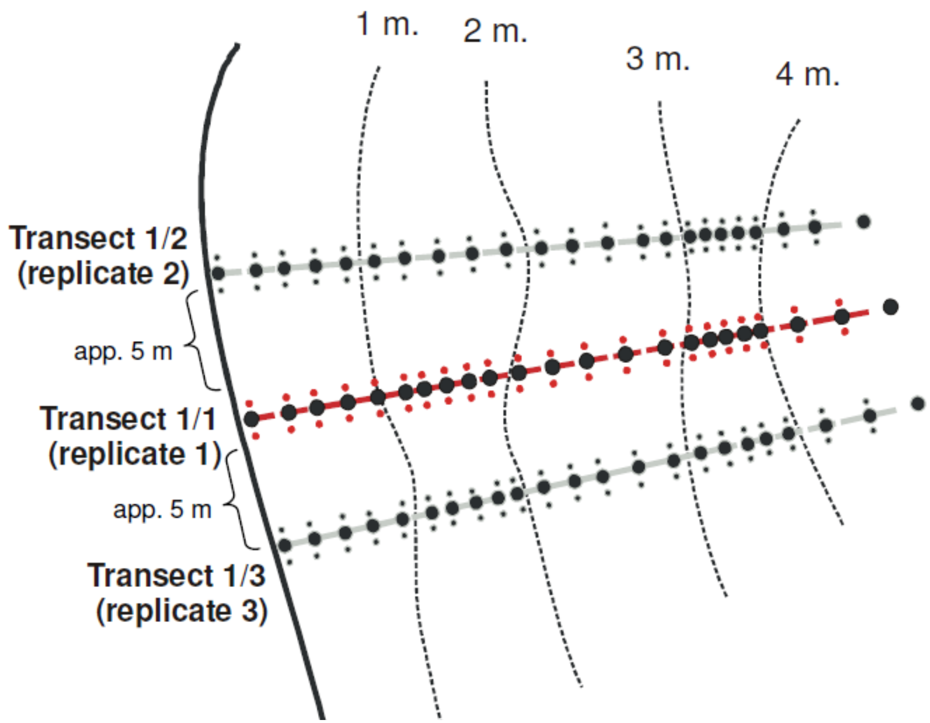
Lake macrophyte uncertainty questions

- How does the choice of using **presence-absence** data or **abundance** data affect metric uncertainty?
- How does **choice of species list** (e.g.) the inclusion or exclusion of helophytic taxa) affect metric uncertainty?
- How does surveying a restricted **depth zone** affect metric uncertainty?
- How variable are metrics between and within a lakes?

Example: Lake Macrophytes

Lake macrophyte uncertainty example

- WISER foreground data
- 28 lowland clear water lakes from 10 countries
  - (TP + alk)
- Six boat sampling stations extending from shore, 1m depth zones
- Three replicate transects per station
- Five sites per depth zone
- Several metrics** calculated



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Findings

- LM-ICM metric slightly more precise than traditional Ellenberg score
- Abundance measures added precision BUT***
- Sampling submerged taxa across a wide depth zone reduces uncertainty substantially
- Uncertainty increases and relationships break down at high pressure (no/few taxa)
- Alkalinity controls response to some extent
- C_{max} looks promising
- Taxon richness uncertain and unhelpful

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Cross-module comparisons

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Phytoplankton analyses

- The PP BQE has many different types of metric: pure taxonomic and morphological identification, and pigment analysis (traditional chlorophyll and HPLC and flouroprobe)
- Lake PP small spatial variance within WB, coastal/ transitional larger variance but manageable
- Both: lab/analytical variations significant, just about manageable
  - especially if reference metric values followed same protocol
- Helpful to have more work to agree common standards and intercalibrate across labs and countries

Phytoplankton analyses

- Spatial vs temporal (WISER background data), PTI metric

Country	0.04	
Waterbody	0.11	
Country + Waterbody		0.28
Year	0.03	
Month	0.02	
Year + Month		0.10
Residual		0.21

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Macrophyte / macroalgae analyses

