Impact of the European Water framework directive on knowledge of biodiversity

The European Water framework directive requires observation and monitoring of certain biological communities to assess the ecological status of aquatic environments. How does the WFD contribute to knowledge and evaluation of aquatic biodiversity? What may be the results in terms of monitoring?

Biodiversity (biological diversity) is a generic term covering a range of notions. Hooper *et al.*, (2005) wrote "The term biodiversity encompasses a broad spectrum of biotic scales, from genetic variation within species to biome distribution on the planet… Biodiversity can be described in terms of numbers of entities (how many genotypes, species, or ecosystems), the evenness of their distribution, the differences in their functional traits, and their interactions." In many cases, biodiversity is described solely in terms of the species richness of a site or an ecosystem, which is a highly simplified view of diversity.

The organisation of communities is nonetheless complex in that it is controlled by various processes involving numerous biotic and abiotic factors interacting on different temporal and spatial scales as well as different levels of organisational complexity (Lévêque, 2001). An attempt to describe all of biodiversity assumes complete characterisation of all its components, i.e. genes, populations, species and functions, as well as their spatial and temporal variations and their interactions, which is virtually impossible. A possible alternative would be excellent knowledge of the factors controlling biodiversity combined with representative sampling of environmental variability on different organisational, spatial and temporal scales. Our current understanding of the processes involved in system operation is not sufficient to carry out such sampling satisfactorily. However, on the European level, implementation of the Water framework directive (WFD, European union, 2000) should result in improved knowledge on biodiversity.

WFD components

The WFD is a European directive that draws largely on the concept of biotic integrity developed by Karr (1981). The text states that the "purpose of this Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater" (European union, 2000). The main goals are to prevent further deterioration of water quality and achieve good water status by 2015. That requires:

• definition of national types of water bodies that are environmentally consistent (the parameters are set in Annex IV) and subject to the same environmental goals;

• definition of water-body status, comprising both the ecological and chemical aspects. That includes the concept of hydromorphological status used to define criteria for high status and also to list certain conditions serving to identify heavily modified water bodies. The ecological status is defined as "an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters". It is measured with respect to a reference value corresponding to a water body not or only slightly affected in its composition and functioning by human activities;

• definition of the elements of biological quality that must be collected to determine the ecological status. The selected criteria are the composition and abundance of communities of phytoplankton, aquatic flora, invertebrate benthic fauna and ichtyofauna. Phytoplankton biomass and ichtyofauna age structures are also taken into account. Not all these communities are used for all


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❶ The Water Framework Directive contribute to measuring aquatic-ecosystem diversity and richness.
Here, a dragonfly larva hunts on a water mint branch.

types of water bodies. Ichtyofauna serves only for continental waters, i.e. it is not used to assess the ecological status of coastal waters and phytoplankton is not used for evaluations of rivers.

In operational terms, the WFD requires that the Member States set up a network of reference sites used, initially, to define the reference conditions and, later, to check the natural evolution of the sites over time.

They are also required to create a surveillance-monitoring network "to establish a coherent and comprehensive overview of water status within each river basin district" for reports to the EU once during each management plan (six years). Finally, an operational monitoring network is required for water bodies that may fail to achieve good water status by 2015.

The WFD thus initially requires an inventory of water bodies grouped in consistent types, then long-term monitoring of a number of the water bodies (at least one per type), taking into account all the criteria for biological quality defined above.

The WFD and improvements in knowledge of biodiversity

The stated purpose of the WDF is not to measure biodiversity, but certain elements contribute to that end.

Ecosystem diversity

In its initial phase, the WFD launched a very useful inventory of all water bodies with a brief environmental description (see box ❶). By defining the mandatory typological criteria, the WFD ensured a certain degree of consistency between the national classifications. It thus contributed to measuring aquatic-ecosystem diversity and richness, as well as to knowledge on the distribution of environmental diversity within the scope of the directive (see photo ❶).

