Biomonitoring in the Water Framework Directive

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December 2000: A Milestone for Water Policy

- December 22, 2000, will remain a milestone in the history of water policies in Europe
- on that date, the Water Framework Directive was published and entered into force
- This Directive is the result of a process of more than five years of discussions and negotiations between a wide range of experts, stakeholders and policy makers.
- This process has stressed the widespread agreement on key principles of modern water managemnt

WFD Overall Goal and Roadmap

- **The Directive aims at achieving *good water status* for all waters in the EU countries by 2015.**

- **What are the key actions that Member States need to take?**
  - Identify the individual river basins and assign them to individual River Basin Districts (RBDs) (Article 3, Article 24);
  - Characterize each river basin district in terms of pressures, impacts and economics of water uses (Article 5, Article 6, Annex II, Annex III);
  - Carry out the inter-calibration of the ecological status classification systems (Article 2 (22), Annex V);
  - Make the monitoring networks operational (Article 8);

What are the key actions that Member States need to take?

- Identify a programme of measures for achieving the environmental objectives of the WFD (Article 11, Annex III);
- Produce and publish River Basin Management Plans (RBMPs) for each RBD (Article 13, Article 4.3);
- Implement water pricing policies that enhance the sustainability of water resources (Article 9);
- Make the programme of measures operational (Article 11);
- Implement the programmes of measures and achieve the environmental objectives (Article 4).

Integration: a key concept underlying the Water Framework Directive

- **Integration of environmental objectives,** combining quality, ecological and quantity objectives for protecting highly valuable aquatic ecosystems and ensuring a general ‘good’ status of other waters;

- **Integration of all water resources**, combining fresh surface water and groundwater bodies, wetlands, coastal water resources **at the river basin scale**;

- **Integration of all water uses, functions and values** into a common policy framework,

- **Integration of disciplines, analyses and expertise,** to assess current pressures and impacts on water resources and identify measures for achieving the environmental objectives of the Directive in the most cost-effective manner;

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Integration: a key concept underlying the Water Framework Directive

- **Integration of water legislation into a common and coherent framework.**
- **Integration of all significant management and ecological aspects** relevant to sustainable river basin planning;
- **Integration of a wide range of measures, including pricing and economic and financial instruments, in a common management approach**
- **Integration of stakeholders and civil society in decision making,**
- **Integration of water management by different Member States,** for river basins shared by several countries

Water Quality Monitoring in the WFD

- Appropriate implementation of Monitoring programmes in line with the Directive will vary from one river basin to another
- This variation is due to the diversity in the following characteristics:
  - The catchment pressures,
  - Water-body types,
  - Biological communities
  - Hydromorphological and physico-chemical characteristics

Is there a prescriptive Methods for the Assessment of Ecological Status

- No prescriptive methods for the assessment and classification of ecological status due to :
  - There are a number of existing classification systems already in use, some of which have been incorporated into National Standards;
  - Individual Member States generally understand local natural variations in biological communities, hydromorphological conditions and physico-chemical variables;
  - The level of habitat detail required varies for different indicators depending on their sensitivity to natural variation in habitat conditions
  - There are existing international, European and national standards for a number of the required quality elements

Key Criteria for Monitoring program

- Appropriate monitoring program should incorporate the following key criteria :
  - Assess the deviation from the reference conditions;
  - Provides for natural and artificial physical habitat variation;
  - Accounts for the range of natural variability and variability arising from anthropogenic activities;
  - Accounts for interactions between surface and ground waters
  - Provides for detection of the full range of potential impacts to enable a robust classification of ecological status.

Monitoring Design Considerations

- What are the biota and flora present in the stream?
- What are the water quality elements to be classified and how?
- How are the surface water quality elements sampled?
- Where are they to be sampled?
- What confidence level is needed for the monitoring system statistical results?
- Is it necessary to sample all streams?
- Will one sample per month or season be sufficient?
- What are the financial resources available for surface water quality?

