River Water Quality

Section **4**: Monitoring

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Monitoring

Data Analysis, Intercalibration & Predictive models

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Monitoring

Biological Indicators

Data Processing

- Since 1970's many uniformly storing methods have been developed in USA & Europe
- Analysis of surveillance data may be carried out by multivariate techniques or by biotic & diversity indices
- When biological impact of water quality is shown by a figure is easily understood but the amount of information is concealed
- Use of Indices enables the relationships between organisms & measured physicochemical parameters - placing the biological management of freshwaters on a sounder footing
- Combination of metrics can form a multi-metric index

Data Processing

- Multivariate techniques-analyses measure the association of biota with extraneous factors
- Such analyses can be carried out on both presence-absence & quantitative data to identify discontinuities present within communities possibly related to environmental change
- Can generate hypotheses about the causality of distribution but needs further studies to evaluate the relationship of distribution to environmental features
- Principal Components Analysis (PCA) should form the basis of a multivariate analysis (Green 1979), the principal component score being the variable which can be subjected to ordination, clustering or other statistical techniques

Multivariate Techniques

PCA

- Principal Component Analysis summarizes sets of correlations between variates
- A principal component is an additive combination of n original variables, with the coefficients
- The first principal component is chosen to make the agreement as close as possible and so on until n principal components have been calculated for the n variables
- Generates a set of correlations (usually) summarized closely by the first two or three principal components
  - ✓ Coefficients of similarity can be calculated before the analysis

Multivariate Techniques

Clustering

- The Jaccard similarity coefficient, *Sj* (Jaccard 1908) for comparing community species lists, can be used for clustering & associating species groups & sites' species composition with external factors (e.g. pollution, flow & other natural abiotic factors)
- A single linkage clustering technique of quotients of similarity to examine the macro-invertebrate fauna per station can be shown in a dendrogram

Multivariate Techniques

PRIMER & SIMPER (Field *et al.* 1982)

- Produces a similarity dendrogram of sampling stations based on the presence - absence & the abundance of benthic macroinvertebrate taxa
- Measures the similarity of stations and groups of stations, using the Bray-Curtis similarity index
- SIMPER analysis explains which macroinvertebrate families contribute the most to the similarity (or dissimilarity) between the clusters produced by CLUSTER or FUZZY groups

✓ Bray Curtis similarity & SIMPER analysis are performed with *Primer for Windows*

Multivariate Techniques

FUZZY (Equihua 1990)

- This technique is used to obtain ordination & classification of sampling sites based on their benthic communities' similarity
- Does not assume the existence of discrete benthic populations along the various stretches of a river system
- Works with the presence-absence of macroinvertebrates families not in an hierarchical way
- Is an extension of TWINSPAN (Hill 1979b), which is hierarchical, & produces a number of clusters in accordance with the partition coefficient, the assemblages of benthic macroinvertebrates & their membership value
  - ✓ Macroinvertebrate communities may overlap in a lot of sites along a river

Multivariate Techniques

CCA analysis-CANOCO

- Non-linear technique (extension of DECORANA)- used to detect covariance between environmental variables & the respective biotic components (taxa abundances)
- Environmental variables are subjected to Monte Carlo test to check their significance ($p<0,05$) & species data are transformed to log(x+1) before the analyses to approach the assumed conditions of normality
- Suits for a forward selection of environmental variables to determine which variables best explain the species data

✓ CCA is carried out using *Canoco* for Windows & the graphs by *CanoDraw* & *CanoPost*

Approaches to biological Monitoring (RIVPACS)

What is the degree to which the existing community differ from that naturally present at a given site?

- Indices & scores over-estimate the effect of pollution on slow-flowing water courses as these habitats favour species absent in unpolluted fast-flowing systems in favour of broadened applicability
- To be objective in the judgment, the ‘best achievable community’ which can occur under a particular set of physical, chemical, geological & geographical conditions must be identified
- Predictive models, applied to data, using standard methodology, can produce a classification scheme related to the degree of pollution that rivers receive, so that the ratio 'predicted' biotic index to the 'actual' one be realistic. Numerous though data are needed.

Approaches to biological Monitoring (RIVPACS)

- River Invertebrate Prediction and Classification System (RIVPACS):

✓ Begun in 1970's from British researchers as an exploration of the relationship between environmental parameters and benthic invertebrate communities in UK rivers by multivariate analytical techniques

✓ Resulted in classification of unpolluted running water sites in Great Britain (England, Wales & Scotland) based on the invertebrate fauna

✓ Offered the ability to predict the type of invertebrate community using physical & chemical features which formed the basis for RIVPACS

Approaches to biological Monitoring (RIVPACS)

- For the analysis of biological communities 2 major clustering techniques were employed:
  - ✓ two-way indicator species analysis (TWINSPAN) for arranging each sites' organisms hierarchically & identifying indicator species
  - ✓ de-trended correspondence analysis (DECORANA), an ordination technique for arranging sites into a subjective order (sites with similar biota are placed close)
- Species lists from >700 sites, from 80 rivers, by qualitative sampling along with a wide range of physical & chemical variables were obtained & processed
- These data were included in the BMWP Score
- The overlap in species composition between adjacent classes means this level of accuracy should give an adequate indication of the expected invertebrates at a given site