Specific diversity of the selected faunal and floristic groups

The WFD also serves, progressively, in step with the establishment of the various networks, to draw up lists of species and determine their numbers on each observation site. It thus contributes to measuring, throughout Europe, the specific diversity of sites and/or the river basin. A number of methods developed as diagnostics tools for ecosystem biological quality have provided results showing that the networks have detected a certain degree of biodiversity erosion or a loss of species richness due to the impacts of human activities on ecosystems. However, the WFD networks do not necessarily

❶ Types of national environments

Annex II of the WFD proposes two typology systems. System A corresponds to a set typology comprising descriptors and thresholds defined in the annex. System B uses criteria (parameters and thresholds) set by the directive, but allows the Member States to include other, optional criteria. In France, all surface waters were classified using system B.

Among the main criteria for river and lake typologies are the ecoregion, altitude, geology and system dimensions. The typology includes 52 "major" types of rivers, 11 types of natural lakes and 18 types of man-made water bodies.

Among the 14 criteria listed in the directive, 10 physical and physical-chemical parameters (ecoregion, salinity, current speed, substrate composition, etc.) were used for the typologies for coastal waters and transitional waters. The ten criteria define 12 types of transitional waters and 26 types of coastal waters.

provide, at least initially, a complete view of the specific diversity because the annual inventories almost never inform completely on the existing communities. The true value of these monitoring networks will certainly become more apparent after several years of operation. The long-term monitoring will also reveal trends that are totally undetectable over a small number of years.

Functional diversity of the selected communities

The functional description of species and communities complements the classic taxonomic description (see box ❷). It establishes more direct links between the environment and the presence of individuals in the ecosystem. It also provides a better understanding of system functioning and a means to compare functioning without calling on taxonomic differences. If we consider that functional diversity ensures the good functioning of ecosystems, its measurement can serve as an indicator of a certain ecological status as required by the WFD. Certain diagnostics tools already or currently being developed for the directive already include information on the functional characteristics of species. For example, the fish index developed to evaluate river status takes into account the number of rheophilic species (suited to living in strong currents) and the density of invertivore fish (whose diet is made up of invertebrates). However, the use of the functional properties of species for bioindication purposes is still in its early stages.

Network limitations

A number of limitations must be mentioned concerning the possibility of basing diversity studies on WFD implementation and still others concerning use of the networks as biodiversity observatories.

In terms of ecosystem diversity, the data provided by the WFD is at best partial because the smallest environments were excluded from the inventories. For example, the minimum size recommended by the EU for transitional water bodies and lakes is 0.5 square kilometres and for rivers, it is 10 square kilometres. That means part of the territory is not directly taken into account by the WFD and is not specifically covered by monitoring. In addition, the optional nature of certain environmental descriptors and the flexibility built into classification systems (extensively used by the Member States) does not facilitate analysis of environmental diversity Europe wide.

Concerning specific and functional diversity, not all WFD sites are monitored because the regulations require only that one water body of each type be monitored. Certain species with reduced spatial ranges can thus find themselves excluded from WFD inventories. What is more, monitoring networks were occasionally (even often) set up without taking into account criteria of interest for monitoring the habitats of threatened fauna and flora. Those issues are present in Natura 2000 networks which are better designed to serve as observatories of specific diversity and that the WFD networks are not intended to replace. The evaluation methods for species composition and abundance used by the WFD networks are designed according to criteria set for large-scale use. They can detect a certain degree of species richness, but the efforts made and the methods used are not sufficient to ensure a complete species inventory. For example, the recommended, standardised protocol for fishing using gill nets, intended for monitoring of lake ichtyofauna, is not suitable for capturing locally rare species or those with special morphological characteristics such as eels. It has also been demonstrated that, in spite of considerable efforts, the maximum species richness of benthic invertebrates is rarely reached in lakes.

Finally, in terms of serving as an observatory for certain environments and certain elements of biological quality, the monitoring frequency may be reduced to once every six years. Under these conditions, detection of trends requiring at least three observations would take 18 years, which is obviously too long for the life cycle of certain taxa.