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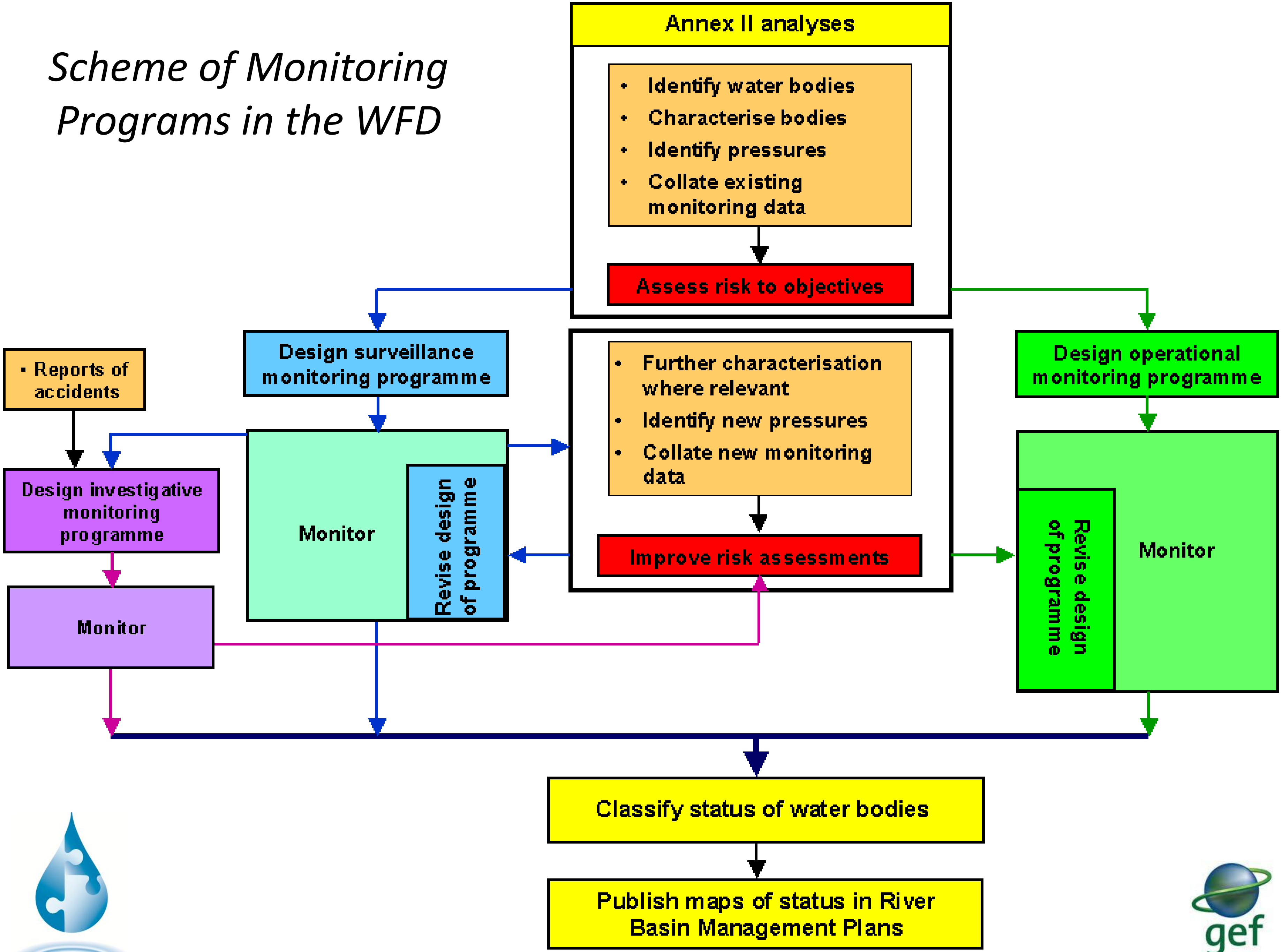
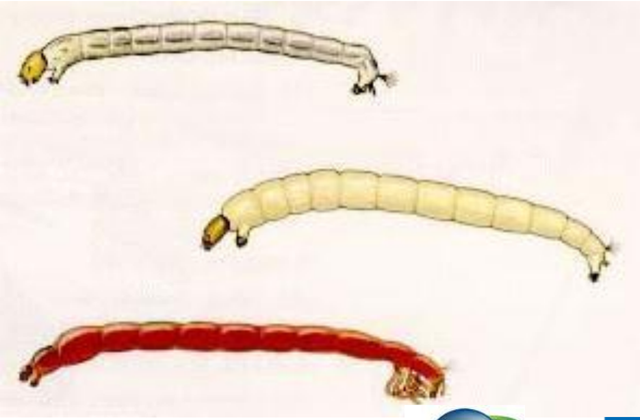
Scheme of Monitoring Programs in the WFD