- Many similarities
- Strong effects of covariates: e.g. alk, depth: can deal with in sampling strategy
- Sampling protocol and conditions
  - : e.g. uncertainty can increase with depth: this is likely partly an inevitable natural process - and partly an observational process: harder to observe at deeper depths
- Need to understand ecological processes to address uncertainty: it's not a turn the key operation.
  - e.g. metrics or even BQEs may only be appropriate for part of the pressure gradient (normally the middle part), different sampling strategies may be appropriate for different waterbody types.
- The uncertainty increases just at the point on the pressure gradient that you are interested in. e.g. for C_{max}. Ecologically, when one stressor: lack of light penetration is highest, plants more likely to be affected by other stressors and limiting factors

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Invertebrate and fish analyses

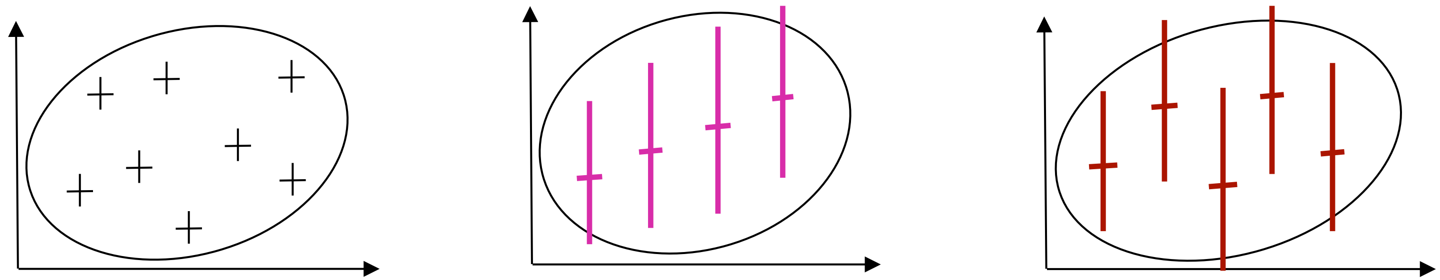
- Macroinvertebrates
  - Differences between shoreline habitats
  - Further work needed to define metrics and sampling protocols

- Fish
  - Again metrics can be tricky: residuals can be highly non-normal. This has implications for metric development and calibration against pressures
  - Clearly covariates, e.g. depth, salinity important

All analyses

- Phytoplankton and macrophytes/algae ✓ ✓

- Invertebrates and fish: more to do



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WISERBUGS

WISER
Bioassessment
Uncertainty
Guidance
Software

WISER Deliverable D6.1.3

Obtainable from :
www.wiser.eu/highlights

produced by

Ralph Clarke

Bournemouth University

Software product written to provide a general means of using SIMULATIONS to assess the effects of sampling variation & other errors on the UNCERTAINTY and CONFIDENCE of assigning water bodies to WFD ecological STATUS CLASSES based on the Ecological Quality Ratios (EQR) for either single metrics or multi-metric indices (MMIs) and/or rules involving one or more BQEs

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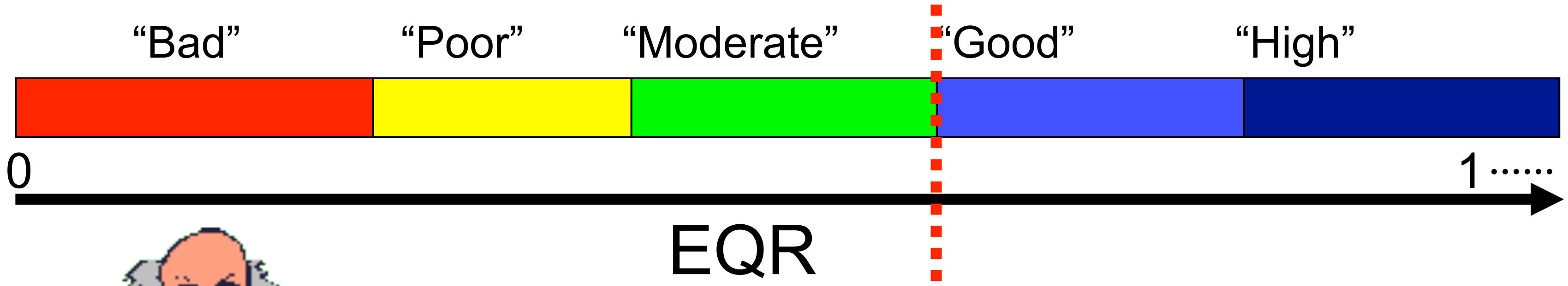
$$\text{Ecological Quality Ratio (EQR)} = \frac{\text{Observed value of metric}}{\text{Metric reference value}}$$

Classify into WFD Ecological status classes



Uncertainty of class

is required by WFD

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WISERBUGS also helps you:

- Assess uncertainty (probability) of status class in single and multi-metric EQR-based assessment systems based on single or multiple BQE sample/survey data
- Easily try out different (multi-metric and/or multi-BQE) status class systems on real WB sample metric values

WISERBUGS does not help you:

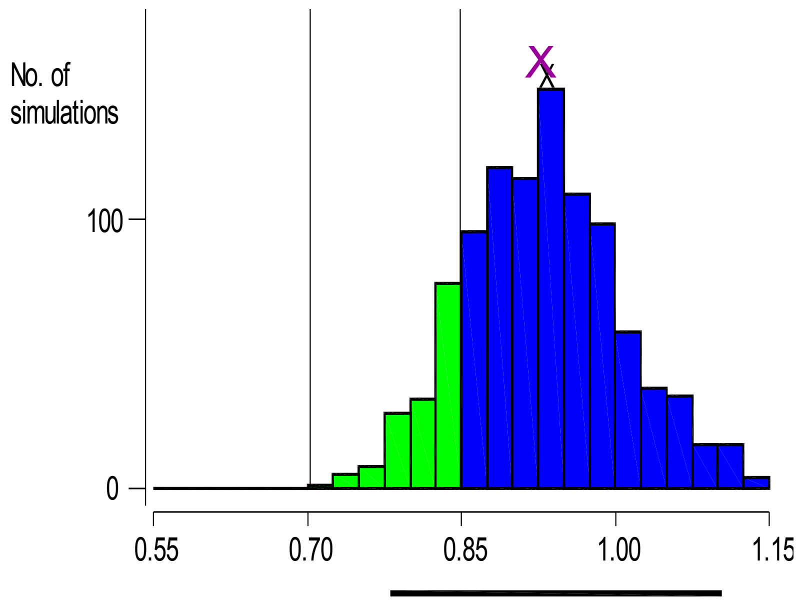
- Derive the required prior estimates of sampling variances for the observed values of each metric for each water body
- Derive reference condition values for EQRs
- Derive status class boundaries
- Make your breakfast

WISERBUGS Uncertainty Simulation model

Metric 1 : EQR = 0.94

X = observed class = ‘high’

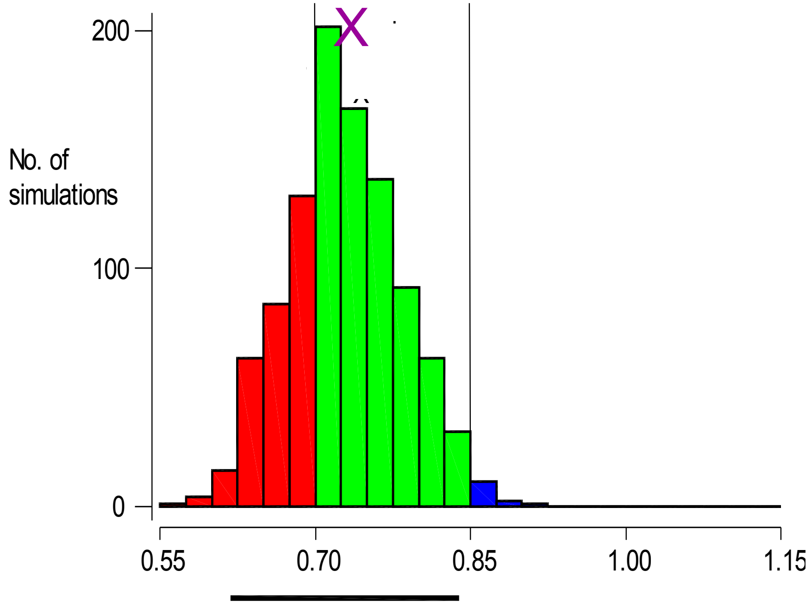
‘mod’ 0% ‘good’ 15% high’ 85%



Metric 2 : EQR = 0.75

X = observed class = ‘good’

‘mod’ 30% ‘good’ 69% high’ 1%



based on *n* = 1000 simulations

Poseidonia oceanica (Bennett et al.)

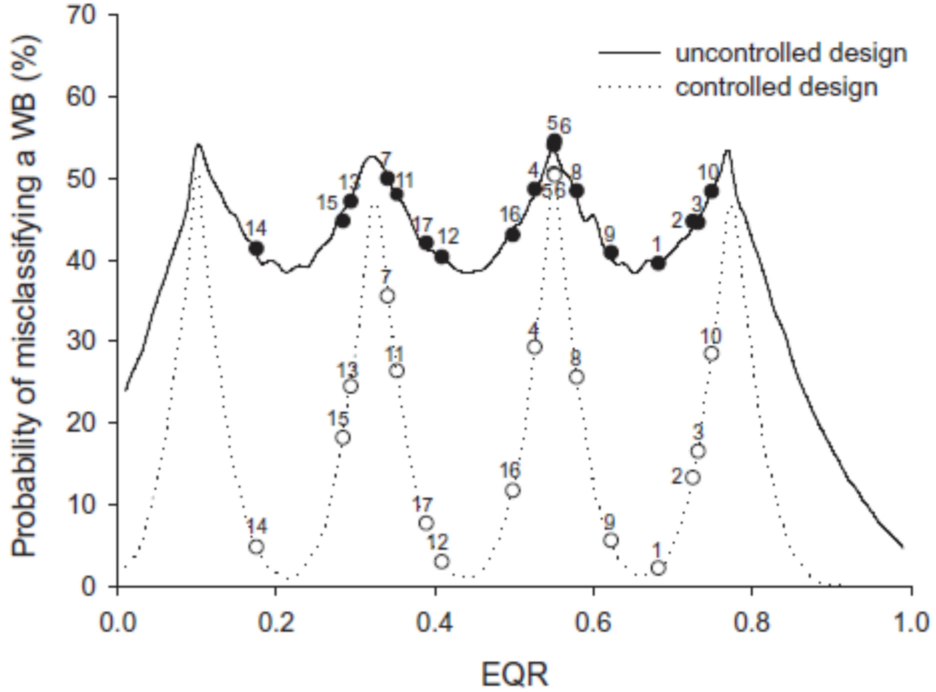


Fig. 3. Probability of misclassifying the ecological status class given the total variability among mean EQR values calculated by POMI 14 based on a 'controlled sampling design' and an 'uncontrolled design'. The controlled design represents among site variation and among depth (10–17 m) variation. The uncontrolled design represents cumulative variation, among zones, among sites, among years, among depths (5–17 m) and among surveyors. Full and open circles represent the actual probability of misclassification for 17 Catalonian coastal water bodies. Numbers represent the water body (Fig. 1). Probabilities are based on the 2008 data series.

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WISERBUGS

Demonstration and/or advice on assessing uncertainty

available for individual users

during this afternoon's poster session

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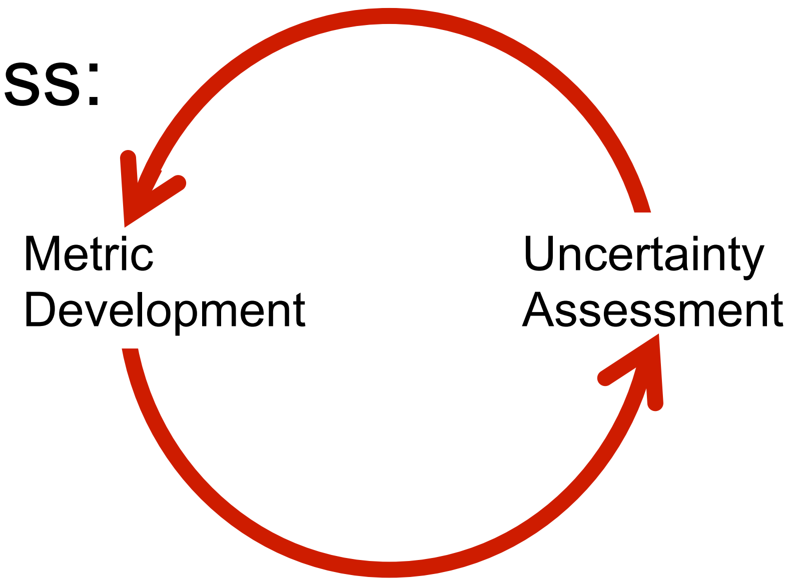
Take-home messages

- Considerable planning needed to quantify uncertainty
- No one observational study can address all aspects of uncertainty
- Data preparation takes a long time....................
- Iterative process:



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Take-home messages

- Many compelling reasons to undertake bioassessment
- BUT uncertainty needs to be managed, not ignored
- Uncertainty depends on the BQE and metric
  - Distributional assumptions
- Uncertainty depends on where you are on the stressor gradient
- Spatial uncertainty – driven by patchiness – for macrophytes / macroalgae, macroinvertebrates, fish
- Temporal uncertainty e.g. phytoplankton
- Sample processing e.g. Phytoplankton
- .... more to come.....

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WISERBUGS messages

- WISERBUGS meets the requirement of the WFD to provide uncertainty estimates of status class
- Where metric near class boundary, class uncertainty will always be high
- Physical / chemical / temporal covariables can remove alot of uncertainty
- .....more to come.....

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Thanks again to everyone who has contributed

Thank you for listening, any questions?

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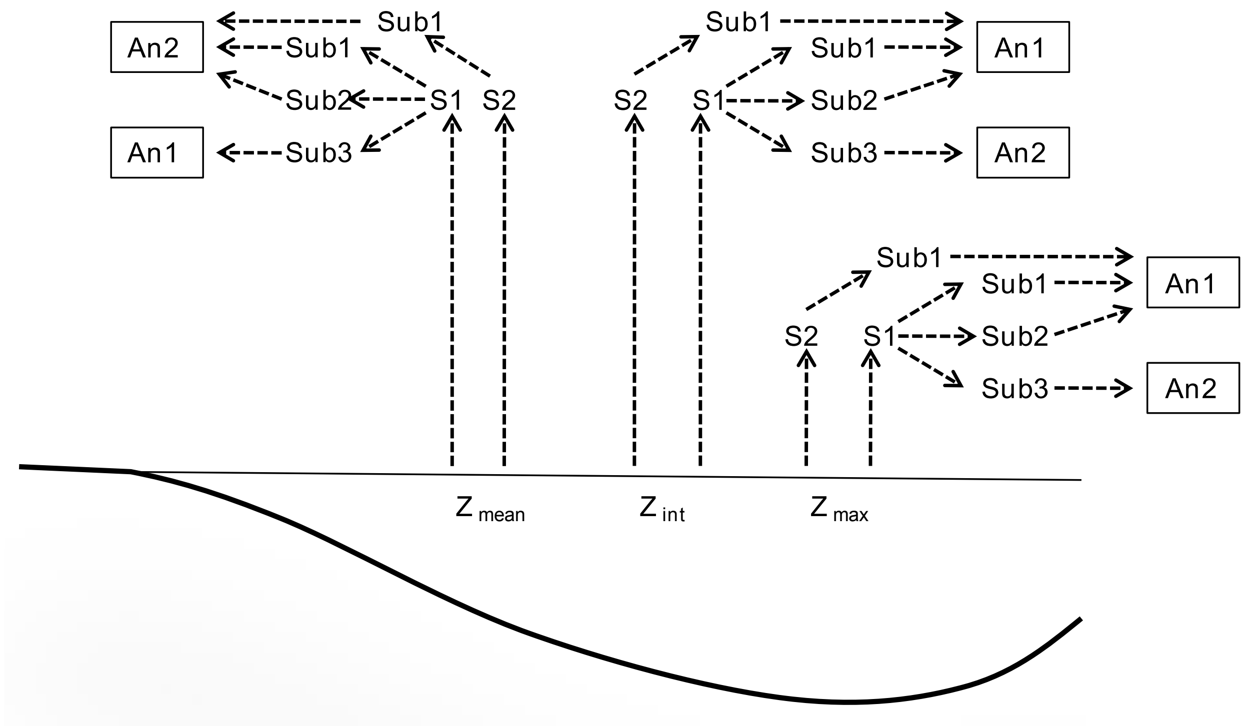

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- Waterbodies vary in abiotic characteristics. Where these characteristics are likely to lead to variations in metrics, this can be controlled for by measuring the characteristics and including them in uncertainty models or by developing a protocol restricting sampling
  - E.g. depth for fish, macrophytes/algae, also salinity
  - Also time of year for phytoplankton

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