The transition toward the application of the European Directive (60/2000 EC)

The Italian experience of LIMNO Project database of the Italian lakes

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Introduction

The future application of the Water Framework Directive (WFD; Directive 60/2000 EC) requires that water bodies within each river basin district shall be characterised using one of two systems, A or B, the methodology of which is given in the WFD. Hydro-morphological, geological and physico-chemical parameters are suggested for the characterisation of different types of lakes. For each lake type, reference conditions must be established representing, as far as possible, undisturbed conditions and including biological as well as hydro-morphological and physico-chemical baselines. The purpose is to identify reference biological communities against which other communities will be compared (Heinonen *et al.*, 2001). Member States shall produce a map of the geographical location of the lakes considered.

Annex V of the WFD gives standard definitions for the classification of lakes into different ecological quality classes, such as high, good and moderate status. The ecological status of a lake is based on its level of deviation from the reference biological population (which corresponds to high status) and includes phytoplankton, macrophytes, phytobenthos, benthic invertebrates and fish data. Class boundaries must be established for each set of reference conditions. Member states are then required to express the results of their assessment as ecological quality ratios, which consist of the biological parameter observed divided by the same parameter in the reference conditions.

This communication is a contribution towards the development of a classification methodology aiding the identification of reference condition of lakes and reservoirs. The method has been carried out within the framework of the LIMNO Project (Tartari *et al.*, 2000), which was developed to help the Italian government during the transitional phase leading up to the implementation of the European Directive (60/2000 EC). This method is presented here to promote its application to lakes in other European Countries with the aim to verify the applicability at the European scale.

The LIMNO database of Italian lakes

Lake management requirements necessitate the development of a modern information system to allow interdisciplinary studies, in accordance with the WFD. The Water Research Institute and the Italian Institute of Hydrobiology (Institutes of the National Research Council) are developing a tool for the management of the limnological data of the major Italian lakes. This is the LIMNO Project, which consists of a limnological database linked to digitised maps to form a Geographic Information System (GIS). LIMNO considers freshwater bodies having a surface area greater or equal to 0.2 km^2, excluding water bodies formed by springs and quarries, and water bodies having renewal times shorter than one week. About 370 lakes and reservoirs are included in the LIMNO DataBase. The development of the GIS, still in progress, includes the digitalisation of the lake perimeters and their catchment boundaries. These will be linked to other geographical data, such as those obtained from the national census. The lake database and GIS will form a link between water quality data and catchment characteristics, which will allow risk assessment evaluations based on different pollutant loadings. Therefore, the LIMNO Project can be a management tool awaiting the implementation of the WFD.

The LIMNO water quality data were obtained from the bibliographical collection of the Water Research Institute, the Italian Institute for Hydrobiology and other Institutions. Further data were obtained from the laboratories of the Regional Environment Agencies, and from a purpose designed monitoring activity carried out in 1999 - 2001 for lakes of Northern Italy.

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The chemical data recorded in the database include the main ions, algal nutrients, metals and organic pollutants. Data were collected during the winter overturn and late summer stratification. The biological data include biomass and/or density of total phytoplankton, total zooplankton, total zoobenthos, together with the species diversity of each biotic assemblage. Each datapoint is associated to a code showing the source, the original units of measurement, the analytical method and other information.

The IRSA Trophic Classification System (TCS)
Using water quality data collected in LIMNO DataBase, the Water Research Institute has developed a new trophic index named Trophic Classification System (TCS) which integrates the main limnological parameters measured at maximum water circulation and at maximum stratification. These are:

Total phosphorus (TP) :surface value during winter overturn and maximum annual value;
Oxygen (O2) :surface value during winter overturn and minimum hypolimnetic value during summer stratification;
Transparency (SD) : minimum annual value;
Chlorophyll a (Chl a) : maximum annual value.

The calculation of the Trophic Classification System consists of two steps: the first step is the identification of the lake trophic state using a traditional classification based on transparency (SD) and chlorophyll (Chl a) as well as a double entrance table of percentage oxygen saturation (O_2) and total phosphorus (TP) concentration for two different periods of the year (maximum thermal circulation and maximum thermal stratification); the second step is the standardization of each of these indices to form an integrated value.

Step 1
The first step for each variable is to identify the lake trophic state using the scale reported in the table 1:

Tab. 1: Identification of trophic classes.

CLASS	TROPHIC STATE
1	ultraoligotrophic
2	oligotrophic
3	mesotrophic
4	eutrophic
5	hypertrophic

As for SD and Chl a each class ranges between the values reported in table 2 and 3 respectively

Tab. 2: Trophic classification for SD (m).

SD Classes				
1	2	3	4	5
> 5	≤ 5 ; >2	≤ 2 ; >1.5	≤ 1.5 ; >1	≤ 1

Tab. 3: Trophic classification for Chl a (µg/l).

Chl a Classes				
1	2	3	4	5
< 3	≥3 ; < 6	≥6 ; < 10	≥10 ; < 25	≥;25

Considering O_2 and TP, the classification is performed using the double entrance table (where the rows are the surface concentration during the winter overturn and the columns are the minimum hypolimnetic values) for O_2 (Tab. 4) and maximum annual values for TP (Tab. 5).

Tab. 4: Trophic classification for O2 (% of saturation) based on double entrance table.

		SURFACE VALUE DURING SPRING CIRCULATION				
		> 80	≤ 80	≤ 60	≤ 40	≤ 20
MINIMUM HYIPOLIMNETIC VLUE DURING	> 80	**1**				
	≤ 80	**2**	**2**			
	≤ 60	**2**	**3**	**3**		
	≤ 40	**3**	**3**	**4**	**4**	
	≤ 20	**3**	**4**	**4**	**5**	**5**

Tab. 5: Trophic classification for TP (μgP/l) based on double entrance table.