❷ Functional types and functional diversity

All species play a role in the functioning of their ecosystem, with which they interact. This role may be understood via a set of ecological functions. For example, the leaf surface and root architecture are functional characteristics used to describe plants. In macroinvertebrates and fish, the functional characteristics comprise biological and morphological aspects (size, fin size, etc.), physiological aspects (types of prey, number of eggs, thermal preferences, hydrogen potential (pH), etc.) or behavioural traits (feeding techniques, care of young, migration, etc.). Some species may share functions, e.g. detritivores or migratory species, and thus constitute functional groups. The number of functional groups is a simple indicator of the functional diversity of a community.

These characteristics of species can also be used to create indices of functional diversity. These indices can be more or less complex and indicate the degree of functional richness and its distribution over a diversity gradient.

What the WFD does not address

Genetic characterisation of populations is occasionally carried out in special programmes for rare or threatened species. The monitoring programmes for bullhead fish, a species comprising genetically isolated populations, are a good example. Genetic diversity is, however, one of the biodiversity components that is clearly not taken into account by the WFD, which addresses elements of biological quality on the level of each taxon. Some information on genetic diversity may be obtained indirectly. For example, estimations of the abundance of individuals in systems (required for the evaluation of the ecological status) is a means to measure on the local and regional scales the decline of certain taxa and the risks of losing the corresponding genetic material, but not of qualifying those losses. But will the frequency of observations and the sampling efforts be sufficient to detect these risks? Probably not. And even if they are, will the risks be detected quickly enough for corrective measures to be effective? It is acknowledged that the introduction of species increases genetic diversity, but also represents a threat to genetic diversity either through hybridisation which leads to homogenisation of the gene pool or through the gradual elimination of native species by the introduced species. An indirect indication of biodiversity and the risks can thus be obtained by looking at the introduced species and their potential negative effects during the evaluation of the ecological status. That implies the formulation of indicators taking into account information on the presence and abundance of non-native species. It also requires drawing up lists of native and non-native species, which is not a simple task. What spatial and temporal scales should be used? Should long-standing presence (preglacial, from the Pliocene) be taken into account? Even though not all the indicators have been fully stabilised, efforts to distinguish species that are non-native to Europe and/or invasive are now well underway.

Finally, the WFD does not take into account all taxa, for example the zooplanktonic compartment was excluded from the ecological-status evaluation for all environments. That is surprising because it is difficult to find an objective reason for that decision, given that zooplankton are primary consumers that provide important functional information. It is even less understandable because the Clean Water Act (the U.S. law intended to protect surface waters, voted in 1972 and which probably served as a model for the European directive) includes zooplankton for the evaluation of environmental status. Furthermore, the WFD does not include phytoplankton for river evaluations or ichtyofauna for coastal waters. Above and beyond the difficulties created for the comprehension of system functioning, it is clear that the WFD cannot provide a complete view of biological diversity.

Conclusion and outlook

It is clear that the WFD already contributes, imperfectly and imprecisely, but significantly, to general knowledge on biodiversity (ecosystems, presence, abundance and distribution of taxa). The long-standing nature of the monitoring networks mean they can also serve to measure changes in biodiversity.

The directive is also designed as an iterative and progressive process.

It would certainly be possible to imagine better convergence between the monitoring goals for ecological and chemical status on the one hand and biological diversity on the other, for adjustments to the networks (changes in the water bodies monitored) and/or the monitoring methods (variable requirements depending on the issues at hand).

In addition, research must still produce many tools and methods to enable complete application of the directive and they should improve our knowledge of biodiversity. Most of the current work is focussed on the basic components required by the WFD, i.e. taxonomic composition and abundance. Very few indicators deal with functional aspects. For example, characterisation of functional diversity, which still requires theoretical work and the incorporation of suitable parameters in the diagnostics tools, is a very promising field. In addition, there is still no cross-evaluation of the various communities. This systemic approach will probably be implemented during the second phase of the WFD and should contribute to better understanding of biodiversity. ■

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