Why Biological Monitoring

- To classify water bodies (high, good, moderate, poor and bad)
- Chemical and hydro-morphological monitoring supplies supporting information
- shows the impact of the pollution on the structure and functioning of the ecosystems
- Macroinvertebrate monitoring in rivers is relatively cheap compared to chemical monitoring.



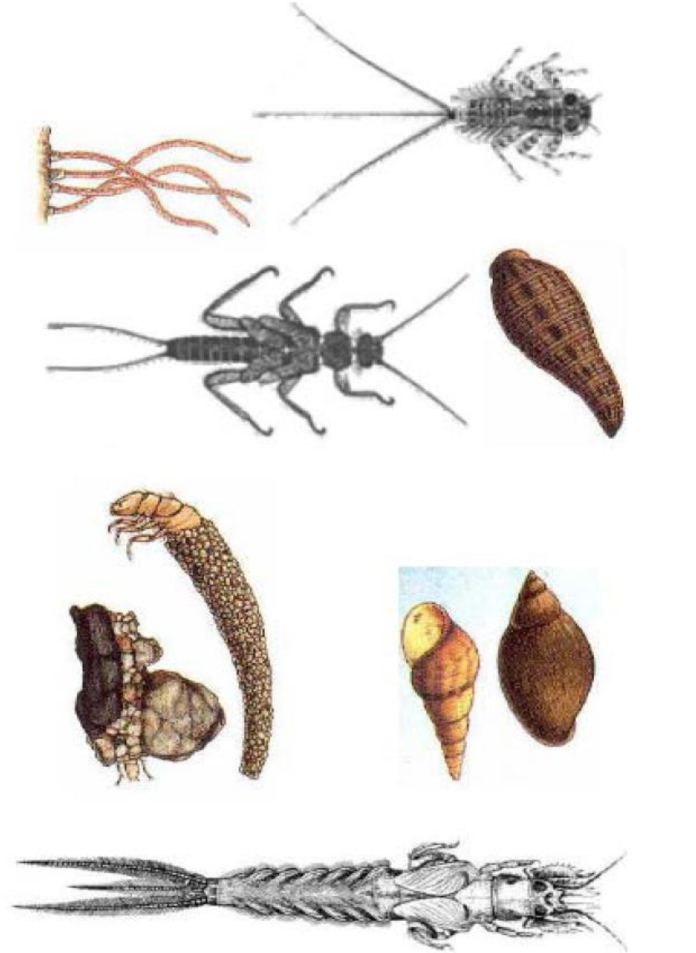
Biological Monitoring in the WFD

- estimates of the values of the biological quality elements using specified indicator parameters.
- The use of indicator parameters should facilitate reliable and cost-effective assessments:
  - Monitoring whole biological quality elements, versus monitoring indicator species.
  - the possibility of using more than one indicator avoiding unacceptable risks of misclassification. This is because the results for different indicators can be crosschecked.

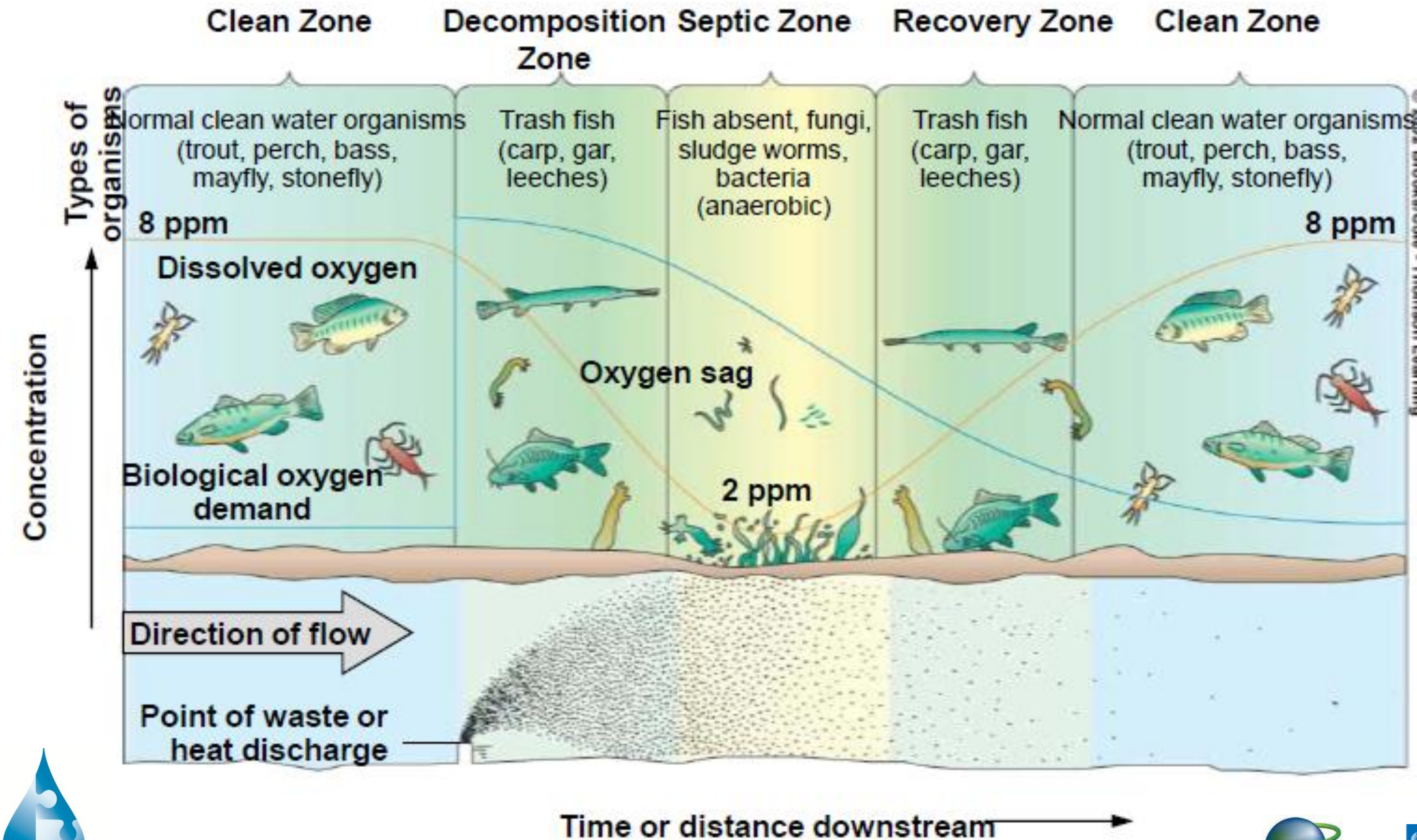
Biological Monitoring in the WFD

- **The use of non-biological indicators may complement the use of biological indicators but it cannot replace it.**

- **Using biological indicators will always be necessary to validate any biological impacts suggested by non-biological indicators**