Approaches to biological Monitoring (RIVPACS)

- RIVPAC predictive system can use physical-chemical parameters to predict: the invertebrate community type, the presence (or absence) of families & of species, the BMWP score & the ASPT
- In this system, safeguards have been incorporated to indicate where its use is inappropriate (e.g. when a site has <5% probability of belonging to any of the groups based on physical-chemical data)
- An EQI can occur from the ratio of Actual/Predicted number of taxa **OR** ASPT

Approaches to biological Monitoring (RIVPACS)

- RIVPACS is an integrated package for: water quality monitoring & site specific prediction, measurement of the extent of pollution, yardstick against which biological improvements can be judged, aid in management & identification of potential conservation sites
- Provides a Classification scheme applicable to a wide spectrum of running waters
- Demands Standard sampling, Measurement & Analytical Procedure that could be followed by all the regions of the Environment Agency
- Provides clearer inter- & intra-site comparisons of actual & expected invertebrate communities

✓ Predictive approaches represent a very powerful tool in biological assessment of pollution but needs refinement & modifications for use outside UK

Advantages & Disadvantages of Multivariate Approach in Monitoring

- Multimetric approaches are conceptually simple, easy to compare with reference values & ecologically sound
- Multivariate modelling techniques are more precise & less dependent upon sample size & site traits (Faush *et al.* 1990). Can generate data used to produce conceptually simple information easily applied (e.g. RIVPACS). **BUT** conceptually complex & difficult to understand & apply (require expertise in the sorting & identification)
- TWINSPAN generates a simple indicator of organic pollution from farms & requires limited biological expertise. The assessment takes the form of a straightforward flow chart based on the collection of selected benthic macroinvertebrates & observations on the presence & amount of "sewage fungus"

Modelling

- Pollution Management is equipped with a wide range of techniques, survey procedures & modeling software for robust computations & estimations for a variety of purposes
- Nationally based policy decisions & country-wide monitoring networks are essential to inform future decisions, along with international cooperation on monitoring
- European Environment Agency (EAA) enhanced the International cooperation in the European Union & coordinates the supply of environmental monitoring data to produce a clearer picture of the state of the environment (basis for future EU legislation)

Intercalibration – STAR European Polymetric Index

- Intercalibration process is needed to achieve comparable ecological quality assessment systems & harmonised ecological quality criteria for surface waters all over Europe
- Since Member States of the European Union use different methods to assess the quality, they need to be harmonized in terms of their resulting water quality classification, so as to obtain equivalent ecological quality classes across Europe (Buffagni *et al.* 2005)
- All used methods should be type specific & express the ecological water quality as a deviation from the respective reference conditions (Working Group 2.3 REFCOND, 2003)

Intercalibration – STAR European Polymetric Index

- Intercalibration of the assessment methods is confined to Ecoregions represented by 13 Geographical Intercalibration Groups (GIGs) across Europe
- Each group consists of Member States with similar ecological types of water bodies & comparable monitoring results. Intercalibration is carried out per water body type within each Ecoregion
- Determination of reference conditions for each type (according to WFD) is fundamental for the effectiveness of intercalibration, aiming at the consistency & comparability in the classification results of the ecological quality monitoring systems

Intercalibration – STAR European Polymetric Index

- 5 **River** Intercalibration Groups: Northern European , Central European & Baltic, Alpine, Mediterranean (MedGIG), Eastern Continental (European Commission 2008)
- The most important boundaries to be determined are those of High / Good status & Good / Moderate status, through indirect comparison & common metrics
- 2 steps for indirect intercalibration procedure:

  i. comparison of the existing national quality class boundaries with the respective boundaries of a benchmark database via common metrics of Intercalibration Common Multimetric index (ICMi)

  ii. harmonization of the quality class boundaries of the national method with the respective boundaries of the benchmark database (when significant discrepancies occur)

Intercalibration – STAR European Polymetric Index

- The ICMi is based on component (biological) metrics (ICMs) which offer comparable information
- The metrics (qualitative & quantitative) fit with WFD definitions expressing the tolerance, the abundance/habitat & the diversity/richness of the bio-community, describe the gradients effectively & discriminate different quality classes which can be calculated from a wide range of geographical contexts

  - Mediterranean: MedGIG defined the boundaries for 3 Multimetric Indices (ICMi): the STAR, the Med ICM7 & MED-ICMI for 3 river types (R-M 1,2,4)
  - Greece: intercalibration was actualized for the Hellenic Evaluation System in R-M4 river types as well as R-M1 & R-M2

Intercalibration – STAR European Polymetric Index

- The finally selected multimetric index for the intercalibration of the MedGIG rivers was the STAR ICMi (also used by the Central European & Baltic GIG)
- Provides a direct trans-GIG comparability & has similar performance against pressures of the Med ICMs (European Commission 2007)

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ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
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ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης