A DATABASE FOR FRESHWATER ECOLOGICAL STATUS IN GREECE

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An environmental database has been created, recording water bodies on a national level and assembling relevant data collected by various public services and institutions in charge of water resources management and research in Greece. Water bodies were classified into categories according to European Union Directive 2000/60/EC. In total 674 water bodies have been registered: 379 rivers, 88 lakes, 121 transitional water bodies (mostly river estuaries, deltas and lagoons) and 105 artificial or heavily modified water bodies (mostly artificial reservoirs). Data consists of physico-chemical parameters, geomorphological descriptions, inventories of fauna and flora species, environmental pressures, vulnerability evaluation and other information useful for the assessment of current and former ecological status. Data gathering has proven to be a challenging task, due to the large number and the generally small size of the surface freshwater bodies as well as the numerous competent services and institutions and the multiple and sometimes conflicting responsibilities that therefore result. The latter is also partly the cause of lack of continuity of data, gaps or sometimes questionable reliability. Performing a global data overview, we note that (a) ecological status can be characterized as good for the majority of the sites, especially for small mountain streams, and (b) the general trend in most cases is degradation of current conditions, related either to anthropogenic pressures or to human activity combined with natural factors.

Table 1. Ecological status of water bodies

Condition	Rivers		Lakes		Transitional		Art./Mod.	
		(%)		(%)		(%)		(%)
High	47	23	10	14	8	9	4	9
Good	118	57,5	33	46	52	57	30	70
Moderate/poor	39	19	26	37	30	33	9	21
Bad	1	0,5	2	3	1	1	–	–
TOTAL	205 / 379		71 / 88		91 / 121		43 / 105	

Table 2. Ecological status evolution in recorded water bodies

Trend	Rivers		Lakes		Transitional		Art./Mod.	
		(%)		(%)		(%)		(%)
Improvement/Restoration	8	4	–	–	–	–	4	10
Stability/Conservation	88	46	20	30	23	27	15	36
Slow degradation	78	40	34	51	35	41	17	40
Fast degradation	19	10	13	19	27	32	6	14
TOTAL	193 / 379		67 / 88		85 / 121		42 / 105	

Before planning a suitable policy aiming to reverse the current situation, it is necessary to establish environmental quality criteria, with respect to each category of water bodies. These criteria should provide general guidelines aiming to define “good surface water status” and must combine precision with flexibility and adaptability. They can be classified in three categories:

A. Water uses oriented criteria, which aim to provide a satisfactory environment for all “users” of the water resource. The word “user” has here a broader meaning, standing for living organisms – which “use” the aquatic environment – as well as human activities. These criteria are the following:

- Populations of all native species should achieve a safe level.

- Reference conditions should guarantee the balanced functioning of the ecosystem and the ability to overcome possible short-term disturbances (accidents etc).
- All quantity, quality and environmental criteria set by legislation and water management agencies (water users) for existing or future water uses (water supply, irrigation, aquaculture, recreation or other) should be fulfilled.

  An additional criterion applies to the particular case of transitional waters:
- The intrinsic character of transitional waters must always be preserved. In other words, the balance between freshwater flows and coastal water influence must remain within natural limits.

B. Economic feasibility oriented criteria which can be formulated as follows: The goal of the strategic management and restoration policy will be to achieve the highest possible grade of ecological status in each water body, provided that the cost for the implementation of measures required to achieve that status: (1) is not disproportionably high with regard to the benefits gained – alias improvement of environmental status, (2) does not compromise the economic performance of activities related to the water resource and (3) does not exhaust economic resources that could have been allocated elsewhere (other water bodies) to obtain better environmental results.

C. Naturalness oriented criteria, which do not take into account financial costs but aim at re-establishing the natural conditions of the water body, a zero-pollution level among other properties. This of course may be impossible, since certain water bodies have been subjected to anthropogenic influence for so long that one can only speculate about their pristine natural conditions. In other cases, the measures to be undertaken may be extremely expensive, so it may be in our best interest to accept a certain level of ecological degradation and allocate the economic resources in better performing environmental projects. For artificial water bodies, for which by definition we have no data concerning reference conditions, this criterion aims to achieve the best possible surface water quality status (i.e. good surface water quality potential) as this can be determined by neighbouring and/or similar water bodies.

The three groups of criteria should be combined and gradually implemented, in accordance with the particular characteristics of each river basin district and of each water body.