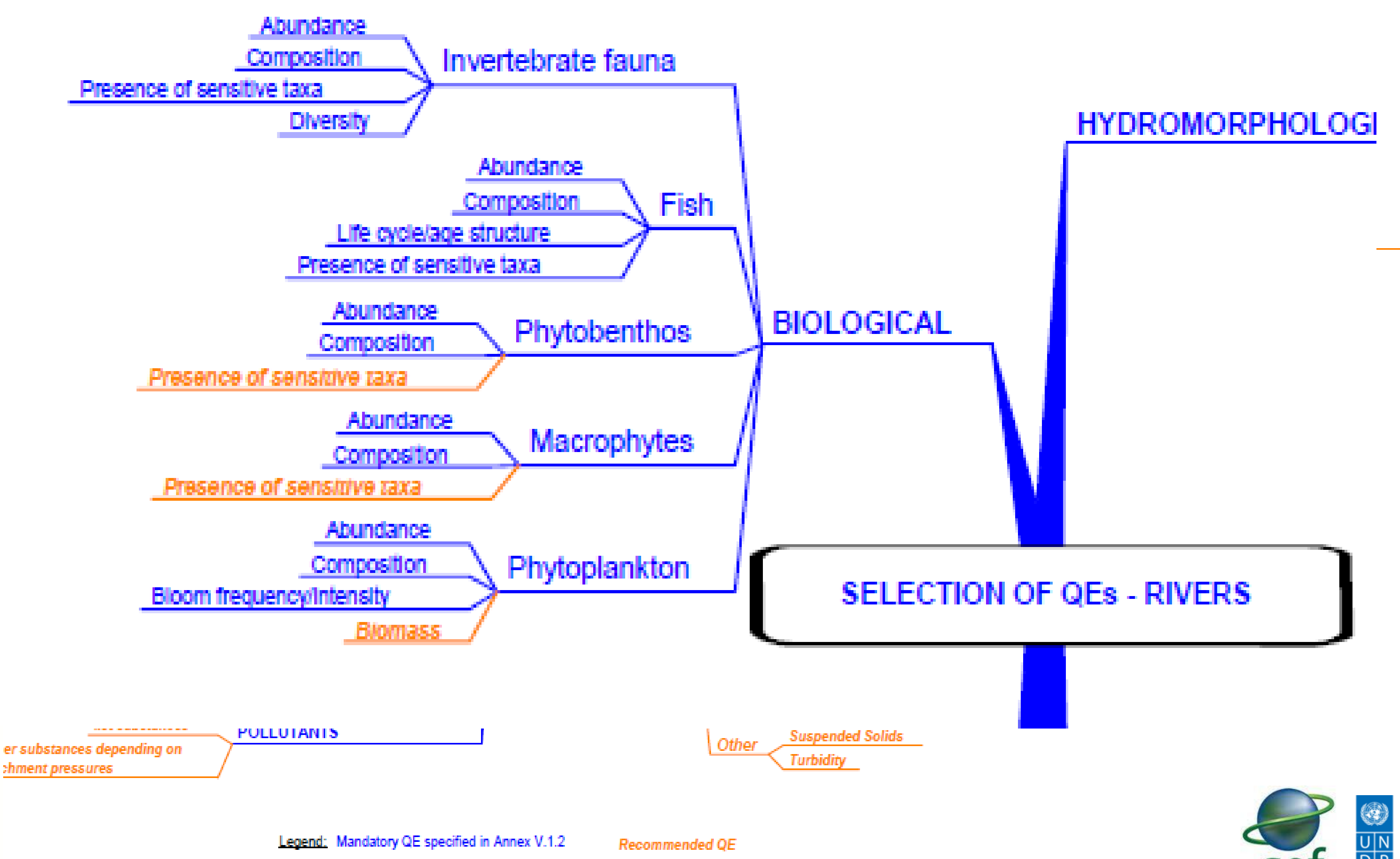
Range of Tolerance



Assessing the Biological Status

- According to the WFD, the biological status of surface water is to be assessed using:
  - the elements phytoplankton,
  - other aquatic flora,
  - macroinvertebrates and fish fauna.
- The preliminary assessments of ecological status should be based on the most sensitive quality elements with respect to the existing physical alterations.
- Effects resulting from other impacts should be excluded as far as possible.

