FRESHWATER CENTRE

Biomonitoring: Indicators and monitoring design

Dr. Kristian Meissner, SYKE, Freshwater Centre, Monitoring and Assessment unit

UNDP/GEF Kura Aras project &
SYKE/NEA Georgia water project joint
Scientific training
Tbilisi 27-30.3.2012

S Y K E

FRESHWATER CENTRE

Educational background

- M.Sc.: Hydrobiology and Limnology, University of Jyväskylä, 1996
- Ph.D.: Zoology (Aquatic ecology); University of Oulu, 2005

SYKE

FRESHWATER CENTRE

Main professional interests

- **Biomonitoring**
  - Sampling designs
    - Coordinator of national biomonitoring
  - Statistics, computer vision & new techniques
    - Research on the application of computer vision to taxonomic identification
    - In depth statistical analysis of the current biomonitoring design and indices
    - Research on new bioindicators and sampling methods
    - Currently supervising 2 Ph.D. students and 3 M.Sc. Thesis (applied aquatic ecology and statistics)
- **Quality assurance**
  - Taxonomical proficiency tests
    - coordinator of proficiency test on macroinvertebrate identification
  - Water quality CEN/ISO standardization biological methods
    - Chairman of the national subcommittee ISO/TC147/SC5 and CEN/TC 230/WG2

SYKE

FRESHWATER CENTRE

Structure of the talk

1. The importance of specifying the goal of biomonitoring

2. Biointegrety and biomonitoring
3. Reference condition
4. Typology
5. Biological quality elements
6. Taxonomic resolution
7. Indices and overall design
8. Quality control

SYKE

The importance of specifying the goal of biomonitoring

What is the purpose of biomonitoring?

- Biodiversity inventories
- Detect long term trends
- Impact assessment
- **Ecological status assessment (WFD)**

What is the temporal and spatial extent ?

- One time survey?
- Before & after?
- **Longterm monitoring ?**

FRESHWATER CENTRE

SYKE

FRESHWATER CENTRE

The goal ?

Effective monitoring schemes based on the use of biological indicators of aquatic ecosystem biointegrity should:

- quantify and simplify complex ecological phenomena
- provide easily interpretable outputs
- respond predictably to damage caused by humans, while being insensitive to natural spatial/ temporal variation
- relate to an appropriate scale
- relate to management goals
- be scientifically defensible

(Norris & Hawkins 2000)

SYKE

FRESHWATER CENTRE

Long term biomonitoring

Any long term biomonitoring requires:

- Long term **commitment and good planning**
- Sufficient monitoring infrastructure and personnel
- Co-operation with other agencies
  - national (e.g. universities)
  - international (neighboring countries, EU)
- Specification of goals
  - e.g. maintenance **biological integrity**
- **Appropriate biocriteria**
  - **variables and indices**
- **Rigorous quality control**
- Continuous revision and improvement

SYKE

Biological integrety (ecosystem health)

- based on the analogy of ecosystems to e.g the human body
- if a system is ”sick” i.e. not in **reference condition**, it changes
- **Detecting ecosytem change** (i.e., degradation and recovery) is one aim of the EU WFD
- Changed state models (CSM) form the basis of WFD classification and monitoring
- Originally based on physico-chemical variables modern CSMs incorporate biological variables (bioindicators)
- CSMs aim at identifying what human-generated pressures (or stressors) are acting as **drivers of change**
- CSMs rely on ecological monitoring and biological assessment

FRESHWATER CENTRE

Reference condition

Interpretation of measured variables from ecological indicators requires that index scores for sampled sites are compared against some expectation this expectation is called the “reference condition” (RC)

Even a set of similar undistubed sites will exhibit variation in biological attributes, therefore RC is always a distribution that includes sampling error and natural variability, both in time and in space

SYKE

Reference condition (RC)

Can refer to :

- Historical condition HC
  - Before settlement or modern agricultural practices
  - Can use paleolimnological data
- Minimally disturbed condition MDC
  - no significant human impact
- Least disturbed condition LDC
  - best available today
  - Can change over time
- Best attainable condition BAC
  - least-disturbed sites if the best possible management practices were in use for some period of time

Stoddard et al. 2006

FRESHWATER CENTRE

Historical condition: an example

Limnologica 42 (2012) 19–30

Contents lists available at ScienceDirect

Limnologica

ELSEVIER

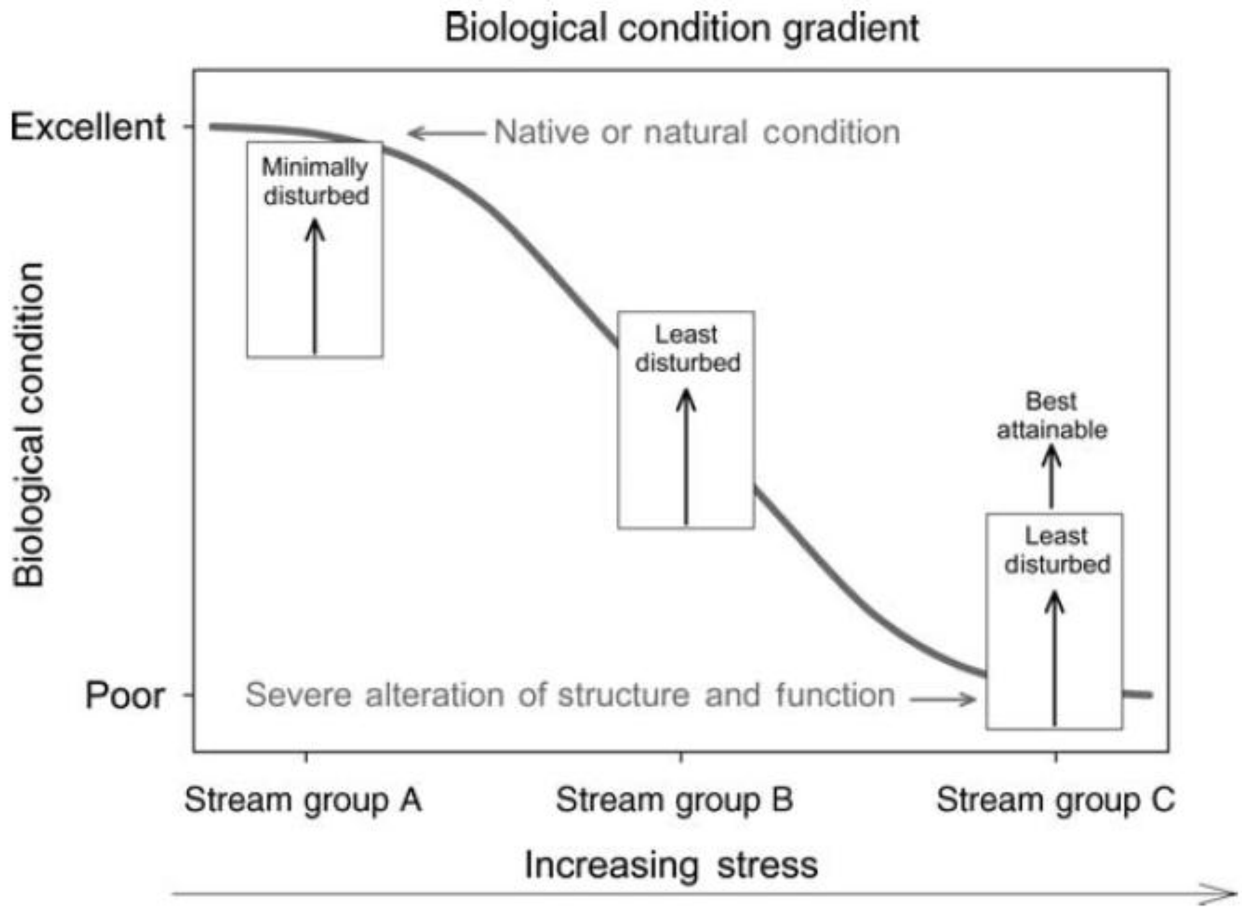
journal homepage: www.elsevier.de/limno

Comparing long term sediment records to current biological quality element data – Implications for bioassessment and management of a eutrophic lake

Tommi Kauppila[a,*], Antti Kanninen[b,c], Matias Viitasalo[d], Johanna Räsänen[e], Kristian Meissner[f], Jukka Mattila[g]

SYKE

Dilemma involved with the different RC definitions



Stoddard et al. 2006 Ecological. Applications. 16: 1267-1276.

Establishing reference condition (RC)

Find and document least-disturbed sites

- ○ if MDC sites are unavailable

- **describe their biological characteristics**
- Finding MDC/LDC sites can involve screening of sites based on known characteristics such as:
  - Phosphorous or nitrate
  - Land use coverage <e.g.10% agriculture
  - **Typology** (e.g. lowland vs. mountain streams)
- Good starting points are freshwaters situated in protected areas or far from human activity
- Having many reference sites will increase ecological status assessment
- Establishing reference conditions is a **long-term effort**
- Cooperation speeds up the process

FRESHWATER CENTRE

RC for river types in Finland

TYPE	Phytobenthos	Aquatic plants	Macroinvertebrates	Fish
Pt[1]	8		28	
Pk[1]	10		53	
Psa[1]				
Pt	34	12	60	8
Pk	37	6	61	4
Psa	1	2		
Kt	29	8	47	44
Kk	39	7	27	30
Ksa		5		1
St	14	4	18	58
Sk	19	4	19	71
Ssa				
ESt			4	21
Esk	11		1	
Pk-PoLa[1]			19	
Pk-PoLa	14		17	
Kt-PoLa	5			
Kk-PoLa	17		11	
St-PoLa				
Sk-PoLa			7	12
Esk-PoLa	6		1	
Total	**244**	**48**	**373**	**249**

SYKE

FRESHWATER CENTRE

Typology

Typology is the devision of waterbodies on the basis of some predetermined characteristics and important for RC

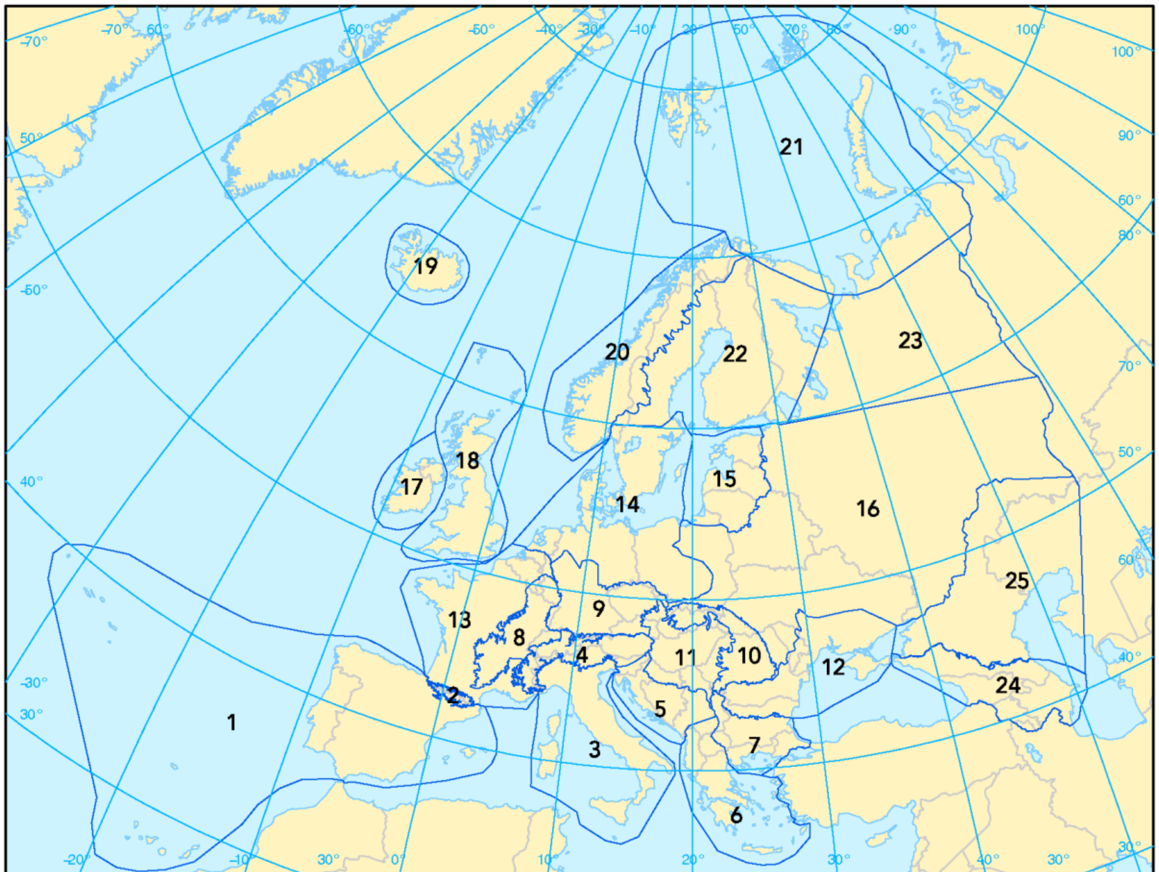
WFD System A (Annex II) creates 36 potential stream types:

- Altitude typology
    - High: >800m
    - Mid-altitude: 200 to 800m
    - Lowland: <200m
- Size of catchment area
    - Small: 10 to 100 km2
    - Medium: >100 to 1000 km2
    - Large: >1000 to 10000 km2
    - (Very Large: >10000 km2)
- Geology
    - Calcareous
    - Siliceous
    - (Organic)

SYKE

FRESHWATER CENTRE

Ecoregion 24- the Caucasus



Ecoregions for rivers and lakes

1. Ibero-Macaronesian region
2. Pyrenees
3. Italy, Corsica and Malta
4. Alps
5. Dinaric western Balkan
6. Hellenic western Balkan
7. Eastern Balkan
8. Western highlands
9. Central highlands
10. The Carpathiens
11. Hungarian lowlands
12. Pontic province
13. Western plains
14. Central plains
15. Baltic province
16. Eastern plains
17. Ireland and Northern Ireland
18. Great Britain
19. Iceland
20. Borealic uplands
21. Tundra
22. Fenno-scandian shield
23. Taiga
24. The Caucasus
25. Caspic depression

source: EEA http://www.eea.europa.eu/data-and-maps/figures/ecoregions-for-rivers-and-lakes

SYKE

After typology: What biological quality element should be measured for RC definition?

Lakes:

- **Macroinvertebrates littoral / (profundal)**
- **Aquatic plants**
- Phytoplankton
- Fish

Streams:

- **Macroinvertebrates**
- Diatoms
- Fish

(WFD Annex V requires several biological quality elements)

FRESHWATER CENTRE

Benefits of macroinvertebrates

- Occur in virtually all freshwaters
- Taxon rich indicator group
- Taxa have different responses to different environmental gradients (organic pollution, acidification, heavy metal loads…)
- Integrate changes over time
  - intermediate timescale responses

SYKE

FRESHWATER CENTRE

Establish national taxonomic resolution

Taxonomic resolution affects metric choice and results, irrespective of biological quality element used. High resolution (gena, species) is advised if possible and reliable

- Gather all available information on the species found in your country/ ecoregion
  - E.g. from old publications & reports; former staff
- Find all relevant taxonomic keys
- Decide which taxonomic resolution will be used
  - May vary for different taxa
  - Can be dependent on the difficulty of keying or availability of taxonomic literature available
  - Exchange ideas with national and international experts
- Update this standardized taxonomy list regularly or as needed

SYKE

Choosing metrics

In the WFD context , macroinvertebrate assessments should provide information on :

- Abundance
- Community
- Ratio of disturbance sensitive taxa to insensitive taxa
- Biodiversity

Choosing metrics

A vast number of indices are available (about 300 in the EU):