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ABSTRACT

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Water resources in Greece

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Water resources management region

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A database for ecological status

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Trend	Rivers		Lakes		Transitional		All waters	
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Ecological status & criteria

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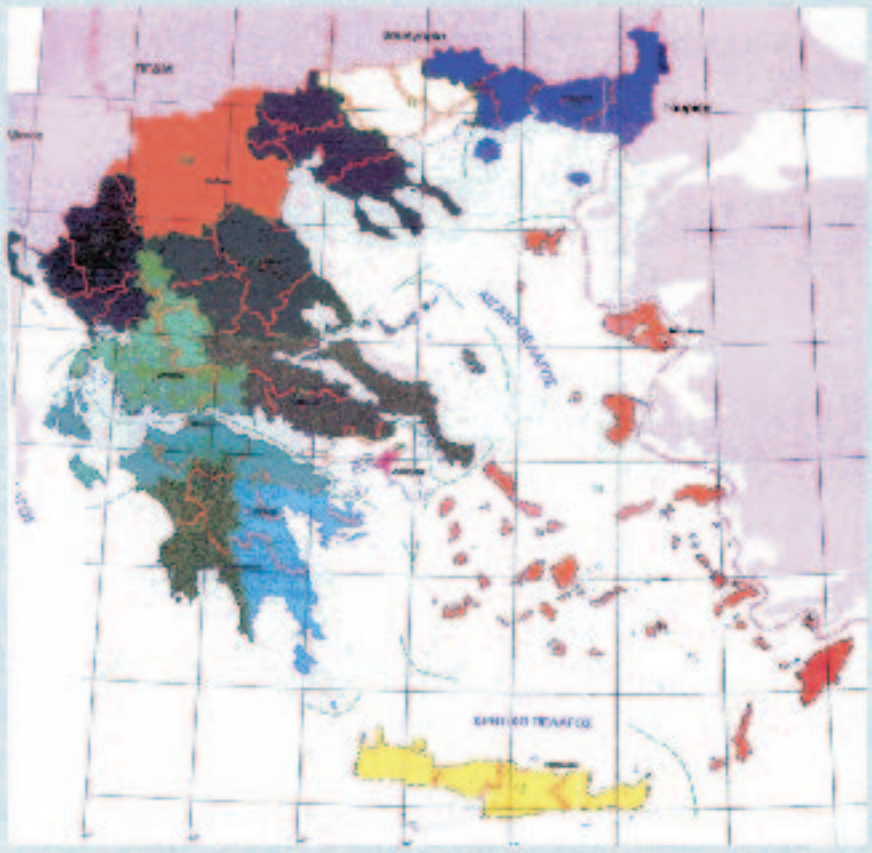

Surface water quality criteria

[illegible]

Environmental policy and research needs

[illegible]

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Towards the definitions (conceptual and operational) of a good ecological status

Marie-Hélène TUSSEAU-VUILLEMIN & Jean-Gabriel WASSON

1 Some conceptual remarks

Ecosystems receive growing interest as full interactive networks among co-existing living organisms and their non-biological physical-chemical environment (Jorgensen, 1992). The flows circulating in these networks consists of mass, energy and information. These fluxes give interesting dynamical information on ecosystems health, besides more static parameters as the biodiversity and the biomass. River ecosystems are particularly characterized by their dynamics and resilience toward natural hydrological perturbations. This adaptation capacity is a key-feature of the ecosystem health.

The “ecological status” of the rivers is a crucial key-word in the new framework directive. It is directly related to a deviation from the “reference conditions” of rivers and the definition of both terms, being from a conceptual or an operational point of view, is of critical interest.

The reference conditions could refer to a kind of pristine status, as often discussed in the USA, supposed to be characteristic of a pre-colombian environment. However, such a concept does not apply in Europe, where pristine conditions could not be found in many regions. Therefore, statistical approaches have been developed as an alternative, considering that the best observed situation in a given area can be considered as a reference level. This operational definition is however likely to be highly influenced by the general level of anthropic pressure in the chosen area. Another approach consists in focusing on the mechanisms of the degradation of the river ecosystem processes. Reference transect would therefore be looked for as areas where the anthropic pressure, though existing, does not alter significantly the most important structuring processes (namely, physical, biochemical and ecological processes).

The “good ecological status”, however, might turn to be slightly differently defined, as it is supposed to be achievable under a reasonable anthropic pressure. Therefore, one of the characteristics of this kind of ecosystems must be an efficient resilience toward the alterations of human origin. Here again, a deep knowledge of the processes and of the way they might be altered by human activities is necessary to evaluate the ecological status.