Selection of Quality Elements for Rivers



Suggestions on the suitability of biological elements as indicators for physical alterations

- Benthic invertebrate fauna and fish are the most relevant groups for the assessment of hydropower generation impacts;
- Long distance migrating fish species can serve as a criterion for the assessment of disruption in river continuum
- Macrophytes are good indicators of changes in flow downstream of reservoirs as well as for the assessment of regulated lakes because they are sensitive to water level fluctuation; and,
- For flood works, benthic invertebrate fauna and macrophyte are most appropriate indicators

Key Biological Quality elements

Monitoring Macroinvertebrates

- The use of macroinvertebrates to assess the effects of organic pollution of rivers is the most commonly used element for biological classification of rivers in Europe.

- More recently methods for using macroinvertebrates as indicators of other pressures including toxic chemicals and alterations in river flows and channel morphology, have or are being developed.

- The sensitivity of macroinvertebrates to a wide range of impacts makes them a very useful tool for assessing river quality.

- They are less useful in deep rivers where they may be difficult to sample.

Key Biological Quality elements

Monitoring Macrophyte

- Monitoring macrophyte community structure and biomass is most relevant for assessing the impacts of eutrophication in small to medium-sized rivers.
- They can be used for assessing the impacts of high flows and flow variation associated with hydropower effects and of stream maintenance.
- They are not widely used in large, deep river systems or in more shallow rivers subject to wide flow variations.
- They can also be used absent in streams in dense forested areas.
- Methods are available and several countries use macrophytes for river quality assessment.

Key Biological Quality elements

Monitoring phytoplankton

- Benthic algae currently have limited use in European countries but are valuable under some circumstances,
- Diatoms and filamentous algae have been used most effectively for this purpose.
- River phytoplankton species and abundance are important indicators of eutrophication but are limited in their use to large, slow flowing rivers.

Key Biological Quality elements

Monitoring Fish

- The use of fish as indicators of impacts on river systems is relatively uncommon across Europe.
- they are difficult to sample without specialist equipment
- The monitoring results are difficult to interpret because of their mobility within the river systems, barriers in the river systems, effects of fishery and stocking etc.
- Care must be taken in choosing the most appropriate indicators of local conditions and impacts, particularly in the case of migratory Salmonids.
- The use of fish as indicators of accidental pollution is an important consideration in setting up monitoring schemes

Why Macroinvertebrates are key indicators of ecological river quality?

- high tolerance sensitivity towards pollution types and pollution levels
- respond rapidly to stressors
- widespread throughout the river continuum,
- easy to sample,
- relatively easy to identify compared with others groups.
- relatively sedentary and are therefore representative of local conditions
- they have a sufficient life span (months to years)
- Macroinvertebrate communities are heterogenic and contain several species.

Key physical-chemical monitoring Parameters

- key physical and chemical parameters should be monitored in situ and in the laboratory based on samples taken together with the biological samples