		SURFACE VALUE DURING SPRING CIRCULATION				
		< 10	≤ 25	≤ 50	≤ 100	> 100
MAXIMUM YEARLY VALUE	< 10	**1**				
	≤ 25	**2**	**2**			
	≤ 50	**2**	**3**	**3**		
	≤ 100	**3**	**3**	**4**	**4**	
	> 100	**3**	**4**	**4**	**5**	**5**

Considering the application to national water bodies, all the boundary values indicated in the previous tables are taken from the Italian classification system reported in national water law (D.Lgs 152/99 and 258/00). This choice can be reconsidered in the case of an Europe-wide application of TCS.

Step 2
The single classifications are standardised to give the final TCS index using the sum of the individual indices. (Tab. 6).

Tab. 6: Standardisation of the trophic classification from the sum of the individual indices.

Sum of the class of single variables	TCS index	Referred trophic state
4	**1**	ultraoligotrophic
5-8	**2**	oligotrophic
9-12	**3**	mesotrophic
13-16	**4**	eutrophic
17-20	**5**	hypertrophic

The integrated index considers the main factors involved in the eutrophication processes: the principal limiting nutrient (TP), two variables that give a biological response of this process (SD and Chl a) and the main variable involved in the mineralization activity following the eutrophication phenomenon (O2). Furthermore, this system considers both hypolimnetic and epilimnetic layers and their evolution during the annual circulation and stratification cycle of the lake waters and allows an integrated interpretation of the lacustrine ecology.

Application of the Trophic Classification System
The TCS has been applied to 29 Italian lakes selected to give a representative sample of the different typologies (natural and artificial) of the national situation. The data used come from two different years and cover the entire range of trophic states.

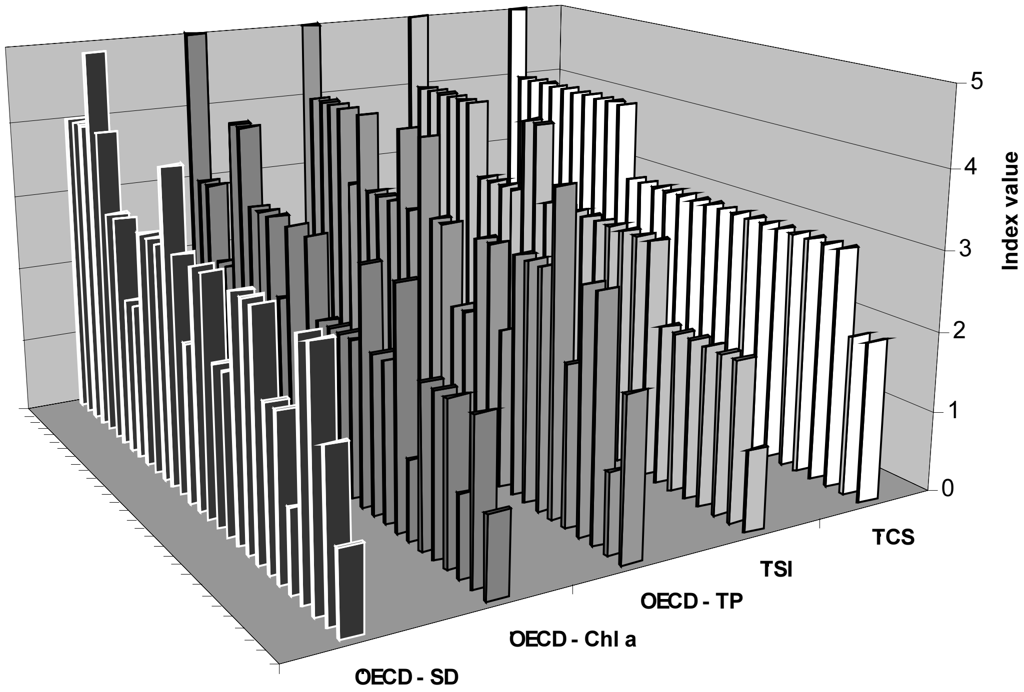

Fig. 1: Results of the comparison between TCS, TSI integrated index and OECD indexes.

The TCS classification methodology is in close agreement with the Carlson index, while the three OECD classifications for single parameters are very scattered. It is important to note that only TCS considers oxygen values in the evaluation of lake trophic state. Oxygen is an important parameter in the evaluation of lakes trophic state, since low oxygen concentrations quickly reduce water quality and accelerate the process of mineralization and the solution of reduced compounds.

Conclusions

The trophic classification system (TCS) reported here is based on four parameters usually measured routinely during lake monitoring activities. This index can be considered as a limnological indicator of water quality that includes both chemical (TP and O2) and biological (SD and Chl a) characteristics of eutrophication phenomena.

The application of this index to 29 Italian lakes shows close agreement between TCS and trophic Carson index. Some differences are due to the introduction of oxygen values in the calculation. The most important contribution of TCS to the description of lake water quality comes from the consideration of the behavior of different variables, both in the epilimnion and in the hypolimnion, during the maximum winter circulation and the maximum summer stratification. These have not been included in previous indexes.

Finally, in this note the boundary limits established by Italian law have been used. These limits could be modified according to future outcomes obtained in the frame of ongoing European projects relevant to the implementation of the WFD.

Acknowledgment
We thank Dr R. Caroni for her contribution to preparation of this document.

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Using phytoplankton in the classification of ecological status

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Finnish lakes are mainly formed 9000 - 6000 years ago, during deglaciation. The geographical location of the lakes, the geography of their catchment area, and the range in chemical composition of water - all result in changes in biota - in species associations along the environmental gradient. Each lake has its own discrete phytoplankton assemblage, and grouping of lakes gives a generalized picture of phytoplankton in each lake type.

Phytoplankton in Finnish lakes

Phytoplankton quantity and composition in Finnish large and moderate large lakes have been monitored since 1963. Phytoplankton biomass is approximately 4.3 mg l^{-1} in lakes situated in coastal low-land area. The soil of their catchment areas consists more or less post-glacial sediments, often rich in biogenic matter. The proportion of Cyanophyta (Cyanobacteria) is ca. 40 % due to the generally high nutrient concentrations in water. In lakes in Central -, Eastern - and Northern Finland phytoplankton biomass, < 1 mg l^{-1} , reflects oligotrophy or oligo-mesotrophy, and the main phytoplankton groups occur in almost equal proportions. In reservoirs in Northern Finland the mesotrophy reflecting average phytoplankton biomass, 1.6 mg l^{-1} , is dominated by diatoms.

Phytoplankton in lakes of Vuoksi river basin

Clear water lakes

Altogether 11 monitored lakes in Vuoksi river basin situated in Eastern Finland belonged to oligotrophic clear water lakes, of which nine were pristine and two impacted. The only clear difference in the phytoplankton composition was the slightly higher biomass of chrysomonads in pristine lakes compared to that in impacted lakes. Total biomass and variation were also higher in pristine lakes. The parameter value / reference value ratio was 1 for different phytoplankton groups; to the total biomass 0.8. The ecological quality ratio (EQR) was not determined. The human impact seems to influence the phytoplankton of the large oligotrophic clear water lakes very little but more clearly in the more nutrient rich ones.

Three clear water lakes were mesotrophic according to the total phosphorus concentration, but according to the mean total biomass, 0,7 mg l^{-1}, they were oligo-mesotrophic. In the only impacted lake the average total biomass of 1.9 mg l^{-1} was mesotrophy indicating and dominated by diatoms. The annual variation also was prominently higher in the impacted lake. The parameter value / reference value ratio varied from 1.2 to 8.0 for different phytoplankton groups with highest ratio for diatoms, to the total biomass 2.9 (in details in Fig. 1).

Brown water lakes

In Vuoksi river basin 21 lakes belonged to brown water lakes (water colour 40-100 mg l^{-1} Pt), of which four were oligotrophic, and ten were mesotrophic or eutrophic. Altogether seven lakes were impacted. Along increasing nutrient gradient first cryptomonads and then diatoms increased. In the eutrophic dark brown water lake (pristine) cyanophytes but also *Gonyostomum semen* (Raphidophyceae) were abundant. In mesotrophic and eutrophic brown water lakes parameter value / reference value ratio of the total biomass between pristine and impacted lakes varied from 1.3 to 2.8. The ecological quality ratio (EQR) was not determined. Total biomass and variation were higher in impacted lakes (in details in Fig. 1).

The group AAAA, including lakes with low total phosphorus, low water colour, low total biomass and with more or less equal amounts of cryptomonads, chrysomonads and diatoms is suitable as a group of clear water reference lakes for high quality (totally undisturbed) lake-phytoplankton. The groups ABAA and ABAB including lakes with low phosphorus, moderate high water colour, and low phytoplankton biomass dominated by chrysomonads or cryptomonads are suitable as a group of humic reference lakes for high quality (totally undisturbed) humic lake-phytoplankton. The human impact seems to influence the phytoplankton quantity and quality of the large, more or less brown water lakes in accordance to their nutritional stage.

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Phytoplankton in the classification of ecological status in Finnish lakes

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Introduction

Finnish lakes were mainly formed 9000 - 6000 years ago, during deglaciation (Figs. 1-2). The geographical location, the geography of the catchment area (Fig.3), and the range in chemical composition of water - all result in changes in species associations of phytoplankton along the environmental gradient. Freshwater phytoplankton is a mixture of Cyanophyta, Cryptophyta, Chrysophyta, Diatomophyta, Chlorophyta and other algal groups. Each lake has its own discrete population. Grouping of lakes gives a generalized picture of phytoplankton in each lake type (Figs. 4-5).

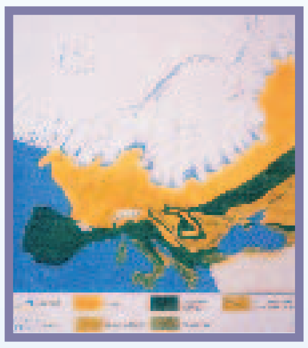

Fig. 1 The continental ice sheet.

Material and methods

Phytoplankton in monitored, moderately large lakes was studied. As a case study the phytoplankton records from altogether 35 lakes of river basin Vuoksi in July 1980-1999 were treated. Lake sites with minor human impact were grouped according to the median total phosphorus concentration, water colour number, total phytoplankton biomass and dominating phytoplankton groups. Furthermore, sites with human impact were treated separately. Ecological quality ratio EQR (parameter value/ reference value) was calculated for similar lake groups (Table 1).

Phytoplankton and the ecological status of lakes

The soil of the catchment area of the lakes situated in coastal low-land area consists mainly of post-glacial sediments, often rich in biogenic matter (Voipio 1981). Phytoplankton biomass is approximately 4.3 mg l^{-1}, and the proportion of Cyanophyta is ca. 40 %. In lakes in central, eastern and northern Finland phytoplankton biomass, < 1 mg l^{-1}, reflects oligotrophy or oligo-mesotrophy (Heinonen 1980). The main phytoplankton groups occur in almost equal proportions. In northern reservoirs the mesotrophy reflecting phytoplankton is dominated by diatoms (Figs. 4-5).

Classification of ecological status, a case study

Clear water lakes

Altogether 11 lakes in Vuoksi river basin were oligotrophic clear water lakes; nine pristine and two impacted. The only clear difference in pristine lakes compared to the impacted lakes was the slightly higher biomass of chrysomonads. Total biomass and the variation were also slightly higher in pristine lakes. The ecological quality ratio (EQR) was ≤1 for different phytoplankton groups; for the total biomass 0.8 (Tables 1-2, Figs. 6a-b).

Three clear water lakes were mesotrophic according to the total phosphorus concentration, but oligo-mesotrophic according to the mean total biomass, 0,7 mg l^{-1} (Heinonen 1980). The biomass, 1.9 mg l^{-1}, in the only impacted lake was mesotrophy indicating, and dominated by diatoms. The variation was prominently higher in the impacted lake. The ecological quality ratio (EQR) for different phytoplankton groups varied from 1.2 to 8.0 (diatoms); for the total biomass it was 2.9 (Tables 1-2, Figs. 6a-b).

Table 1 Study lakes grouped according to some parameters

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Table 2 The EQR-ratio of mean phytoplankton biomass in clear water lakes, in July 1980-1999 (n=76).

	Cyan	Cryp	Dinop	Chrys	Diat	Chlor	Others	bm	min	max
AAAA	0.04	0.08	0.02	0.10	0.06	0.02	0.01	0.34	0.06	0.95
AAAAi	0.03	0.07	0.02	0.08	0.06	0.02	0.01	0.28	0.15	0.57
EQR	**0.7**	**0.9**	**1.0**	**0.8**	**0.9**	**0.8**	**1.0**	**0.8**		
AABB	0.05	0.25	0.03	0.22	0.09	0.03	0.01	0.69	0.52	0.88
BAAB	0.03	0.12	0.01	0.05	0.05	0.02	0.01	0.29	0.13	0.41
BABB	0.10	0.20	0.04	0.11	0.11	0.08	0.01	0.66	0.24	1.38
BABBi	0.19	0.34	0.10	0.23	0.87	0.14	0.02	1.88	0.96	3.36
EQR	**1.9**	**1.7**	**2.5**	**2.0**	**8.0**	**1.7**	**1.2**	**2.9**		

Table 3 The EQR-ratio of mean phytoplankton biomass in brown water lakes, in July 1980-1999 (n=103).

	Cyan	Cryp	Dinop	Chrys	Diat	Chlor	Others	bm	min	max
ABAA	0.06	0.16	0.01	0.13	0.05	0.02	0.00	0.44	0.12	0.84
BBAB	0.03	0.14	0.01	0.10	0.05	0.02	0.01	0.35	0.16	0.69
BBABi	0.06	0.30	0.05	0.14	0.13	0.03	0.06	0.76	0.34	1.43
EQR	**2.3**	**2.1**	**7.6**	**1.4**	**2.6**	**1.3**	**4.5**	**2.2**		
BBBB	0.03	0.37	0.03	0.10	0.08	0.04	0.03	0.68	0.51	1.16
BBBBi	0.03	0.35	0.02	0.17	0.27	0.03	0.01	0.89	0.40	1.76
EQR	**1.1**	**0.9**	**0.7**	**1.7**	**3.6**	**0.8**	**0.4**	**1.3**		
BBBC	0.04	0.16	0.03	0.30	0.61	0.04	0.09	1.27	0.53	2.30
BBBCi	0.04	0.56	0.03	0.39	0.78	0.12	0.03	1.96	0.78	3.18
EQR	**1.1**	**3.6**	**0.9**	**1.3**	**1.3**	**2.9**	**0.4**	**1.5**		
CBBB	0.02	0.41	0.08	0.20	0.38	0.04	0.09	1.22	0.48	3.59
CBBBi	0.67	0.95	0.03	0.22	0.98	0.15	0.46	3.45	1.10	8.89
EQR	**34.4**	**2.3**	**0.4**	**1.1**	**2.6**	**3.3**	**5.1**	**2.8**		

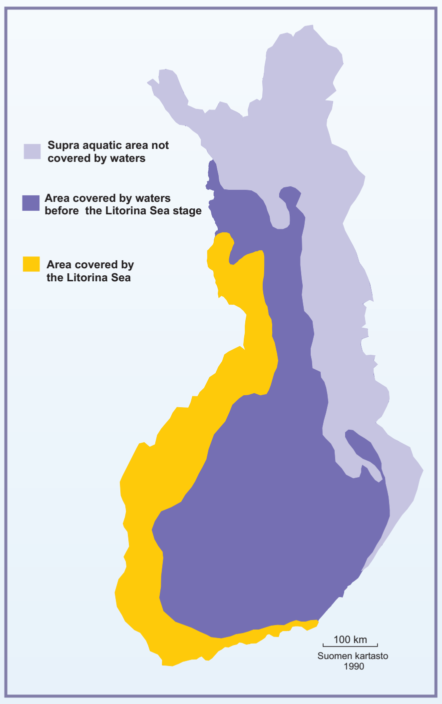

Fig. 2 Withdraw stages of waters after the glaciation.

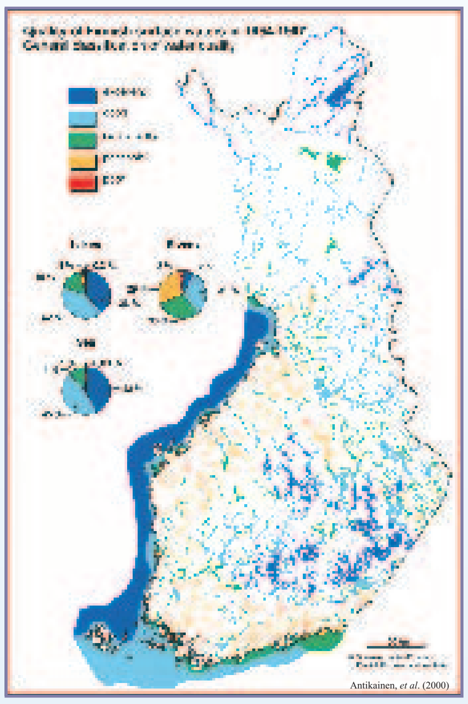

Fig. 3 Water quality of Finnish surface waters.

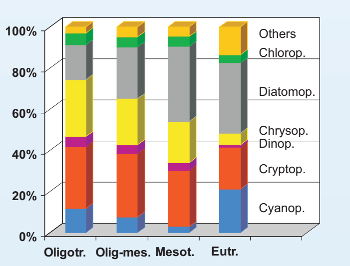

Fig. 4 Phytoplankton composition in the study lakes.

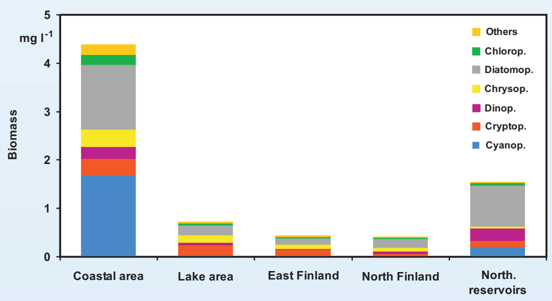

Fig. 5 Geographical variation of phytoplankton.

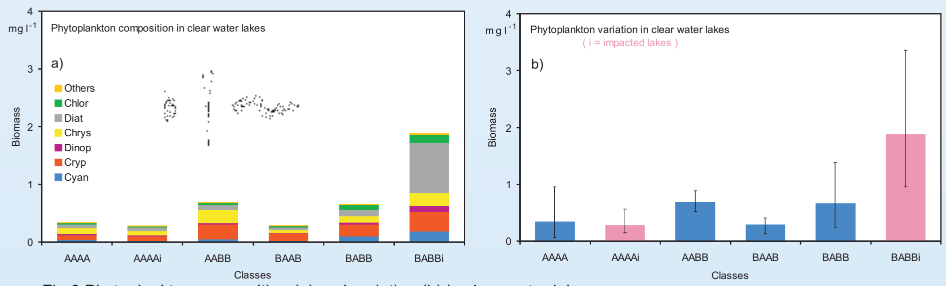

Fig 6 Phytoplankton composition (a) and variation (b) in clear water lakes.

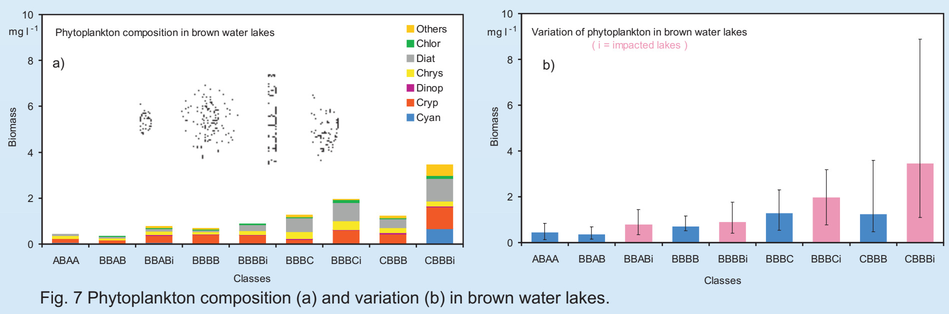

Fig. 7 Phytoplankton composition (a) and variation (b) in brown water lakes.

Brown water lakes

In Vuoksi river basin 21 of the studied lakes were brown water lakes; four oligotrophic - pristine, and ten mesotrophic or eutrophic including seven impacted lakes. Phytoplankton was more abundant in brown water lakes as in clear water lakes. Along increasing nutrient gradient first cryptomonads and then diatoms increased. In the eutrophic dark brown water lake (pristine) *Gonyostomum semen* (Raphidophyceae) was abundant. In mesotrophic and eutrophic brown water lakes the total biomass EQR-ratio varied from 1.3 to 2.8. Total biomass and variation were higher in impacted lakes (Tables 1 and 3, Figs. 7a-b).

Conclusion

The human impact in this case study seems to influence the phytoplankton of the large oligotrophic clear water lakes very little. Phytoplankton associations in the lake groups AAAA and BABB are suitable as reference for undisturbed oligotrophic and mesotrophic lakes.

The human impact seems to influence the phytoplankton of the large, more or less brown water lakes in accordance to their nutritional stage. Phytoplankton associations in the lake groups BBAB - CBBB are suitable as reference for undisturbed mesotrophic and eutrophic brown water lakes.

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Graphic design Sirkka Vuoristo

Macrozoobenthos community structure and it´s relation to environmental variables in some Finnish lakes

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Macrozoobenthos community structure and its relation to environmental variables were examined in the profundal zone of 22 Finnish lakes during September– October in 1989–92 (Fig. 1). Both the macrozoobenthos data and the physical and chemical data were collected as part of the Finnish national monitoring programme. According to water quality measurements, ten of the lakes were oligotrophic, six eutrophic and the rest generally mesotrophic. Six research stations are situated beside waste water recipient areas of large lakes. Most of the study lakes were oligohumic or mesohumic and their maximum depth varied between 6 and 97 m. The Benthic Quality Index (BQI) and Oligochaeta/Chironomidae ratio (O/C) were used to describe the trophic status of the benthic environment. Both BQI and O/C, with depth correlation, correlated significantly with the chlorophyll *a* content of the surface water. In most lakes differences in species composition between the intermediate depth and deep area sampling sites were small. Temporal and spatial differences in species composition and its relation to environmental factors were studied by using canonical correspondence analysis (Figs. 2 & 3). Deep, oligotrophic lakes like Suontienselkä, Pääjärvi, Vuohijärvi and Inarinjärvi and hypereutrophic lake Tuusulanjärvi formed clearly separated groups in ordination diagrams. Mesotrophic lakes formed a third group with a more heterogenic nature. Besides the sampling depth and summer temperature which proved to be one of the most important factors affecting species composition, variables associated with eutrophication also explain the variation in the species data.

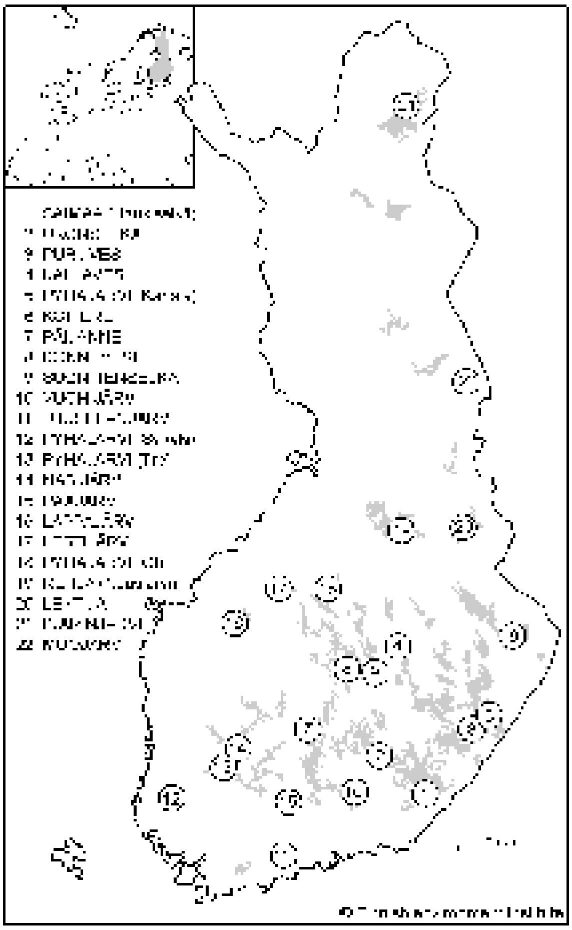

Figure 1. *The location of the study lakes.*

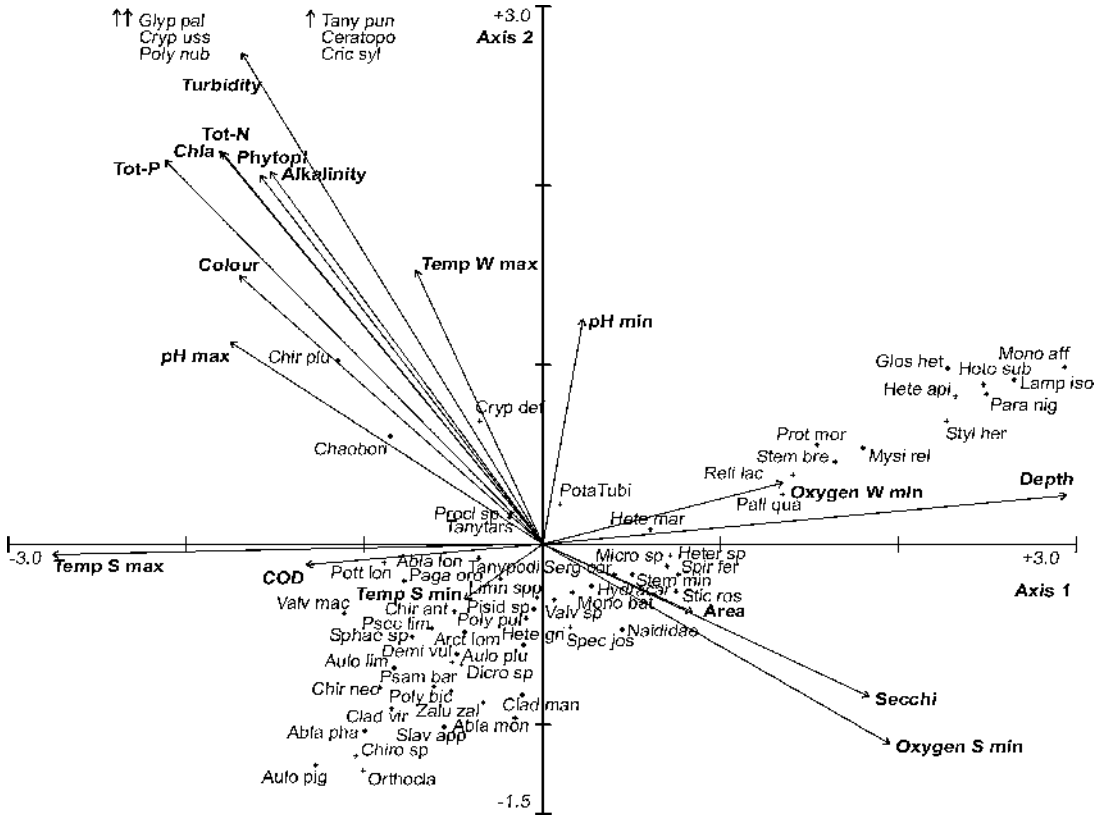

Figure 2. *CCA ordination diagram of species and environmental variables.*

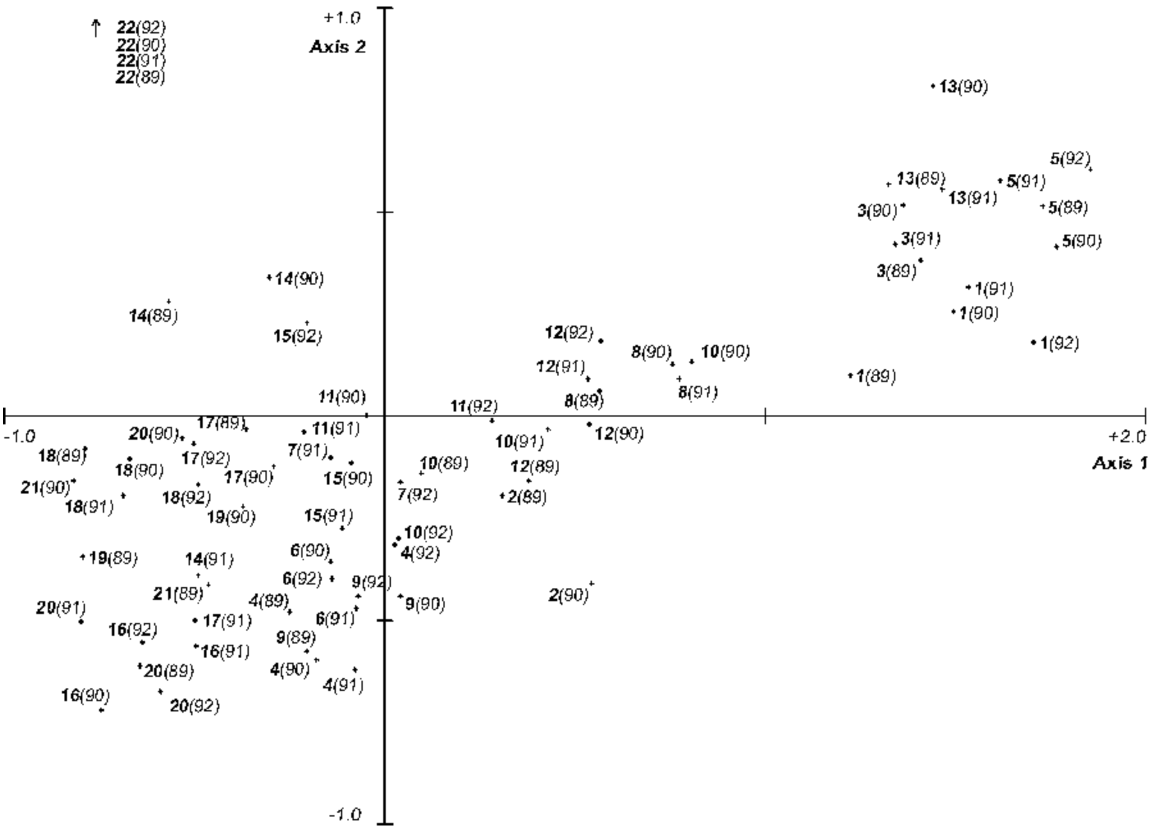

Figure 3. *CCA ordination diagram of sampling sites for separate study years (lake number: see Fig.1).*

Ecological indicators systems to assess the ecological status and reference conditions on Spanish Mediterranean rivers (*Guadalmed* project)

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The Water Framework Directive (WFD), Article 2 (Definition 21), defines clearly the Ecological Status as "an expression of the quality, of the structure and functioning of aquatic ecosystems associated with surface waters, classified in accordance with Annex V". It involves the knowledge of structure and functioning of aquatic systems in each European region. To achieve this objective, the use of integrated systems which consider all characteristic ecological parameters in aquatic ecosystems (also including riparian zone and land use influence) is necessary, since each parameter or index by themselves are not enough to reach a good definition of system global ecological status.

At a world scale, Mediterranean zone is one of the most modified areas by human activities (vegetation cover destruction by fires or overgrazing, bad management or reforestation with non-native species, pollution, overexploitation of water resources, etc...). These conditions make difficult to distinguish from natural or human origin of ecological processes. The problem is increased by the relatively heterogeneous lotic aquatic ecosystems at a space-temporal scale and by the special Mediterranean climatic and hydrological conditions, some of them located in semiarid regions.

So far, ecological status assessment on lakes and rivers has not been undertaken in Spain in an extensively, operational way nor in thoroughly accordance with the terms laid down in the WFD. However, some biological monitoring programs have been carried out on streams throughout Spain, mainly focused on macrobenthos indices.

The Project GUADALMED ("*Ecological status of Mediterranean rivers*") is a coordinated project with 28 researchers belonging to 7 different Spanish research institutions: Universities of Barcelona, Balearic Islands, Vigo, Murcia, Almería and Granada, and CEDEX. Project is divided in two phases:

Main objective (1st phase)

The project is aimed to study 10 Mediterranean river basins in Spain where the establishment of their ecological status may present several difficulties due to ecological conditions of these rivers (droughts, flash floods). The results must help us to define an integrated index that using the biological quality of waters and the conservation of the aquatic habitat and riparian forest, allow us to classify the Mediterranean rivers in the five classes of ecological status defined in the WFD. This objective is being gained by means of following tasks:

- The establishment of a common sampling methodology for all Mediterranean rivers.
- The study of macroinvertebrates communities in 12 Mediterranean river basins located along a latitude, thermal and rainfall gradient.
- The study of riparian vegetation in those Mediterranean river basins.
- Definition of multimetric indexes of biological quality: habitat, riparian vegetation, macrophytes and macroinvertebrates, together with water physicochemical characteristics, appropriate and comparable in all Mediterranean rivers.
- The establishment of ranges of quality variation for the indexes according to hydrological characteristics of the studied river stretches.
- The study of the temporal variability of these indexes during two annual periods.

During years 1999-2000, 12 river basins along East Spanish Mediterranean coast have been studied with 142 sampling stations. In each station, data from physicochemical, hydromorphological and biological parameters were taken with the same sampling systems.

Objectives of 2nd phase

- The regionalization in equivalent stream ecological types according to Annex II of WFD.
- The selection of reference localities without any human alteration and necessary to establish the good ecological status of each ecotype.

- The elaboration of an integrated index of ecological quality that allow to define the good ecological status using biological, hydromorphological and physicochemical parameters, according to the Annex V of the WFD.

Also, a predictive model applying multivariate statistical analysis will be defined with the data of the macroinvertebrate communities collected in all the studied rivers, following techniques similar to RIVPACS or AusRivAS.

Acknowledgements

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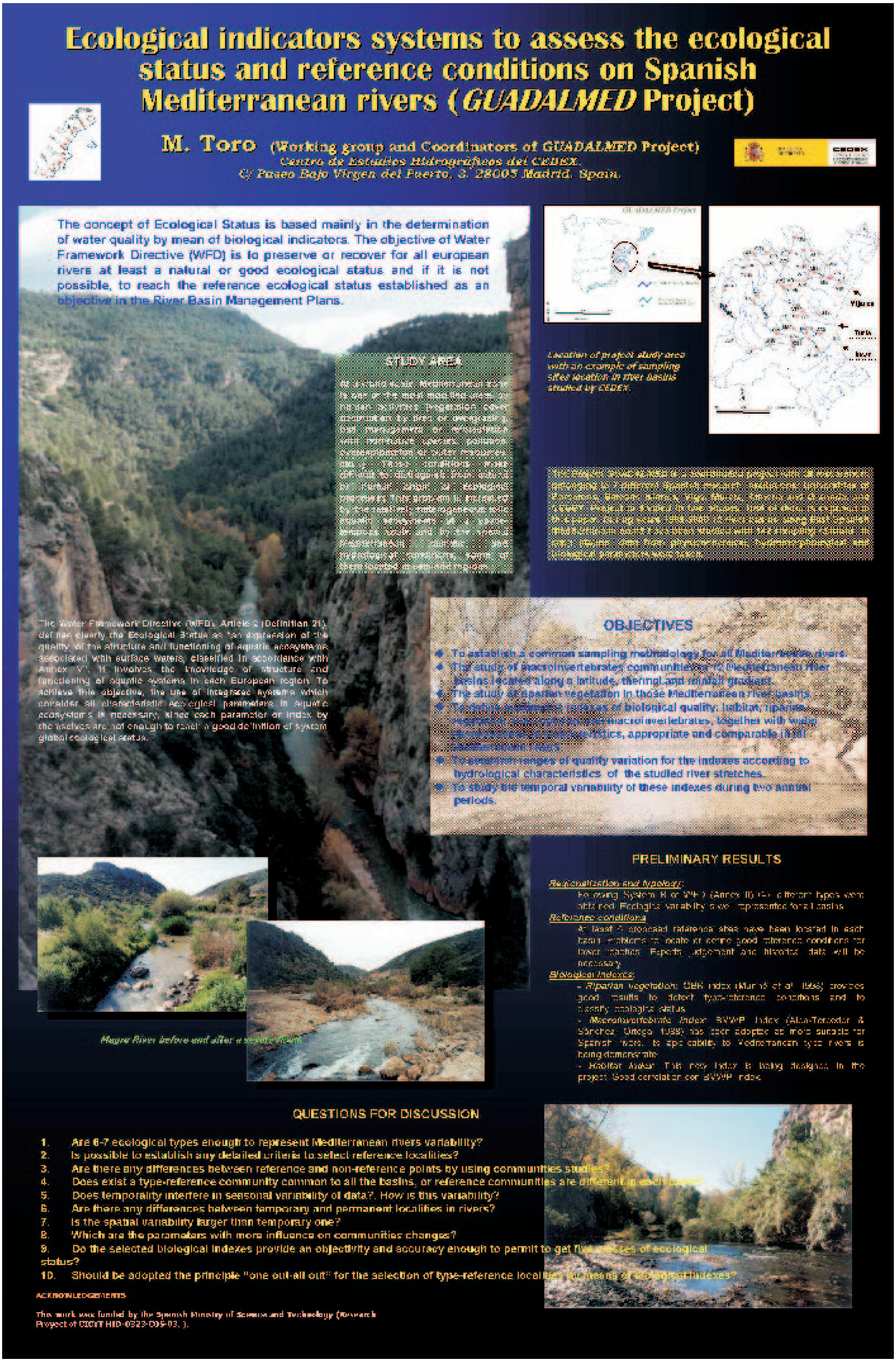

Figure 1. Poster presentation of the Spanish Project *Guadalmed*.