From these conceptual considerations, it appears that an ecological status is primarily to be observed and understood as *a pattern of dynamical processes* within an ecosystem, *including their response to external forcing*, especially from *anthropogenic origin*. This conceptual definition is much wider than the usual examination of physical and chemical parameters that are supposed to characterize the water quality. However, its operational application should be less difficult than it may appears, for two reasons : 1) these processes are mainly conditioned by large scale physical structures and 2) their temporal variability is much lower than that of the instream physical and biological parameters.

2 How to proceed, what research to engage?

The definition of reference conditions and the diagnosis of ecological status need to be pursued on a typological basis. As physical processes usually deeply structure the biota, interesting typologies based on hydro-morphological processes can be derived on a spatial basis, isolating homogeneous regions. An “Hydro-ecoregion” approach, based upon geo-climatic determinants, has been tested by Cemagref on the Loire basin (Wasson et al. 1993) (Wasson 1996), and is currently extended at the national scale. This typology and its potentialities (Andriamahefa 1999) (Cohen et al. 1998) will be detailed in the poster.

The following step is the definition of reference conditions for biotic communities for each ecosystem type (Ivol-Rigaut 1998), that will be achieved in many cases only in using some kind of models (Boët and Fuhs 2000). Pertinent tools also need to be developed in order to evaluate the ecological status of a river. Besides the classical chemical parameters, some fluxes might be evaluated as representative of the functionalities of the ecosystem (e.g. primary production). The framework directive focuses upon biotic parameters to evaluate the ecological status. Many existing indexes (invertebrates, diatoms..) can be used for this purpose; but the use of biological traits appears to be one of the most promising way to discriminate between perturbed and preserved rivers, and even to track the origin of the perturbation (Charvet et al. 2000). Current development of research at Cemagref will be presented in the poster (the Seine river case study).

At last, future and on-going research will certainly be concerned with the identification of the key-processes that govern the stability and resilience of an aquatic ecosystem toward various perturbations, being of natural (including a possible global climate change) or anthropic origin. Some examples of this kind of research at Cemagref will also be presented.

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Boët, P., and T. Fuhs. 2000. Predicting presence of fish species in the Seine River basin using artificial neural networks. Pages 131-142 *in* S. Lek and J. F. Guégan, editors. Artificial neuronal networks. Application to ecology and evolution. Springer-Verlag, Berlin/Heidelberg.

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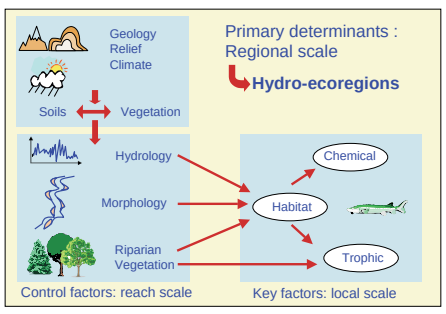
Towards the definitions (conceptual and operational) of a good ecological status

M.-H. Tusseau-Vuillemin[1] and J.-G. Wasson[2], Ph. Boet[1], J. Garric[2], M. Coste[3], B. Dumont[4], M. Lafont[5], M. Bousquet[6]

Scientific and Technical Review *Good ecological status: reference conditions*
Helsinki, 24-25 October 2001

Physical aspects

Hierarchical Control Factors concept



Stream and river systems are primarily governed by their physical structures and dynamics, under hierarchical control of the primary determinants, which allow a **regionalization**.

Lotspeich, 1980
Frissell *et al*, 1986
Omernick, 1987
Naiman *et al*, 1992
US-EPA experience

Region → Strahler order → River types

Wasson, J. G. 1996. Structures régionales du bassin de la Loire. La Houille Blanche 6/7-1996:25-31.

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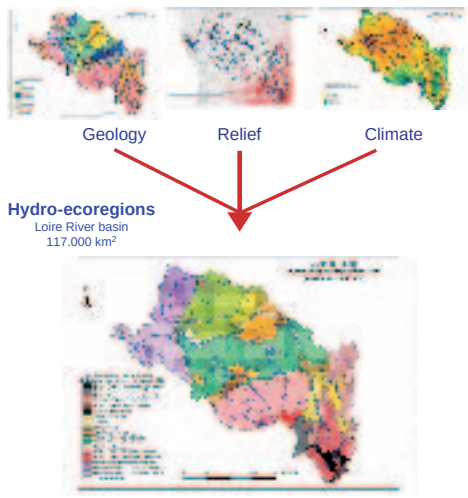
Application to the Loire river basin (France)



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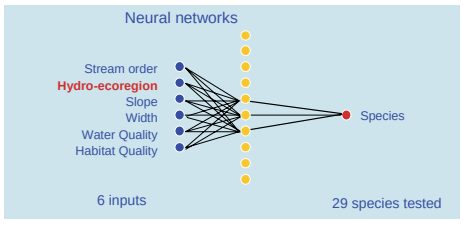
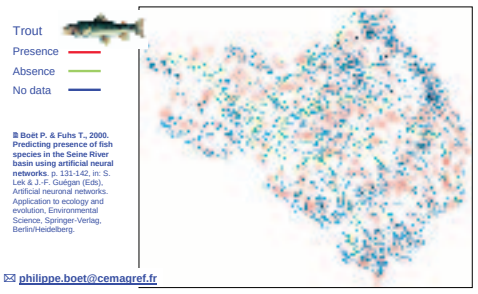
The hydroecoregions, an input for spatialized predictive Modeling → Species Prediction



A preliminary example : the Seine river basin (France)



Boët P. & Fuhs T., 2000. Predicting presence of fish species in the Seine River basin using artificial neural networks. p. 131-142, in: S. Lek & J.-F. Guégan (Eds), Artificial neuronal networks. Application to ecology and evolution, Environmental Science, Springer-Verlag, Berlin/Heidelberg.

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The "ecological status" is directly related to a deviation from the biological "reference conditions" expected from a typology based upon physical parameters.

An ecological status is primarily to be observed and understood as *a pattern of dynamical processes* within an ecosystem, *including their response to external forcing*, especially from *anthropogenic origin*. This conceptual definition is much wider than the usual examination of physical and chemical parameters that are supposed to characterize the water quality. However, its operational application should be less difficult than it may appears, for two reasons : 1) these processes are mainly conditioned by large scale physical structures and 2) their temporal variability is much lower than that of the instream physical and biological parameters.
In Europe, reference conditions should be searched (or assessed) in systems where man has not significantly altered the fundamental processes and biodiversity. It lies somewhere between "pristine" systems and a "natural" status including sustainable human activities.
On-going and future research will focus on the identification and modeling of the key-processes that govern the stability and resilience of aquatic ecosystems.

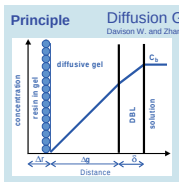
Biological reference communities will be linked to the physical structures by statistical distribution models. For the ecological status assessment, metrics with functional significance (such as biological traits), should be included in the classical biological indices in order to track the origin of the perturbations.

River ecosystems are characterized by their dynamics and resilience toward natural hydrological perturbations (reversibility). This adaptation capacity depends upon structures and processes at the basin and reach scales. It is a key-feature for the ecosystem health and thus for its capacity of resisting to human pressure. The processes that maintain ecosystems functioning can be analyzed by means of mass, energy and information fluxes.

Chemical aspects

Towards an *in-situ measurement* of **bioavailable trace metals**

Principle — Diffusion Gradients in Thin Films (DGT)
Davison W. and Zhang H., Nature, 367, 564-548, 1994. DGT Research Ltd.



The diffusion flux is accumulated on the Chelex resin and is proportional to the concentration of cations + labile complexes

Used for trace metals

Correspondence between DGT measurements and biological effects - Current developments at Cemagref

Through Dynamical modeling — For quantifying the contribution of labile complexes to DGT measurements

Tusseau-Vuillemin M.-H., Roulier J.-L., Labadie, Dec. 2001 Measuring free cupric concentrations with DGT : numerical estimation of the labile complexes contribution subm. to 2nd European meeting on Env. Chem.., Dijon, France

DGT along with biotests

Adequacy of DGT measurements for predicting the bioavailability of TM?

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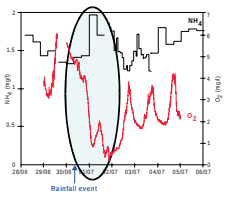
Pollutants joint effects

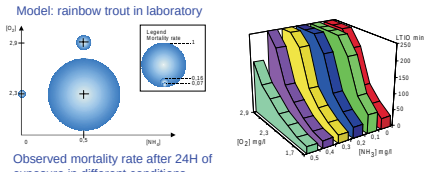
Water quality is regularly affected by multiple pollutants.
Urban rainoff or dam draining lead to well-known short term toxic effects due to an increase of the ammonia concentration and a decrease of the oxygen level.



Ammonia and oxygen concentrations in Seine following a 06/30/92. From Piren Seine 1992

Synergistic effect of NH_4 rise and O_2 depletion ?

Model: rainbow trout in laboratory



Observed mortality rate after 24H of exposure in different conditions
(from Magaud et al. 1997)

The definition of the Ecological Status requires more than a collection of chemical parameters.
Synergistic effects need also to be modeled.
(Garric et al 1990, Wat. Res 24; Magaud et al. 1997, Wat. Res. 37).

Magaud H., Migeon B., Morfin P., Garric J., Vindimian E. Modelling fish mortality due to urban storm run-off : interacting effects of hypoxia and un-ionized ammonia, 1997, Water research, vol. 31, n° 2, p. 211-218

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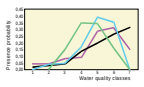
Biological aspects

Assessment of ecological status of rivers using diatoms (Bacillariophyta) or oligochaetes

The DBI (Diatom biological index)

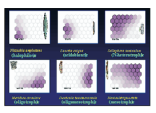
The DBI (standardized* diatom biological index) has been established on 1332 sampling sites, 15 000 chemical data for 14 classical parameters and more than 1000 taxa . Ecological profiles have been defined for 209 taxa + 60 matched species and for 7 chemical quality classes. DBI is calculated from the barycentre of ecological profiles of the best represented species. Final score is expressed by a scale: 1(bad quality) to 20 (best water quality). It is widely used by French water agencies for monitoring river status
** : AFNOR NT 90 354*

Ecological profiles of the main species found in good quality sample



Prygiel J., Coste M. 1999, Progress in the use of diatoms for monitoring rivers in France, Use of algae for monitoring rivers III, PRYGIEL J.,WHITTON B.A./BUKOWSKA J., 1999, p. 165-179

Species distributions using Kohonen maps



Towards more predictive assessment

In the framework of the FP5 Paeqann* project, the most relevant environmental parameters are selected to link structure and diversity of diatom assemblages under natural or disturbed conditions, by using predictive modelling (artificial neural networks, ANN). The comparison between predicted and observed communities allows to identify disturbances in hydrosystem functioning and to evaluate the ecological status.
**(Predicting of Aquatic Ecological Quality using Artificial Neural Networks contract n° EVK1-CT1999-00026)*

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The Oligochaetes index

The Sediments Bio-indication Oligochaetes Index (SBOI) is based on the observation of oligochaete communities in fine sediments and relates non linearly to the contamination of sediments by organic micro-pollutants and heavy metals. The SBOI is now standardized and routinely used by private offices for the biomonitoring of fine sediments.

Lafont, Camus, Rosso, 1996, Superficial and hyporheic oligochaete communities as indicators of pollution and water exchange in the river Moselle, France, Hydrobiologia 334, pp/ 147-155.

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Towards new biological assessment methods using macroinvertebrates traits

A combined assessment method to promote functionnal approach

Information on taxonomic traits is largely available, but there is a need to select or to define relevant traits according to scale perceptions.

The challenges are :

- Which biological traits allow to discriminate the relative weights of both physical habitat and water quality factors (*sensu stricto*) ?
- How to correlate sets of biological traits with gradients of disturbance ?

The additionnal use of macroinvertebrates traits improves biological assessment of water ecosystem status at various scales

Charvet S., Statzner B., Usseglio Polatera P., Dumont B. 2000, Traits of benthic macroinvertebrates in semi natural French streams: an initial application to biomonitoring in Europe. Freshwater biology, vol. 43, n° 2, p. 277-296

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Comparing biological assessment methods

« Building the future in ecological status assessment means use of complementary biological methods... and complementarity means prior sensitivity comparisons.»

Two comparison types

Of methods based on the same kind of organisms → *intercalibration*

Of methods based on different kinds of organisms (oligochetes, diatoms, fish, …) → *harmonization*

Sampling requires :
- synchronous knowledge on various variables
- various time scales in order to consider the various time scales of each of the biological integrative processes involved

The SBOI, IBGN and DBI indexes are integrated in an operational harmonization system of biomonitoring tools.

In the future, will allow to specify the crossed functional meanings and the quantitative links between the different indexes. Beyond a better knowledge of biological meaning of each index, this harmonization will help to define their discriminatory abilities within a region

Research issues :

How to solve reference conditions problems and develop unbiased ecological assessment ?

- by getting quantitative metrics in studying connected processes,
- by building integrated reference systems on the basis of validated theorethical aspects.

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