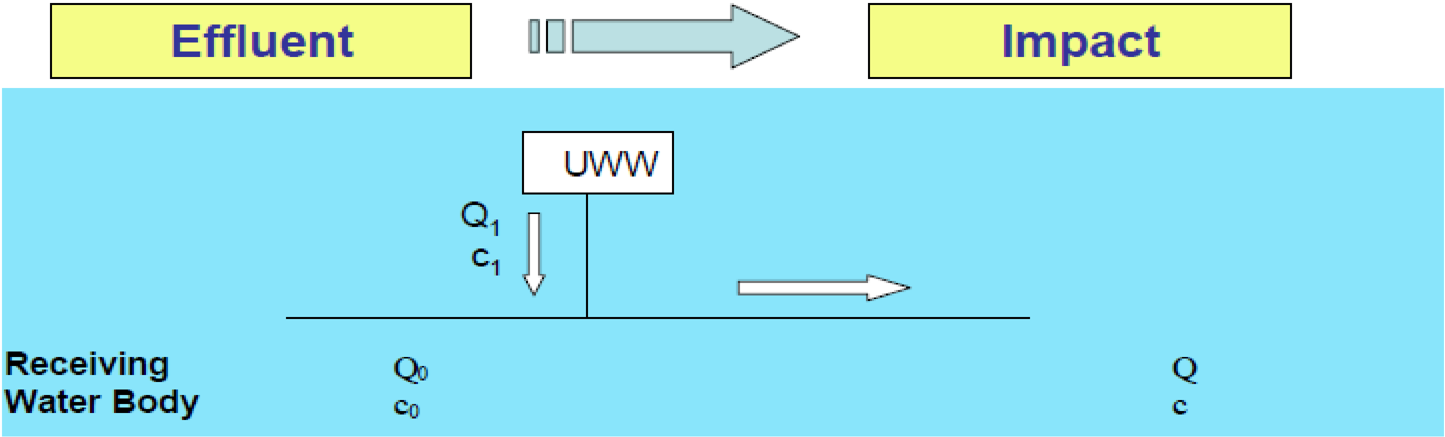
Water flow	Total phosphorus
Temperature	Dissolved, reactive phosphorus (PO_4-P)
Oxygen	Total nitrogen
pH	Ammonium nitrogen (NH_4-N)
Particulate matter (suspended solids)	Nitrate nitrogen (NO_3-N)
COD (dichromate) or TOC	Nitrite nitrogen (NO_2-N)
BOD_5	Reactive Silicium (mainly reservoirs/lakes)
Water transparency (Secchi depth) - (mainly reservoirs/lakes)	Chlorophyll a (mainly reservoirs/lakes)

Holistic Assessment of Ecological Quality

- the WFD requires that a classification system be capable of incorporating the full range of impacts.
- Numerous predictive systems have been developed, which compare the observed communities to those expected under reference conditions.
- The outputs of such systems give unitless ratios of observed to expected values that are ideally suited to the WFD.
- the ratio is a numerical value between zero and one, with ‘good’ ecological status represented by values close to one and ‘bad’ ecological status by values close to zero

Chemical monitoring is relatively easy to establish link between a pressure and the resulting concentration in the receiving waters

Simple Mass Balance Model for Estimating the Concentration of Pollutants from UWW in Rivers



Q = flow
c = concentration of pollutant

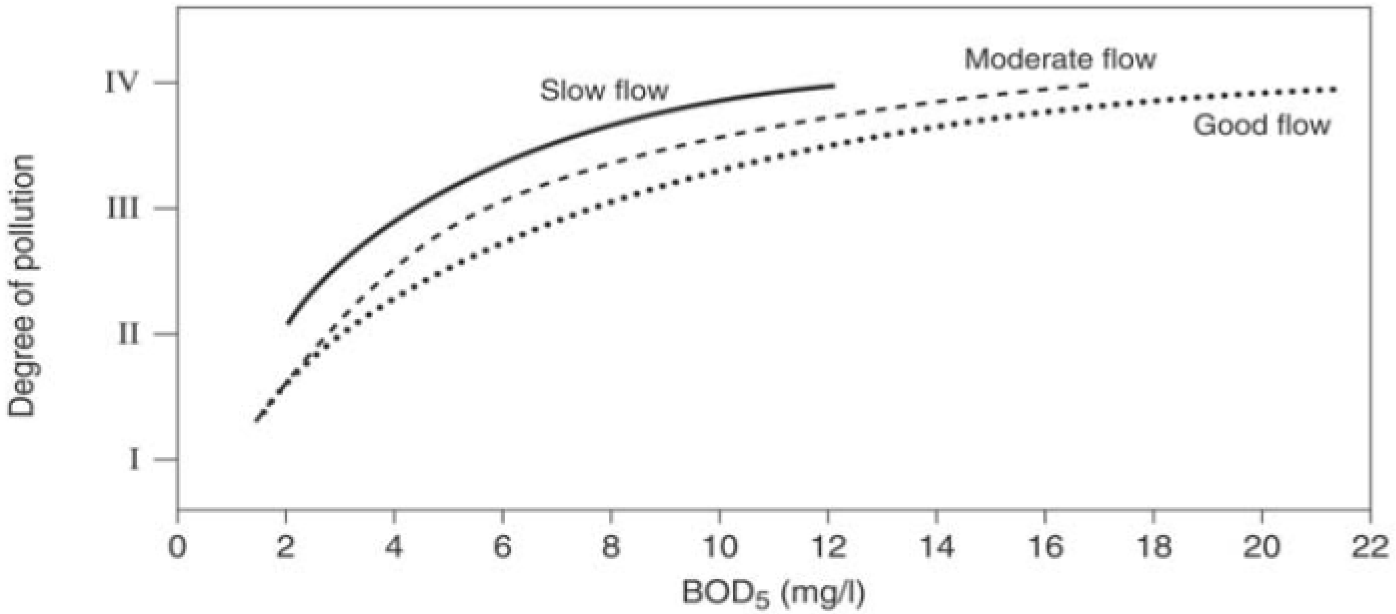
c for at specific pollutant can then be compared with the EQS/hygienic norm