- AverageScorePerTaxon (ASPT , Armitage et al. 1983)
- Number of species, gena or families belonging to the EPT (Ephemeroptera, Plecoptera, Trichoptera) **streams**
- Number of species, gena or families belonging to the ETO (Ephemeroptera, Trichoptera, Odonata) **lakes**

Metrics that require RC:

- Type specific taxa (EPT or other)
  - requires information on species occurrences
  - Requires standardized taxonomic resolution
- Percent model affinity (Novak & Bode 1992)

FRESHWATER CENTRE

Uses of your taxonomic data

Short-term benefits:

- Taxa data can be used to calculate a vast array of different indices
  - Establish current ecological conditions

Long-term benefits

- Taxa data can be used to assess geographical trends and changes in water quality
- Can substitute missing “before” data in cases of environmental accidents
- Multivariate analysis

Note: Not all indices are necessarily relevant or useful

FRESHWATER CENTRE

Example: Indices chosen into the Eastern Continental Geographical intercalibration group (EC- GIG)

COMMON METRIC	WFD INDICATIVE PARAMETER	INDICATED PRESSURE
Average Score Per Taxon (ASPT)	Sensitive Taxa	Organic Pollution, General degradation
Total Number of Families	Taxonomic composition	Diversity, General Degradation
[%] EPT Abundance	Taxonomic composition, Abundance, major taxonomic groups	Organic Pollution, Structural and General degradation

SYKE

The benefit of using standardized operating procedures

The WFD requires that methods used for sampling are based on standards (CEN/national)

- Results will be comparable between location and sampling occasions
- Variation between operators will decrease significantly
- SOP will guarantee long term comparability
- Using the same SOP on a national (and international) level will increase the amount of data available for status assessment and decrease overall costs
- Intercalibration on an international level is easier

Joint training and cross auditing of SOPs

- Organizing joint training for sampling staff will maintain high data quality
  - Training should demonstrate procedures and point out the most common mistakes

- Regular cross auditing of trained sampling operators helps spotting problems at an early stage and will increase
  - overall commitment
  - operating safety
  - data reliability
  - co-operation between different organizations
  - information exchange
  - further development of sampling methodology

Monitoring design

Starting long-term monitoring requires good planning

- Continuity is important
- When financial resources are scarce,
  - rotating designs may help
  - Co-operation and exchange of data on reference sites will extend your capabilities
    - Requires common SOP

FRESHWATER CENTRE

Rotating panel design

- Urquhart, N. S., S. G. Paulsen and D. P. Larsen. (1998). Monitoring for policy-relevant regional trends over time. Ecological Applications 8 : 246 – 257.
- Rotating panel designs reduce the amount of sampling needed (saves resources) by using rotation of sites instead of continuously monitoring the same sites
- This highly increases the number of sites that can be sampled with the same effort
- Powerful design that will pick up trends well (a major aim of the WFD)

SYKE

Rotating panel: simple & augemented

PANEL	SIZE	TIME PERIODS (=YEARS)												
		1	2	3	4	5	6	7	8	9	10	11	12	...
DESIGN 1 = SAME SITES (= LAKES)														
1	60	X	X	X	X	X	X	X	X	X	X	X	X	...
DESIGN 3 = AUGMENTED SERIALLY ALTERNATING														
1	50	X				X				X				...
2	50		X				X				X			...
3	50			X				X				X		...
4	50				X				X				X	...
COMMON	10	X	X	X	X	X	X	X	X	X	X	X	X	...

Urquhart et al. 1998:Ecological Applications 8 : 246 – 257.

Rotating panel: augmented and alternating

DESIGN 4 = PARTIALLY AUGMENTED SERIALLY ALTERNATING														
1	35	X				X				X				...
2	35		X				X				X			...
3	35			X				X				X		...
4	40				X				X				X	...
1A	5	X	X			X				X				...
2A	5		X	X			X				X			...
...	...													...
1B	5	X				X	X			X				...
...	...													...
1C	5	X				X				X	X			...
...	...													...

Urquhart et al. 1998:Ecological Applications 8 : 246 – 257