$$Q = Q_0 + Q_1$$

$$c = \frac{Q_0 c_0 + Q_1 c_1}{Q}$$

But It is more difficult to establish the cause-effect relationship for biological quality elements

Relationship between ecological and chemical status



Relationships between BOD5 and saprobic status in rivers (based on macro-invertebrate monitoring)
Degree of pollution (saprobic index) equals impact on ecological status

CONCEPT OF QUALITY ASSURANCE

- It is a Managerial concept to promote the reliability of monitoring data
- do not interfere with the scientific design of the studies and their purposes
- assuring laboratory management and users of the data produced that facilities, personnel, methods, practices, records, and controls conform to accepted principles
- Quality Assurance main requirements:
  - Monitoring plan
  - Standard Operating Procedures (SOPs)
  - Documentation and Record Keeping
  - Laboratory inspection and auditing
  - Inter laboratory testing (proficiency tests)

POTENTIAL MEASUREMENT STRATEGIES

- EFFLUENT TOXICITY MONITORING
- AMBIENT TOXICITY TESTING
- ECOSYSTEM RESPONSE MONITORING

POTENTIAL MEASUREMENT STRATEGIES

- EFFLUENT TOXICITY MONITORING
  - Testing and steering the progress of technology based improvement of effluent quality, to complement chemical specific assessment
  - Permit compliance testing, provided that toxicological criteria are part of the permit formulation
  - The prevention/reduction of effects occurring in receiving water bodies
  - Early warning of calamities and accidental spills, provided that measures can be taken to contain the released toxicity

POTENTIAL MEASUREMENT STRATEGIES

- AMBIENT TOXICITY TESTING
  - may be used in conjunction with effluent toxicity tests to provide additional valuable information.
  - may reveal or confirm the existence of toxic conditions in the receiving water,
  - may demonstrate the presence of unknown toxicants and the location of unknown toxic point-source or diffuse discharges.
  - They may also be used to evaluate the combined effects of multiple discharges,
  - It can be stated that ambient toxicity testing mainly fulfills a signalling function for pollution control.

POTENTIAL MEASUREMENT STRATEGIES

- ECOSYSTEM RESPONSE MONITORING
  - Measurements on the physical status of the water body

    (depth, substrate composition, flow, turbidity, temperature, etc.)
  - Measurements on the chemical status of the water body

    (concentrations of nutrients and salts, oxygen levels, pH, etc.)
  - Measurements on the biological status of a water body including:
    - quantitative and qualitative inventories of the incidence of biochemical or morphological deviations and diseases in individuals of particular species,
    - inventories of biological structure,
    - assessments of biological functioning

Thank you